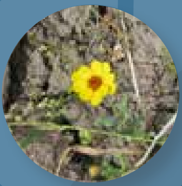
arbor
Biomass for Energy

Case Study Report

Development of low-impact energy crops

June 2015



*Improving **sustainable biomass utilisation** in North West Europe*

Colophon

This report was compiled in the framework of action 6 of the ARBOR[*] project.

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This report further received input from the other ARBOR partners on specific aspects related to the regional transferability of the investigated case study results. Willem Dhooge (FlandersBio, BE) also helped with text corrections and lay-out.

[*] Arbor is an Interreg IVB NWE project with 13 partners from 6 European regions dealing with the development of technological solutions and regional strategy development for improved sustainable biomass utilisation. ARBOR is cofunded by local authorities from the United Kingdom, Flanders, Saarland, Luxemburg, the Netherlands, and Ireland.

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Please check **www.arbornwe.eu** for the other reports that have been compiled within ARBOR:

- Five case study reports on a diversity of subjects like nutrient recovery, low impact energy crops, agro side streams, synergy parks and biomass closed-loop systems.
- An update of the 2012 Benchmark report on biomass for energy use in NWE
- A strategies report on biomass for energy for regional authorities in the North West European region.

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1. Introduction

The case study report on low-impact energy crops is part of the deliverables for ARBOR, an Interreg IVB project for North-West Europe. ARBOR is an acronym for **A**ccelerating **R**enewable Energies through valorisation of **B**iogenic **O**rganic **R**aw Material. The aim of the ARBOR project is to promote an innovative and sustainable approach for the development of bio-energy. With the increasing dependency on fossil fuels, biomass plays a key role to ensure the security of sustainable energy supply.

The ARBOR project runs from 2011 till 2015, and has a total budget of € 7 361 959.
The different project partners are:

- From Germany: IZES gGmbH
- From Luxembourg: LIST, Luxembourg Institute for Science and Technology
- From Belgium: VCM, POM West-Vlaanderen, Ghent University, Inagro, FlandersBio
- From the Netherlands: Wageningen UR, Provincie Utrecht, DLV Plant
- From the UK: Stoke-on-Trent city council, Staffordshire University (lead partner)
- From Ireland: UCD Dublin

This report describes the outputs of ARBOR action 6 'Development of low-impact energy crops', within the individual partner regions. Low-impact energy crops were defined as crops that have a relatively low need for inputs, such as water, mineral fertilizers or pesticides. By promoting solely low-impact energy crops, the action doesn't engage in the food versus fuel discussion.
Four types of low-impact energy crops were identified:

- Multifunctional short rotation coppice
- Biomass from buffer strips
- Energy crops on contaminated land
- Biomass from cover crops

In chapter 2, the European framework for energy crops is briefly described, including the governing policies (agricultural, environmental, energy, innovation) and the potential of energy crops with regard to the availability of land and the energy demand in the European region. Detailed results of the pilots that were realized within the ARBOR project are described in chapter 3. Four types of energy crops were tested at a pilot scale and were evaluated in terms of the multifunctional use, because this minimizes the competition for food production. The pilots for which the environmental and economical assessments turned out positive will be further promoted and implemented in the project region. Finally, chapter 4 discusses on the outcomes of the first ARBOR Transnational Advisory Board, which was held on the 26st of April 2013 in Ghent and dealt with 'Low impact biomass from agriculture and nature protection areas'.

The case study report 'Low-impact energy crops' was edited by Inagro and POM West-Flanders with input from Ghent University, DLV Plant and LIST. The lay-out of the report was designed and implemented by FlandersBio. An online version of the report is available on **http://www.arbornwe.eu/**.

2 – European framework analysis for low-impact energy crops

2.1 Policy assessment

The growing and processing of energy crops is covered by a broad range of European policies, including policies related to agriculture, energy and environment. Depending on the type of crop and on the type of the land on which the crop is grown, different policies need to be taken into account when producing biomass for energy purposes.

2.1.1 Agricultural policy

The Common Agricultural Policy (CAP) is a system of subsidies and aims at encouraging the supply of bioenergy from agriculture and forestry and the use of bioenergy on farms and in rural areas (European Commission, 2013). The CAP combines direct payments to farmers together with other instruments, including quotas and tariffs on some imported products. As a result, the CAP supports farmers through:

- Direct payments to farmers (1st pillar): these have been fully decoupled from production and are granted regardless of what farmers grow or for what purpose (food, feed, energy, material), but should however comply with the cross-compliance scheme.

- The rural development policy (2nd pillar): this provides a variety of measures (see Table 1) through which the member states can support i.a. bioenergy production and consumption.

Table 1: Types of operation that can be supported in the rural development program in order to enhance renewable energy production

Types of operations	Measures	Potential effects
Biogas production – anaerobic digestion plants using animal waste	Modernisation of agricultural holdings Diversification into non-agricultural activities	Substitution of fossil fuel Reduction of methane emissions
Cultivation of perennial energy crops (short rotation coppice and herbaceous grasses)	Modernisation of agricultural holdings	Substitution of fossil fuel Carbon sequestration Reduction of nitrous oxide emissions
Processing of agricultural/forest biomass for renewable energy	Adding value to agricultural and forestry products	Substitution of fossil fuels
Development of installations/infrastructure for renewable energy using biomass	Diversification into non-agricultural activities Support for business creation and development Basic services for the economy and rural population	Substitution of fossil fuels

Investments and infrastructure related to the establishment of energy crops such as short rotation coppices (SRC) and other grasses for energy purposes (miscanthus, switch grass, reed canary grass, etc.) are supported by the direct payment. The financial support for this kind of investments consists of:

- **Basic direct payment (70%)**: this payment is granted if a compulsory basic layer of environmental requirements and obligations are met by the farmer.

- **Green direct payment (30%)**: in addition to the basic payment, each farmer can receive a payment per hectare for respecting certain agricultural practices that are beneficial for the climate and the environment. The payment is granted if one of following three obligatory agricultural practices are respected:

  1. Maintaining *permanent* grassland.

  2. *Crop diversification*: at least 2 or 3 crops must be cultivated when the arable land exceeds respectively 10 and 30 hectares. The main crop may cover at most 75% of arable land, and the two main crops at most 95% of the arable area.

  3. Maintaining an *ecological focus area* of at least 5% (this figure will rise to 7% in 2017) of the arable area of the holding for farms with an area larger than 15 hectares (excluding permanent grassland). This ecological area can include for example field margins, hedges, trees, fallow land, landscape features, biotopes, buffer strips, afforested area. Member states have the possibility to grow perennial energy crops on these ecological focus areas, under the condition that no pesticides and chemical fertilizers are used.

The focus of the second pillar on sustainability is visible by the fact that at least 30% of the budget of the rural development program must be reserved for voluntary measures that are beneficial for the environment and prevent climate change.

The instruments and mechanisms that support actions to improve the environmental sustainability within the CAP, are summarized in Figure 1. The details of the European framework are defined by the 'delegated acts' and 'implementing acts', which were approved in the summer of 2014. These acts involve the calculations of the payment scheme, the greening measures, sanctions and controls, communication requirements, etc. Within the European framework, the member states can choose individually how to interprete these different acts.

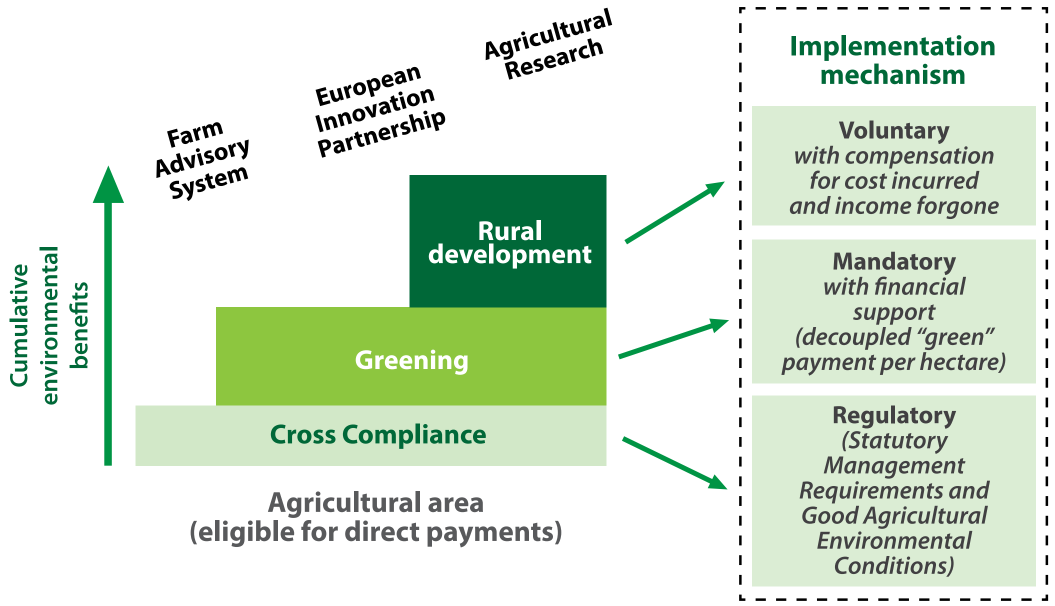

Figure 1: The new greening architecture of the CAP (source: European Commission, 2013)

2.1.2 Energy policy

Energy from biomass is promoted by the current EU policy, mainly in order to achieve a reduction in the emission of greenhouse gases. Under the renewable energy policy there are some guiding sustainability criteria that govern the production of some forms of bioenergy. Biofuels and bioliquids consumed in Europe have to comply with requirements on minimum greenhouse gas emissions savings, high biodiversity value areas and conversion of high-carbon stock areas.

Renewable Energy Directive 2009/28/EC (RED): directive on the promotion of the use of energy from renewable sources. The directive mandates 20% renewable fuel use and a 6% greenhouse gas emission reduction in member states by 2020.

Fuel Quality Directive 2009/30/EC (FQD): contains a set of sustainability criteria to ensure that the use of biofuels (used in transport) and bioliquids (used for electricity and heating) is done in a way that guarantees real carbon savings and protects biodiversity. In order to receive government support, following criteria have to be fulfilled:

1. Biofuels must achieve greenhouse gas savings of at least 35% (or at least 50% in 2017) in comparison to fossil fuels.
2. Biofuels cannot be grown in areas converted from land with previously high carbon stock such as wetlands or forests.
3. Biofuels cannot be produced from raw materials obtained from land with high biodiversity such as primary forests or highly biodiverse grasslands.

However, the RED and FQD are not applicable to solid biomass as fuel, e.g. when using short rotation coppice in a biomass combustion unit.

2.1.3 Environmental policy

Environmental policies are relevant for support of low-impact energy crops so that a significant improvement effect on the soil, water and air quality can be reached. When cultivating energy crop on contaminated land, policies concerning soil contamination and processing of pollutants play a role. When cultivating energy crops in buffer strips along rivers and canals, policies related to the prevention of eutrophication of rivers and erosion of soils play a role.

Soil protection: the 6th Community Environment Action Programme requires the development of thematic strategy on soil protection. The variety of functions, the variability and complexity of soils, the specific features of soils and the range of degradation processes, require a comprehensive approach to soil protection. The general objective within the strategy of soil protection is the preservation of soil functions rather than the development of soil quality standards. The guiding principles for the protection of soil within this common objective are:

1. Preventing further soil degradation and preserving its functions.
2. When soil is used and its functions are exploited, action has to be taken on soil use and management patterns.
3. When soil acts as a sink/receptor of the effects of human activities or environmental phenomena, action has to be taken at source.
4. Restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of the restoration of soil.

The application of energy crops for phytoremediation fits within the policy of restoring degraded soils and preventing the erosion of soils. Although it is expected that phytoremediation is supported by the direct payments to farmers for rewarding the application of soil recovering/stabilizing agricultural practices, these measures are not implemented everywhere meaning that some farmers cannot receive supportive payments if implementing phytoremediation.

Water Framework Directive (WFD): this directive requires that both surface and groundwater waterbodies within all European Union member states achieve a 'good status', and that no such waterbodies experience deterioration in status. Good status is defined by a number of quality elements:

- Biological elements, e.g. fish, invertebrates, macrophytes
- Hydromorphological elements, e.g. channel morphology, channel planform, lateral connectivity
- Physio-chemical, e.g. phosphate, nitrate, dissolved oxygen
- Chemical, e.g. pollutants, heavy metals

If one of the above individual quality element is not achieving a good status for a particular watercourse, then the entire waterbody cannot be granted a good status. In such situation achieving the objectives of the WFD will require changes in soil management and soil protection, but only where soil degradation hinders water quality.

According to the EU Water Framework Directive a reduction of nutrient input in rivers is targeted in order to achieve the goals. The WFD addresses soil as far as it is a pressure to water but does not provide a protective regime for soil in all circumstances. The agricultural impacts on nutrient input in water bodies is mainly caused by erosion aspects. As such, the WFD can be seen as a kind of stimulus for the development of low-impact energy crops (from buffer strips, cover crops or used for land recovery/stabilisation) since the crops have a positive effect on the water balance, they buffer the water in the soil and prevent the leaching of contaminants. Here short rotation coppices as buffer strips between agrarian area and river can lead to ecological improvements as nutrient load reduction of the waters as well as an ecological upgrading of the riparian area and provide a productive function.

2.1.4 Innovation policy

Technology innovation in the energy sector is crucial to address climate and energy challenges and to maintain Europe's leading position in the renewable energy industries. The European Commission has developed several plans in order to stimulate innovation.

European Strategic Energy Technology Plan: the plan aims at accelerating the development of low-carbon energy technologies and recognises the essential role of renewable energy sources as a part of the EU's strategy to improve the security of the energy supplies and to foster a competitive edge in the related highly innovative industries.

Eco innovation plan: the plan describes a comprehensive set of initiatives to improve the EU's uptake of eco-innovation. Innovative urban design that serves multiple purposes can help to achieve this goal. As phytoremediation adds a social value (in addition to an ecological value) to polluted sites by creating attractive public spaces, it is considered as an advisable approach for urban renewable projects.

2.2 Potential of energy crops

2.2.1 Availability of land

A piece of land is considered to be available for the production of energy crops if following general principles are applicable (IEEP, 2012):

1. The land should not displace food production within land that is currently in agricultural use.
2. The cultivation of energy crops should happen with minimal negative impacts on the environment.
3. The cultivation of energy crops should fulfill the minimum sustainability criteria set by the Renewable Energy Directive.

The amount of land that is available for the **sustainable production of energy crops** in the EU is approximately 1 350 000 hectares (IEEP, 2012). This corresponds to about one-third of the amount of land used for biofuels production in 2010. The potential available land mainly consists of recently abandoned agricultural land (both cropland and grassland), some of the existing fallow land areas, other unused areas and a small fraction of contaminated land.

More than two hundred years of industrialisation have left Europe with a historical contamination of the soil, mainly due to the presence of dangerous substances in many production processes. There are potentially 3,5 billion **contaminated sites** in the EU (European Commission, 2006). A thorough remediation or stabilisation of these sites is necessary to prevent pollutants leaching into groundwater or accumulating in food crops. The estimated total cost for cleaning up the contamination, including both on-site and off-site measures, sum up to 17,3 billion euro per year.

Traditional methods of cleaning up polluted sites rely on excavation and disposing of contaminated soil into landfill, treatment on site, or containment using plastics, pavements or layers of clean soil. Such methods are very expensive and containment additionally only prevents emissions but doesnot allow soil recovery to its previous ecological function. By contrast, phytoremediation has a low capital and operating costs. Furthermore, the plants after harvest can sserve as a bioenergy resource. Given the availability of contaminated land and the high cost of classic remediation methods, there is a high potential for growing energy crops on contaminated land.

2.2.2 Contribution to the energy demand

The Commission's Impact Assessment of the 2030 Climate and Energy Policy Framework assume that additional demand for bioenergy by 2030 will to a large extent be met through increases in the production of fast rotating plantation wood. The amount of cropland for perennials is assumed to grow from almost no hectares cultivated in 2005 to 7 million hectares in 2030. However, this is five times more than the land that is available for sustainable energy crops cultivation within the EU.

If all available land was used to grow energy crops within sustainable production limits, there would be between 7,7 and 16,7 million dry tonnes of biomass available. From this amount, between 139 and 300 petajoule of energy could be extracted, which equals 0,5% of the EU's energy needs in 2012. If all energy crops were used in one sector, they could supply 0,5 – 1% of the energy demand for road transport or 0,4 – 0,9% of the electricity demand. The potential for energy crops would be most significant in the heating sector, and could cover up to 5,3 – 11,4% of the heat demand.

3 - ARBOR pilots on low-impact energy crops in Flanders (BE) and South West Netherlands

The aim of the ARBOR project is to promote an innovative and sustainable approach for the development of bio-energy. Therefore, different pilots were set up to evaluate possible strategies for biomass production and biomass valorization. An overview of the pilots and investments within the ARBOR project can be found in the report '*Biomass for energy in the Northwest European region: an overview of pilots and investments*' (available at www.arbornwe.eu).

By promoting solely 'low-impact energy crops', the project doesn't engage in the food versus fuel discussion. Low-impact energy crops were defined as crops which are cultivated with a relatively low inputs, such as water, herbicides, mineral fertilizers or pesticides. Within the project, 4 types of 'low-impact energy crops' were identified and were tested at a pilot scale for a multifunctional use, in this way minimizing competition for food production. If the environmental and economical assessments of these pilots turned out positive, it would be further promoted and implemented in the project region.

The first analyzed biomass production mode is **multifunctional short rotation coppice**. This is a woody biomass crop, that is harvested periodically, often in cycles of 3 years or 5 years. The harvested wood chips are used in wood boilers to produce green heat and/or electricity. This perennial crop may add new functions to the domain of agroforestry, biodiversity, nature conservation and buffering (see chapter 3.1).

The second type of low impact crop production tested is **biomass from buffer strips**. Buffer strips are important for preventing pesticides and minerals to pollute surface water, soil conservation and biodiversity, but often don't have any direct economic return. The project investigated if harvesting the biomass for bio-energy production may alter this situation and if this could be accepted by the general public (see chapter 3.2).

Thirdly, the project evaluated cultivation of **energy crops on marginal land** that because of its location, e.g. near high ways, or because of its characteristics, e.g. contaminated land (see chapter 3.3) has no real function for agriculture, industry, nature, living.

The last study included growing of **cover crops** as the winter culture preceding the main crop coming in the spring. These old but, due to the development of the intensive agriculture, abandoned practice may contribute to the production of significant amounts of biomass for bio-energy without harming the food production during summer (see chapter 3.4).

In total, the project realized:

- 11 pilots on multifunctional short rotation coppice of which 6 in industrial area and 5 in agricultural area,
- 4 pilots on biomass from buffer strips,
- 2 pilots on biomass from marginal land, and
- 2 pilots on biomass from cover crops.

All pilots are located in Flanders (Belgium) or in the South West Netherlands. Thanks to the pilots, different technologies including all their practical aspects could be demonstrated and communicated to different stakeholder, including farmers, industrial estate owners, bioenergy plants, public sector policy makers and legislators. Based on the results of the pilots, a comprehensive biomass strategy for the region of Northwest Europe was developed. The strategy can be found in the report '*Development of regional strategies for the acceleration of bioenergy in Northwest Europe*' (available at http://www.arbornwe.eu/). This report describes how the biomass from energy crops can be used for energy production and which challenges have to be dealt with.

3.1 Multifunctional short rotation coppice

3.1.1 Legal assessment

3.1.1.1 Status of short rotation coppice

The *Forest Decree* (Flemish legislation) states that SRC is a fastgrowing woody crop, which is harvested periodically, with harvest intervals of maximum 8 years. The Decree states that it is not recognized as being a "forest" as such, but as being an "agricultural crop". However, it becomes a forest if:

- The harvest intervals are longer than 8 years;
- It is planted in Vulnerable Zones (Flemish Codex Spatial Planning, 01/09/2009), eg. agricultural areas with ecological value or importance, forests, nature conservation areas, flooding areas, dunes,…

The *Farm Laws* (Federal/Belgian legislation) define the distances between forests, trees, shrubs and the adjacent parcel. For example to plant forest, a distance of 6 m is obliged from the adjacent parcels, while for standards there should be kept 2 m distance. However, the Farm Laws do not define rules for SRC, so there is no certainty which requirements should be met for SRC.

The *Land Tenure Law* (Federal/Belgian legislation) does not say anything about SRC. However, it does include some rules concerning the planting of trees. For example, for planting trees, the tenant needs to have the landlord's permission. It is not clear if SRC is also included in these rules. It is also not clear that when the leasing is ended the plantation of SRC will have lead to an increase of the value or a decrease of the value of the land and which criteria will be used to decide.

The *Nature Decree* (Flemish legislation) doesn't mention SRC either.

3.1.1.2. Combining chicken farming and SRC

Regulation EC 889/2008 (European legislation) states that organically produced eggs should be produced by free range farming that is subject to the following conditions:

- 4 m² per chicken free range space available,
- provide shelter, and
- free range area should be planted.

At the moment, most farmers doesn't provide shelter in the free range area because they are afraid that trees could attract predators and other birds. Also, they fear that the chicken will stay outside during the night or that they will lay their eggs outside.

KAT[1] and *SKAL*[2] regulations impose that when SRC is combined with chicken, it should be done by planting strips of SRC (rather than one big plot) interspersed with grass strips. In this way there is shelter over the whole area, the plantation is very accessible and the overview is retained (for the control of the farmer).

3.1.1.3. Biomass combustion and emissions

Installations with a nominal power > 300 kW

Table 2 shows the emission thresholds that apply in the Flemish region since January 2014, for installations with a power larger than 300 kW. At regular moments, the compliance with these thresholds should be tested. These tests can only be performed by acknowledged labs, or if they are performed by the process operator, the method should be acknowledged by a lab.

Table 2: Emission thresholds (in mg/m³) applying for different nominal heat ratings of combustion installations (VLAREM II, Art. 5.43.2.4)

	Total nominal thermal power (MW)	Dust (mg/Nm^3)	Dust (mg/Nm^3)	Dust (mg/Nm^3)	Dust (mg/Nm^3)	Dust (mg/Nm^3)
New installation (license for exploitation after 1 January 2014)	≥ 0,3-1	200	450	600	375	0,6
	≥ 1-5	50	450	450	375	0,6
	> 5-20	20	450	350	300	0,15
	≥ 20-50	20	250	250	300	0,15
Older installations (license for exploitation after 7 January 2013 or installation in use after 7 January 2014)	≥ 50-100	10	200	150	200	0,15
	>100-300	10	150	150	200	0,15
	>300	5	50	55	200	0,15

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[1] SKAL is the European regulation that describes the minimal requirements that should be fulfilled in order to sell a product as biologically cultivated.

[2] KAT is the German regulation that describes the minimal requirements to sell a product on the German market. This regulation is not specific for biologically grown products but also concerns requirements with regard to stable infrastructure and free range.

Installations with a nominal power < 300 kW

Biomass combustion in a < 300kW installation, does not fall under the Flemish Rules for Environmental Permits (VLAREM). This implies that these installations do not have to comply with the emission thresholds as defined in Table 2. These installations have to comply with the Flemish Ordinance regarding the maintenance of combustion installations (Vlaams Besluit, 08/12/2006) and with the Royal Decree regarding the minimum efficiency requirements and emission thresholds for combustion installations (KB, 12/10/2010). Table 3 shows the required efficiency and emission thresholds.

Table 3: Efficiency requirements and emission thresholds (KB, 12/10/2010)

Equipment	**Minimum efficiency (cfr. Standards)**		
Boiler NBN EN 303-5	≥ 24/11/2011	≥ 24/11/2011	≥ 24/11/2011
	≥ 75 % nominal power	≥ 75 % nominal power	≥ 75 % nominal power
	Maximum rate of particle emission		
	≥ 24/11/2011	≥ 24/11/2011	≥ 24/11/2011
Boiler NBN EN 303-5	≤ 180 mg/Nm^3 nominal power	≤ 180 mg/Nm^3 nominal power	≤ 180 mg/Nm^3 nominal power

Emission measurements of biomass combustion units in Flanders

POM and Inagro performed emission tests and evaluated ash content at 4 different biomass combustion sites in Flanders. The goal of these tests within the ARBOR project is to evaluate performance of current biomass combustion installations and identify critical points in the management of such an installation. The outcome is a manual for optimal management of a combustion installation, in order to comply with the prevailing legislation. The manual '*Green heat from wood cumbustion for agriculture, SME and industry: guidelines for an optimal combustion and minimal emission*' is available at http://www.arbornwe.eu/

Dust, SO$_2$, NO$_x$ and CO were measured in the flue gases of 4 installations:

1. Installation of 500 kW burning 3 different samples:
   a. 65% SRC chips + 35% Miscanthus
   b. 50% SRC chips + 50% Miscanthus
   c. 35% Miscanthus + 65% treated, but non-polluted waste wood chips
2. Installation of 37 kW burning 100% Miscanthus
3. Installation of 55 kW burning 3 different samples:
   a. 100% wood chips from forest
   b. 100% wood chips from hedges
   c. 100% SRC chips
4. Installation of 120 kW burning 3 different samples:
   a. 100% wood chips from forest
   b. 100% wood chips from hedges
   c. 100% SRC chips

In the ashes all relevant parameters were tested for the VLAREMA-criteria, which define if a waste can be allowed as a soil improver or not.

Results show that dust measurements in installation 3 and 4 were good. Installation 2 did not comply with the criteria set out in the Royal Decree (Table 3). The results also indicated that the use of wood from fertilized SRC gave rise to a higher NOx-emission. When analyzing the nitrogen content of the different wood chips there was a clear relation between N-content and NOx emissions from each type of wood chip. Installation 1 also showed too high levels of dust and CO. As this installation needs an environmental permit (>300kW), it needs a thorough study of how combustion settings can be finetuned to lower CO and dust emissions.

The results of the ash content analysis show that in installation 1 and 2 the results comply with the VLAREMA criteria. The ashes of installation 3 and 4 exceed the standard for cadmium. There was no relation found between the Cd concentration in the ashes and the one in the wood chips.

3.1.1.4 Subsidies for farmers and companies

The VLIF (Vlaams Investeringsfonds) supports the investment of heating installations that use renewable fuels by subsidizing the investment up to 30%, on the condition that the production is sustainable. Several other conditions should be fulfilled (see http://lv.vlaanderen.be/nlapps/docs/default.asp?id=1837). The most important conditions are that the main profession of the applicant is farming and that the investment should be minimum 15 000 €.

There is a raised investment deduction for investments that aim at a more rational use of energy in the industry, and more specific at improvements of the industrial processes with respect to energy savings. The tariff for energy saving investments is 13,5%. More information can be found on the website below.
http://www.energiesparen.be/inleiding-formulier-verhoogde-investeringsaftrek

For investments in projects that produce green heat (with a capacity of at least 1 MW), financial support can be requested through the „Oproep Call Groene Warmte" of the Flemish Energy Agency (VEA). More information can be found on the website below.
http://www.energiesparen.be/call-groene-warmte

3.1.1.5 Spatial planning in industrial areas

Spatial planners (at municipal, provincial or regional level) often include the following restrictions for planting buffer zones or green strips, which exclude the use of SRC: use of indigenous species, species that stay green during winter and species that create a maximal visual buffer.

3.1.2 Pilot description

As the cultivation of short rotation coppice is different for agricultural land and industrial land, the set-up and the results of the pilots are discussed separately. However, all pilot results are combined to formulate the conclusions and lessons learned concerning SRC.

3.1.2.1 Multifunctional short rotation coppice on agricultural land

In total there were 5 pilots SRC on agricultural land:

1. Zonnebeke (focus on biodiversity): 1 ha willow (Swedish clones), 0.5 ha poplar (Italian clones + INBO clones) + indigenous species (grey alder, white willow, common hazel)
2. Oostkamp (focus on biodiversity): 1 ha willow (Swedish clones) + indigenous species (grey alder, common hazel, goat willow)
3. Poeke (focus on combination with laying hens): 1 ha willow (Swedish clones)
4. Merelbeke (ILVO) (experimental plantation of willow in combination with chicken) 0,5 ha willow (Swedish clones)
5. Staden (focus on biodiversity): 2,2 ha of willow (Swedish clones) and 0,4 ha of indigenous species. (black poplar, fluttering elm, black alder, goat willow, white willow and common osier)

The pilots on agricultural land can be subdivided in 2 different subpilots: a subplot that evaluates the effect of SRC on animal welfare and income of the farmer, and a subplot that evaluates the effect of SRC on biodiversity.

Combining SRC with chicken farming

The role of SRC as a mean to increase chicken welfare and the income for farmers by planting SRC was evaluated at a chicken farm. Chickens are naturally forest animals and don't like large open spaces. This implies that the presence of SRC could improve the chicken welfare and the potential production (Dawkins *et al*., 2003; Hegelund *et al*., 2005) Also, the trees could be a natural drain outlet and buffer for odor (Aarnink *et al*., 2006). Finally, they integrate the chicken farms better in the rural landscape and increase land use efficiency.

To test some of the assumptions made regarding the combination of chicken and SRC, an experimental set-up was determined, together with the Institute for Agricultural and Fishery Research in Flanders (ILVO). The following parameters were tested in a set-up with chicken kept in an SRC plantation:

- Which factors influence the uniform use of the free range area (grassy areas vs areas planted with SRC)?
- Parameters directly related to animal welfare, animal health and egg production;
- Quality and yield of SRC;
- Soil parameters;
- Natural pest and weed control.

Increasing biodiversity with SRC

The other subpilot focuses on biodiversity in the agricultural area by optimizing the planting system of SRC as well as the SRC management. Several measures have been tested to optimize the ecological value of SRC:

- Introducing other species than the classic monocultures of Swedish willow clones and Italian poplar clones, bred for their biomass production;
- Ecological management of headlands: pollen and nectar margins were sown for pollinators and other beneficial or butterfliesIncreasing nest places (2 large insect hotels of 210 x 140 cm and 16 nest boxes);
- Phased harvesting (subsequent removal of the trees);
- Sowing white clover and rye grass between poplar rows, to host natural predators of occurring pests and to reduce pesticide and herbicide use;
- Conservation of nearby small landscape elements.

In this second pilot SRC, functions as a green stepping stone or corridor (small surfaces and preferably oblong), creating landscape connectivity, in the fragmented small-scale agricultural area with monocultures of maize, which is typical for Flanders, are taken into account.

Preparation and follow-up of the pilots

For each of the pilots, following actions were carried out:

1. Soil samples were taken to evaluate the necessity of fertilization, at the beginning or after a few harvest cycles.
2. The soil was prepared through ploughing in February-March. After planting end of March-beginning of April, a pre-emergent herbicide was applied.
3. The willow cuttings were planted with an adapted leek planting machine. The poplar rods were planted manually. The planting material consisted of Swedish willow clones (a mix of Tora, Olof, Tordis, Inger, Klara), Italian poplar clones (AF2, AF8) and com-mercially available INBO poplar clones (Skado, Bakan, Grimminge).
4. During the first year after planting there was a very close follow-up of the weed growth, and if necessary, a mechanical weed treatment was performed.
5. First harvesting of the willow trees was carried out in February 2015. Several harvest-ing machines were evaluated: the adapted maize chopper of CNH, or the Stemster, developed by Nordic Biomass.
6. It is also evaluated how wood chip drying could be carried out at the sites where the owners wish to use the wood chips in their own boiler, or if the owners wish to sell dry chips. Preferable the chips will be dried in an existing building or silo with good natu-ral ventilation. If it is not possible to use the chips at the site itself for green heat production, Inagro and POM search for a local farmer or company, interested in buying the wood chips, fresh or dry.

3.1.2.2. Multifunctional short rotation coppice on industrial land

SRC was planted at unused industrial sites. The 6 pilots were placed on industrial land belonging to the following companies:

1. MIROM in Roeselare: 1,6 ha willow (Swedish clones and experimental INBO clones) – MIROM Roeselare processes household waste, collects garden waste, coordinates sensitizing projects related to waste recycling and distributes waste bags. Waste (green) heat of the incinerator feeds one of the biggest district heating systems in Flanders.
2. OB&D in Meulebeke: 0,8 ha willow (Swedish clones) – OB&D is responsible for the management of a landfill site and explores and pads clay pits.
3. Vyncke in Harelbeke: 0,5 ha poplar (Italian clones) – Vyncke is expert in burning any type of biomass or other solid fuels and producing energy in the form of steam, thermal oil, hot water, hot gas or electricity, individually or in any combination.
4. Vanhalst in Wevelgem: 0,5 ha poplar (Italian clones and INBO clones) – Vanhalst is specialized in small birth gifts.
5. Cras in Brugge: 0,5 ha willow (Swedish clones) – Cras is a big wood and wood products selling company.
6. A&S Energie in Oostrozebeke: 0,8 ha willow (Swedish clones) – A&S Energie processes non-recyclable wood waste to green electricity.

At the start of the project the goals of this set-up were (i) to create a natural buffer for odour, particulate matter or other emissions, (ii) to support biodiversity on industrial sites and (iii) to integrate the company in its landscape and besides this to provide an extra income for the company who owns this land,.

The planting preparation and realization, harvest preparation, harvest and wood chip handling procedures were identical to those of the pilots on agricultural land. The pilots at OB&D in Meulebeke and MIROM in Roeselare were harvested in March 2015. The harvest of the pilot at Cras in Brugge is foreseen in the winter of 2015, while the harvest of the pilots at A&S Energie, Vyncke and Vanhalst is foreseen in the winter of 2016.

3.1.3 Pilot based findings

3.1.3.1 Practical implementation of SRC

Bottlenecks with respect to the utilisation of short rotation coppice for energy production, are related to some pratical aspects of SRC, including planting, harvesting, drying and storing the wood. Based on the experiences from the pilots, some guidelines are formulated.

Site selection

Finding suitable parcels on industrial land is not easy. Often they are waiting for development, and cannot be blocked for several years, which is the case when planted with SRC. Other bottlenecks are irregular shapes, compacted soil or soil that is full of gravel and bricks, soils that are very wet, parcels under a steep slope, etc.

The same counts for agricultural land. Wrongly, farmers often want to plant SRC on small, irregular or very wet land since it is less suited for conventional production. Though these are far from ideal for SRC production neither, since SRC is harvested with big and heavy machinery during often wet conditions in winter. Small, irregular and wet soil conditions are being problematic from this point of view. Another case why farmers are often interested in SRC because they wrongly think that it can replace permanent grassland. As mentioned earlier, also chicken farmers were quite reluctant to cooperate in setting up a pilot plantation for several reasons mentioned above.

Most of the parcels where finally SRC was planted was on farms where the biomass could be used on the own company and where the land was not intensively used at the moment (land was leased or was part of the free range area for chicken; previously grassland).

Design

In order to develop optimal conditions to improve biodiversity by SRC, the following guidelines should be taken into account:

- only plant in fragmented small scale agricultural landscape on arable land (keep away from open agricultural landscapes, threat for farmland and meadow birds);
- increase structure and variation by introducing indigenous coppice species and phased harvesting;
- plantations should not be too big, rather oblong;
- preserve nearby small landscape elements (eg. hedges, solitary trees, pollard trees, pools, …);
- pollen and nectar mixtures and ecological management of the headlands;
- nest boxes and insect hotels for respectively birds and insects.

In case of combining SRC with chicken the most optimal way to introduce SRC in the free range is by planting strips (rather than one big plot) away from the stable (perpendicular) interspersed with grass strips. In this way there is shelter over the whole area, the plantation is very accessible and the overview is retained (for the control of the farmer). These conditions are meanwhile also imposed by KAT and SKAL regulations when planting SRC.

Planting and harvesting

Regarding the crop itself and the planting procedure, we can conclude that poplar and willow planting is straightforward. To have a good result it is anyhow important to have a good soil preparation and to have soil that is pressed firmly using a packerwals roll.

The adapted leek planter works well, however, if leek planting season starts, it is difficult to find one available for SRC planting. For example at the Cras site, we planted very late, in June, and it was hard to find any planter available. Late planting generally results in lower growing speed and more drop-outs. For this reason the yield at the Cras site will be much lower than at the other sites. However, this is also due to the fact that the preparation of the soil was not done properly, as large clods and parts of turf were still present, impeding good planting by the leek planter. In order to facilitate future planting of SRC in the early spring we found the constructor of leek planters (Vermeulen construct NV) willing to adapt a planting machine especially for planting SRC. This should improve the availability of a planting machine during the whole planting season, even when there is some overlap with the leek planting season. The machine was finished in spring 2014 and was used for the first time to plant the extra pilot (2,2 ha) at Staden.

We also intended to plant with a stepplanter coming from Northern France, but this option was finally discarded since it was too costly.

Cultivation technique and follow-up

Weed control after planting is minimal for the Italian planting system, because the poplar rods are already big when planted, and don't suffer so much from weed growth. However, for the Swedish planting system, a weekly check is necessary during the first few months after planting (April, May, June), and mechanical weed treatment should be performed immediately when necessary, because the weeds tend to overgrow the willow cuttings very quickly. This type of intensive follow-up can be discouraging for companies who are interested in planting SRC, because in the current situation, they often have a farmer who takes care of the maintenance of the industrial fallow, and it is not the company's core business to follow-up the plantation. Knowledge about agriculture in general is often lacking, so it can be daunting to be responsible for their own 'crop' and its successful growth. For farmers this is different since they are very familiar with following up the development of crops and weed control. The same counts for the harvest. Since growing biomass is not the core business of the company it is not evident for them to organise the harvest and assure that this is done under the most favourable conditions. For this reason we believe that support with regard to the cultivation technique from Inagro and POM will be necessary in next harvesting cycles.

An experiment was set up to compare different methods of weed treatment. In one plot white clover was sown, in another plot English rye grass and in a third plot mechanical weed control was done. We clearly saw a very big difference in growth of the willow between the plots with rye grass and white clover. The rye grass seemed to compete quite heavily with the willows and by this inhibited their growth. The difference between the mechanical weed treatment and the clover was less clear.

Another experiment was realized in cooperation with the company 'Vanhoucke'. The classical weed control consists of a shoveling machine with rubber fingers , which was compared with a diagonal weeder (a special form of a tine weeder or weeder/comb harrow) and with a 'weed burner'. Both the shoveling machine and the diagonal weeder gave good results to remove weed in an efficient way without damaging the trees, while weed burning damaged the trees too much and caused die-off. For more information and photo's, consult the website below.

http://www.vanhouckeinfo.com/nieuws/proefveld-testen-met-korte-omloophout-update-2.

Besides the mechanical weed control, we also carried out a treatment with a pre-emergent herbicide (combination of AZ and Kerb). The effectivity of this treatment varied strongly in function of the wheather conditions shortly after application. If the treatment was not followed by a little rain to moisten the soil, the herbicide did not function well.

Storage, drying and selling produced biomass

In contrast with farmers, another practical issue to tackle by industrial companies can be the need for drying space, if they want to sell the chips dry (which is financially more interesting than selling them wet) or store them till prices are more favourable. For the first two harvests on industrial land (at the OB&D and MIROM-site) storage for drying was not a big problem, but often companies don't have redundant spaces that are suitable for storing and drying wood chips, while farmers do.

Marketing wood chips at a reasonable price that covers the investment costs (even dry chips) is hard. Especially industrial companies that don't have any affinity with the biomass sector are not willing to put much effort in finding a buyer that is willing to pay a good price for the wood chips. Known buyers that deal with biomass at a large scale often give the lowest prices, while small-scale installations, that are very dependent on good biomass quality are often willing to pay more. However, these small-scale installations, often owned by farmers, don't get into contact with industrial companies that easy. POM and Inagro can be a facilitator in this. One could opt for burning the wood chips in the company itself, but the heat demand of companies is often so high that it can never be covered by the wood that they grow themselves. Natural gas is often a much easier and even cheaper way of heating for industrial processes. Heating office buildings with wood chips is an option, but it requires investments to start with, and a time consuming level of maintenance and knowledge which need to be much higher than for conventional boilers on fossil fuels. In the workshop '*green heat from wood burning from SME and farmers*' POM asked the question if an Energy Service Company (ESCO) can overcome those barriers. Opinions varied amongst the 65 participants but in general small-scale installations were viewed less suited for an ESCO approach.

3.1.3.2 Productivity of SRC

The productivity of one pilot (MIROM site) which was harvested for the first time on industrial land, together with an economic analysis, can be found in the report 'Development of regional strategies for the acceleration of bioenergy in Northwest Europe', available on http://www.arbornwe.eu/.

In 2010, the first planting of the five-year plant system in Flanders has been realized in Waarschoot on the initiative of the companies Sylva and Xylempor. A total of half an acre was planted on which 11 different varieties were tested. In winter 2013-2014, the trees were 4 years old and for the first time the yield of this system was determined. This was done by development of an allometric relation for four of the most promising clones of poplars.

The average diameter of the trees was 12 cm and they reached a height of more than 12 m. The most productive clone (AF2) had an average yearly production of 10 ton DM/ha/year, while the clone AF8 was the least productive with a yield of 6,5 ton DM/ha/year. In between lies the Monviso with 7,8 ton DM/ha/year and the AF19 with 9,3 ton DM/ha/year. Important to mention is that the biomass production during the first two years is quite a bit lower than the average over four years. This means that we can expect the biomass production of the fifth year to be higher than the average biomass production till now.

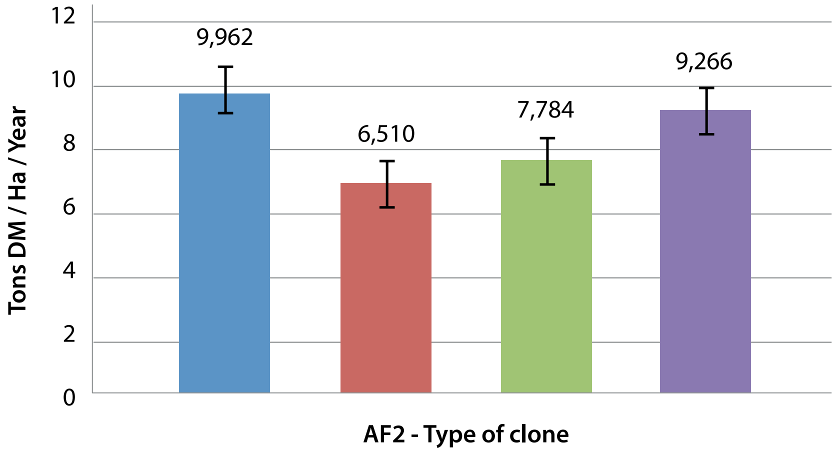

Figure 2: Average yield of poplar on the ARBOR pilots

In spring 2010 there was also realized a plantation of one ha of Swedish willows (15 000 cuttings/ha) and indigenous coppice species like silver birch, black alder and goat willow (15 000 trees/ha) in Zedelgem. After 4 years, the parcel was harvested and the productivity was measured by means of allometric relations that were developed for each tree species or clone. Following productivities were registered:

- The general average productivity of indigenous species was 8,5 ton DM/ha/year. The general average production per tree species gave the following arrangement; goat willow 17,6 ton DM/ha/year, followed by black alder 5,3 ton DM/ha/year and silver birch 3,4 ton DM/ha/year (see Figure 3).
- The mixed plots with the indigenous species showed the higest productivity in case black alder was mixed with goat willow, namely 13,3 ton DM/ha/year, while the lowest productivity was found in the plots with only silver birch, namely 4,5 ton DM/ha/year (see Figure 4).
- The general average production of all Swedish willows was 12,1 ton DM/ha/Year. The average production per clone gave the following arrangement: Tordis seems to be the most productive with an average yield of 15,2 ton DM/ha/year, followed by Klara with13,8 ton DM/ha/year and Gudrun with 7,8 ton DM/ha/year (see Figure 5).
- The mixed plots with the Swedish willows showed more or less the same level of productivity around 12 tons DM/ha/year, with a slightly lower productivity in case all three clones (Tordis, Gudrun and Klara) were mixed in one plot (see Figure 6).

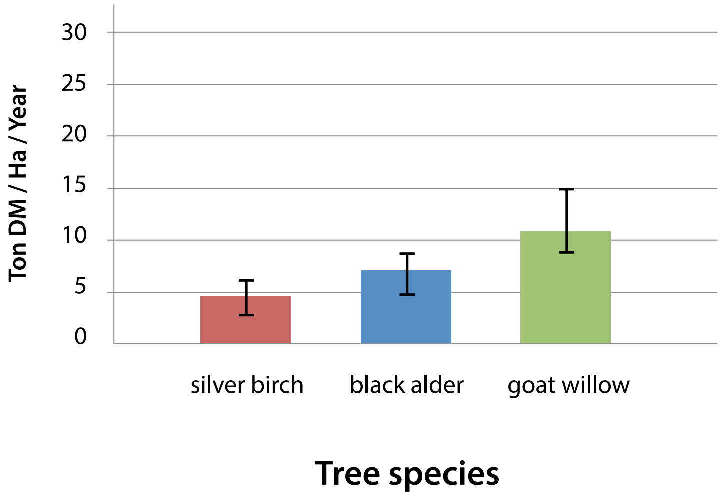

Figure 3: Productivity of the SRC per tree species and per plot (indigenous plantation)

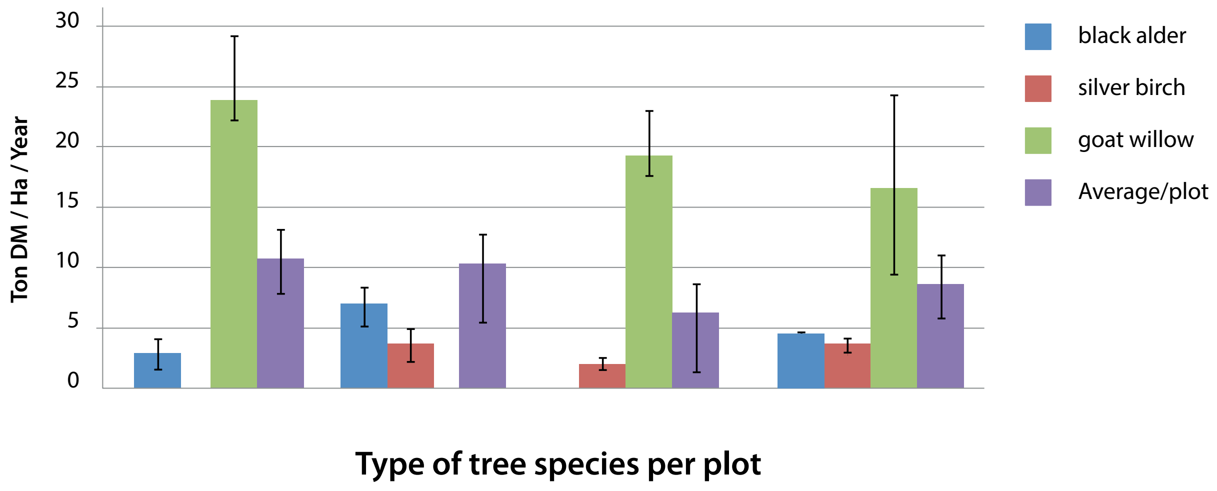

Figure 4: Productivity of the SRC per tree species (blackw alder, silver birch, goat willow) and the average productivity per plot

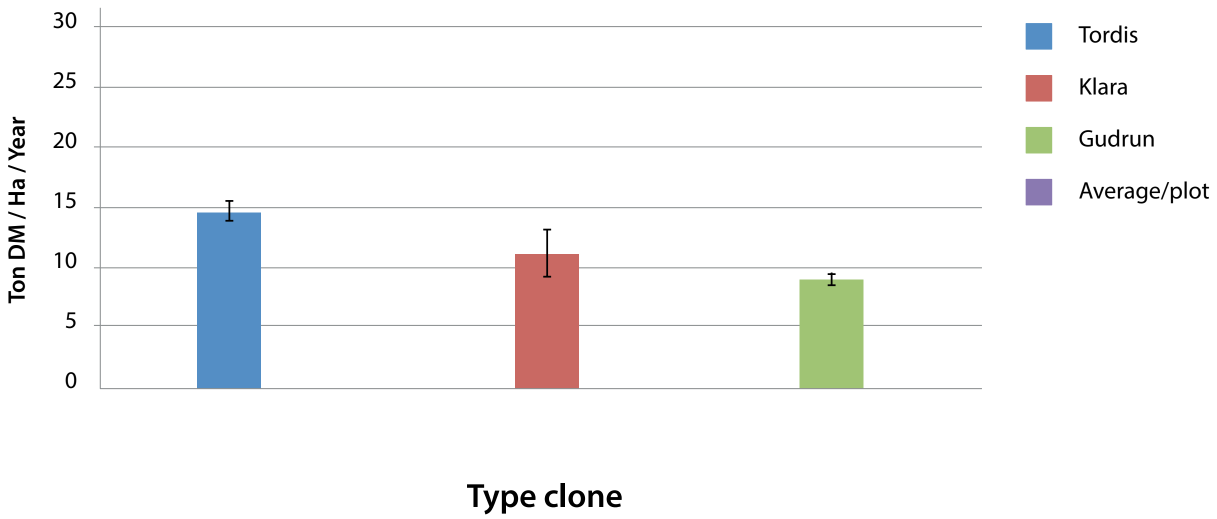

Figure 5: Productivity of the different clones (Tordis, Klara, Gudrun) per willow plot (Swedish plantation)

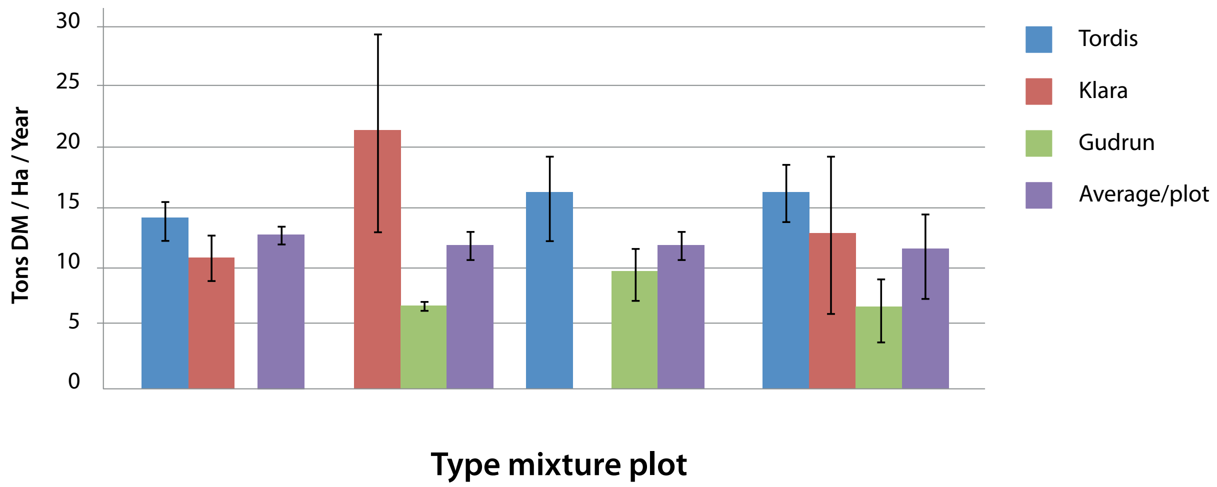

Figure 6: Productivity of the mixed willow species per plot

3.1.3.3 Added values of SRC

Biodiversity

In order to get to know the potential of SRC plantations to reinforce functional biodiversity in agricultural landscapes, ten SRC – maize pairs were compared to quantify the differences in diversity and composition of both vascular plants and arthropods. On average it could be concluded that:

- The total cover of vegetation was 10 times higher in the SRC plantations while taxonomic and trait diversity were also consistently higher.
- Arthropod activity densities were significantly higher, sometimes almost double in SRC plantations.
- Regarding functional groups, the activity densities of omnivores, detrivores, mycophages, phytophages and parasitoids were significantly higher in SRC.
- While activity densities of predators were not different among the crop types, their effective species number was higher in SRC, indicating a more evenly distributed and diverse predator community (Verheyen *et al.* 2014).

For the plantations enriched with indigenous species there was found a significant effect of the planting type and the distance in the field on the arthropod species composition, but not on the overall diversity. The fact that species composition is different between sites, but not the total diversity means probably that several species that are present in the classical plantations are substituted in the enriched fields. How this differences in species composition is reflected in the functional groups and has an impact on the ecosystem services should be looked at in more detail in the future (Boffin A, 2014).

SRC can thus increase both vegetation and arthropod abundance and/or diversity significantly in agricultural landscapes when replacing annual biomass crops such as maize. Along with the increased abundances and diversity, also the functional diversity of both the vegetation and arthropod community can increase, indicating a higher potential for the delivery of, sensu, in situ and local proximal ecosystem services. Therefore SRC has the potential to be an effective, and probably also efficient, agri-environment scheme when the aim is the enhancement of functional biodiversity values (Verheyen *et al.* 2014).

Free range for chickens

By intensive contact with the partners of several Dutch projects, namely 'Bomen voor buitenkippen' and 'kiplekker onder wilgen' we exchanged experiences and learned from each other. Their first experience was that foreseeing SRC in the free range area does improve the use by the chicken and predation by raptors decreased. An important condition for the plantation to be effective is to plant in small margins away from the stable (length ±150-200m), interspersed with open grassy margins. Providing shelter in this way over whole the free range area and conserving in this way the open character of the free range.

Chickens with acces to free range with willow tend to go more often outside. Next to this they also went farther away from the stable than chickens with only grass in the free range. The meat of these chickens with willow was more yellow and dark than those without free range. A taste panel concluded as wel that the meat was more tender, less fibrious and more juicy. Although the quality of the product is higher, the overall weight of chickens in free range with SRC was lower than those without free range. This because the chickens in free range had a lower feed intake. On the scale of welfare the chickens with free ragne scored higher than those without. An extra advantage is that the growth of willow isn't effected by the chickens. To conclude it can be stated that the plantation of willow has overall positive effects on chickens.

3.1.3.4 Desktop study and harvest demonstration

The harvest is one of the most expensive operations in the whole cultivation process. For this reason it is important to decide whether or not to harvest depending on the actual standing biomass. Normally for willow average rotations of 3 years are applied, but in order to improve efficiency it can be decided to postpone the harvest keeping in mind the limitations of the harvester (max diameter) and the legal obligations to harvest within 8 years.

Often the wet conditions during winter are an obstacle to harvest or alternative machinery should be used. For the harvest of 2ha of SRC in Zedelgem during the winter 2013-2014 the Danish harvest machine 'Stemster' from the company Nordic Biomass was used. This machine has following advantages:

- The machine is able to harvest on soft tracks and to harvest the biomass in one operation causing minimal soil compaction.
- The machine has a good harvesting capacity and that it is capable of harvesting trees with a diameter up to 15 - 20 cm and rows up to 200 m length.
- In a comparative study of three types of harvesters (Berhongary *et al*, 2013) the 'Stemster' was also described as the most efficient since it was able to harvest 94,5% of all potential harvestable biomass. This in contract with the self-propelled corn harvester who was only able to harvest 77,4% of harvestable biomass.
- Less damaged and cracked stumps were found when harvested with the 'Stemster' because the trees are not put under tension before being cut-off. The harvest rate should not be the only priority but also pursuing an optimal regrowth of trees should be taken into account besides the efficiency of the harvester and the quality of the final product (Berhongaray G. *et al*, 2013).

Unfortunately, the 'Stemster' seemed to be the most expensive way to harvest. This is partly due to the fact that the speed is almost twice as low as the speed of the self-propelled corn harvester, but afterwards the timber should also be chipped before it can be used as fuel. Also this operation means an extra cost. Table 4 illustrates the costs for the two different harvesting machines (based on th real harvest cost of the plantation in Zedelgem) and the revenues depending on what product is sold (fresh or dry).

Since at this moment only the self-propelled corn harvester is available in Flanders, optimal harvesting conditions will be pursued in order to maximize efficiency and regrowth and minimize soil compaction. Optimization of efficiency will be done through following actions:

- *Intermediate storage of chips to dry them till 30% humidity*. Don't sell wet chips
- *Minimizing transport cost* of both harvest machine and biomass by searching for local valorization and coordinating the harvest of all SRC plantations in West-Flanders. Transporting biomass should be done with the same harvest trolleys in a radius of 15 km.
- *Combining harvest and chipping in one operation*. Try to harvest in autumn underd dry conditions. New plantations are planted in a wider plantdesign (4 m instead of 3,75 m) in order to allow harvesting with self-propelled cornharvesters on soft tracks.

Table 4: Costs and benefits of the SRC harvest with two different harvesting machines

Harvest with 'Stemster'(Nordic Biomass) Costs		Harvest with self-propelled corn harvester (New Holland)	
Harvest	990,75 €	Harvest	2600 €
Chipping SRC	2300 €	Transport cost harvest machine	(500 €)
Transportcost harvest machine	(1500 €)		
Expenses	(250 €)		
Cost excl. Transport & expenses			
Cost/ton (fresh)	42,30 €	Cost/ton (fresh)	33,77 €
Cost/ton (dry 30% humidity)	48,56 €	Cost/ton (dry 30% humidity)	38,37 €
Benefit			
Selling fresh chips (77 ton)	2362 €		
Selling dry chips (67,76 ton)	5760 €		
Revenue/ton (selling fresh)	30,68 €	Revenue/ton (selling fresh)	30,68 €
Net surplus	**-12,05 €**	**Net surplus**	**-3,09 €**
Revenue/ton (selling fresh)	85 €	Revenue/ton (selling fresh)	85 €
Net surplus	**36,44€**	**Net surplus**	**46,63€**

3.1.4 Future implementation in West-Flanders

3.1.4.1 Multifunctional short rotation coppice on agricultural land

SRC in a free range can be planted by a poultry farmer for several reasons:

- Additional income for the farmer
- Animal welfare and ecological production (since chicken are forest animals).
- Draining the site
- Buffer for odor
- Integration of the exploitation in the landscape

Although there are some clear advantages of cultivating SRC in the free range area, it seemed not easy to convince farmers in doing so. The main reason why most farmers don't plant trees or shrubs in the free range is because they are mainly afraid to attract unwanted species like foxes, rats and other predators. But also the fear possible attraction of birds with an increased risk of avian flu together with the fact that chicken would lay their eggs in the SRC plantation or would stay out overnight makes them reluctant. This was also the reason why it was so hard to find farmers willing to cooperate in setting up a pilot plantation. Other bottlenecks were of a more practical nature, like for example the restrictions to replace permanent grassland by SRC or the permission needed to plant SRC from the land lord in case the land is leased. Finally we can conclude that the biggest added value of SRC would it's contribution to the energy demand for heating on the farm and the contribution to being self-sufficient.

Creating free range area for chickens

By the European regulation (nr. 889/2008) today there are already commitments for the establishment of the free range area for poultry:

- Open air areas for poultry shall be covered for the most part, provided with protective facilities, and permit animals to have easy access to adequate numbers of drinking and feeding cribs
- Each animal should have at least 4m^2 of free range
- The free range should exist mainly out of plantations.
- Chickens should have acces to the free range for at least 1/3 of its life.

But also the regulations of KAT en SKAL pose specific requirements for the establishment of the free range and the amount of shelter opportunities present. But in practice, we see that today shelter is lacking in most conventional farms.

In Flanders there is ca. 575 ha of free range. At this moment it mainly consists of grassland, but in some cases also crops are cultivated, eg. corn. More strict interpretation and control of the regulations in the future can maybe give rise to more SRC.

In order to convince farmers to valorize their free range in this way we felt that we had to gather information and experience on the bottlenecks mentioned. For this reason we installed an experimental plantation of 0,5 ha of SRC in order to monitor the effects of the trees on the chickens and the other way around. The main goal will be to identify the added value of the SRC for the chicken. The plantation was realized in 2013 and was cut back at the end of the year. The research was started by January 2014 and will go on for the next four years.

Creating support for SRC by the farmers

To get a more clear view on the attitude of farmers towards SRC and the feasibility to install this energy crop, a questionnaire was developed together with ILVO. It was send to all 53 poultry farms in Flanders.

According to the survey, most farmers acknowledge the positive influence for the welfare of poultry. This follows out of the question if shelter delivers more welfare, whereof 69% of the farmers answer that it is (very) beneficial. 75% of these farmers already have natural shelter for their poultry. This consists of fruit trees, poplars, willow, etc. The majority of the surveyed farmers who have a type of shelter are rather happy with their plantation of SRC, especially the spreading of the chickens in the free range is very good (70%). Which lowers the risk of nitrate leaching by more spreading of the manure in the free range.

Only one company indicates it owns a SRC plantage, whereof the wood is harvested and used on the own company. As main reason why SRC is not planted the farmers indicate the lack of knowledge they have of it. Although they find it effective for biodiversity(55% beneficial to very beneficial). Also they don't think it delivers extra workload (40% neutral, 35% beneficial to very beneficial), but the overall assumption is that it's too difficult to maintain a SRC plantage (40% difficult to very difficult, 40% neutral).

Overall conclusion from our experience is that at this moment there is only limited enthusiasm to install SRC plantations in the free range because of the number of above bottlenecks mentioned above. Besides this, of course also the limited profitability of this energy crop played an important role. Only when the wood can be used on the own farm to fill in energy needs, we can reach a more or less profitable situation. Since only broiler farms need heating and they are mainly situated in the Walloon part of Belgium, poultry (laying hens) farms in Flanders can only valorize the wood for other activities on the farm, if present (eg. sew farm, green house, ...)

3.1.4.2 Multifunctional short rotation coppice on industrial land

SRC can be planted on industrial land for several reasons:

- As a buffer zone surrounding industrial area;
- On industrial fallow (either in ownership of project developers or as a strategic reserve of companies);
- As a green strips surrounding individual companies (often a requirement in the environmental permit of the company).

SRC as buffer zone

A buffer zone is a plantation zone that separates industrial area from areas with another allocation. There is about 173 ha of this buffer zone area in West-Flanders. However, not this entire area is suited to plant SRC. For example some zones are difficult to access, very narrow or SRC can come in competition with other functions. POM made a selection of buffer zones that meet the theoretical conditions we assumed to plant SRC:

- Total surface ≥ 1ha
- Circumference ≤ 1297m

This leads to a total available area of 27 buffer zones representing 39 ha, that are in theory suitable for planting SRC. Bottlenecks to realize this are for example: the slope of the buffer zone or the fact that there is an obligatory passage for the fire brigade. Also, certain conditions in the area development plan can impede the use of SRC in these buffer zones:

- If the use of indigenous species is obligatory (can be countered by planting grey alder, common hazel,…);
- If it is obliged to plant species that stay green during winter;
- If they want a maximal visual buffer, as high as possible;

However, if SRC is planted in buffer zones, it is recommended to harvest in phases, ensuring that there is always a visual buffer present.

POM questioned several municipalities to ask for their opinion on planting SRC in a buffer zone. Their answer was quite unanimous. They state that they have no policy at municipal level to evaluate buffer zones, they almost always follow the project developers in their vision on the most suitable plantation plan. POM contacted the two most important public project developers in West-Flanders to work out a hypothetical case study together with them. One developer showed almost no interest in the case study, for the other one study was carried out. This case study compared the classic way of planting a buffer zone, with a buffer zone that consists of SRC. Furthermore, pictures have been taken to evaluate the visual buffering of SRC after harvest and to define how long it takes before the trees provide a full visual buffer again.

Economical results of the case study show that SRC (willow) in a buffer zone is more than two times cheaper than regular buffer zone plantations. For SRC investment, plantation, maintenance and harvesting costs were included next to the yield of selling wet chips. The regular scenario had no harvesting costs and yields. It should however be mentioned that the regular buffer zone costs of public project developers taken into account were mean costs, which can vary strongly depending on the type of plants used. In the studied zone it was legally forbidden to develop 'agricultural production' and required to use species that stay green during winter. Though economical aspects seemed promising, awareness of local governments to plant SRC need to be increased in order to take SRC into account when recording urban design prescriptions.

SRC on industrial fallow land

POM West-Flanders assumes that there is in total about 500 ha of industrial fallow in West-Flanders. About 470 ha of this is in the ownership of project developers, about 30 ha are strategic reserves of companies. The land that is in ownership of project developers is often managed by a third party, for example a farmer. The land is 'waiting' to be industrially developed. In this way there are no costs for the project developer and the contracts with the farmer are terminable without notice. A precondition to plant SRC is that there can be several harvests (at least 2 or 3) to make sure that the planting investment is at least reimbursed. However, a long-term fixed use of these parcels (e.g. 9-15 years) cannot be guaranteed by project developers. Nevertheless, the industrial fallow that is in ownership of individual companies, and that is used as a strategic reserve, has a high potential for SRC planting. It is on these types of parcels that we have planted the 6 ARBOR pilots. Unfortunately, these are often smaller parcels, with irregular shapes.

We do feel that there is a tendency towards higher site occupancy ratios, because industrial zones are scarce in Flanders. Industrial fallow is therefore not encouraged, and it is definitely not encouraged to block it from being built on during several years by planting SRC. Also, doubts are rising if SRC, in combination with a biomass boiler on site, isn't more of an agricultural activity, that does not belong on industrial land.

SRC as green strips

The conditions for a green strip surrounding individual companies, often laid down in the building permit of the company, are similar to those for buffer zones: use of indigenous species, species that stay green during winter and species that create a maximal visual buffer. SRC alone can't meet these criteria, and on top of that, these green strips are often quite narrow and have a small surface area, which makes harvesting and planting with big machinery impossible. For these cases manual planting and harvesting should be considered, which increases costs.

To promote further implementation of SRC in Flanders, a promotion film was made and is available at the website of POM West-Flanders: www.pomwvl.be/koh

As a general conclusion of the pilot results on industrial land, it can be concluded that we do not expect many parcels of SRC to be planted in the next years on industrial sites, although it is practically feasible, several important bottlenecks (amongst others financial return, scarcity of industrial land) impede SRC from being successful on industrial land in Flanders.

3.1.4.3 Miscanthus giganteus desktop study

POM wanted to evaluate also other options besides SRC, and chose to perform a desktop study on Miscanthus, as an alternative to SRC. POM evaluated the economical impact of a Miscanthus plantation, and also evaluated the legislative aspects. ILVO provided for the cultivation specifications.

Miscanthus is a perennial Asian grass. It is planted by means of rhizomes. It is very productive and reaches heights of 2.5-3m. Once the rhizomes are planted with an adapted leek/potatoe planter or rhizome planter (if available), the crop can stay at that site during more or less 15-20 years. Harvest can be performed annually between January and May with a regular maize chopper. Unlike SRC, the Miscanthus chips are dry enough at harvest time to be burned immediately. The estimated annual yield is 15-25 tonnes of DM/ha. The harvested Miscanthus chips can be used for burning, as mulch for gardens, as a bedding for stables, as a building material, in paper industry or as a substitute for peat in potting soil. All these valorization pathways are currently being evaluated in the FP7 OPTMISC project. Results can be consulted on the project's website: https://optimisc.uni-hohenheim.de

The legal aspects concerning biomass combustion, emissions, subsidies and spatial planning are equal to those for SRC. When burning Miscanthus an adapted biomass burner is necessary, because it contains quite a high amount of Si, which, combined with K, makes that sintering of the ashes occurs at 600°C and the high amount of Cl can be very corrosive. Note that fine dust emissions when burning Miscanthus might be a big problem.

3.1.5 Economic assessment

3.1.5.1 Scope and assumptions

Fast growing willows constitute nearly 80% of the total planted surface for all the analyzed pilots. In several sites e.g. Meulebeke and Poeke solely willows are cultivated. Based on the data delivered by Inagro, Luxembourg Institute of Science and Technology (LIST) carried out a cost analysis for SRC. However, to simplify the analysis and the transfer of the results to other regions, a master pilot (close to characteristics of Meulebeke and Poeke sites) was assumed for the analysis. The assumptions which have been made are as follows:

- 1-6 ha willow plantation with 3-year rotation cycle, plant density of ca. 15.000 trees/ha and life span of 21 years;
- Average crop yield of 10.5 tonnes of dry matter (DM) per hectare & year;
- Mean calorific value of 1 tonne DM of SRC wood: 16,7 GJ = 4,63 MWh;
- Outsourcing of all agricultural activities e.g. planting, site management and maintenance, harvesting and transport within 50 km;
- No costs for land lease, use of own land (belonging to a company or a farmer);
- Wood from short rotation coppice used in own heating installation (50-300 kW);
- External financing for heating installation, drying- and storage room; 10-year loan with a basis interest rate of 6%;
- Harmonized index of consumer prices (inflation rate) of 3% (5% for fuel);
- Discount rate of 4% included to consider the time changing value of money
- No financial subsidies included;
- Not including value added tax (VAT).

The costs included in the assessment are presented in Figure 7.

Agricultural works

- Preparing land (herbicides, cultivator, ploughing, harrowing)
- Planting cuttings (acquiring cuttings, planting with pre-planter, pre-emergence herbicides, mechanical weed control)
- Management of the site and administration
- Harvest and transport
- Plantation removal

Investments (incl. 10-year loan)

- Storage
- Heating installation

Heating maintenance

Figure 7: Costs included in the economic assessment of short rotation coppice

3.1.5.2 Results for woodchips

Based on these assumptions and conditions, the non-recurrent cost for the establishment of a SRC plantation rise up to 2400 €/ha. The heating installation, as well as the drying and storage location, has to be operational in the third growth year of the plantation at latest. Depending on the heating system the installation costs range between 30 000 € for a 50 kW installation and 70 000 € for a 300 kW installation. The investment cost of drying and storage installations sums up to 5 500 €/ha. For harvesting and transport around 1 800 €/ha needs to be paid every third year, while the annual heating maintenance costs add up to ca. 260 €.

All costs included, annual SRC wood chips production costs sum up to 815€/ha (see Table 5) or 1125 €/ha depending if storage costs are included or not. The costs for equivalent wood chips to be purchased on the market sums up to 1082 €, resp. 1185 € incl. storage, per hectare of SRC equivalent.

Fuel type	Equivalent of 1 ha SRC*	Costs for equivalent of 1 ha*
Wood chips from own plantation (SRC)	10.5 tonnes DM	815 €/a**
Wood chips from the market	10.5 tonnes DM	1082 €/a**
Heating oil	4871 liters	3665 €/a
Natural gas	4078 m^3	2474 €/a

* 1 ha of SRC with 10.5 tonnes DM equals ca. 4.6 MWh energy
** only production costs, storage not included

Table 5: Total costs of fuel for different heating systems (value presented in energy equivalents of 1 ha SRC)

Total costs of the heating energy production from SRC wood are by 45-63% lower than for oil-fired heating and by 30-43% lower than for natural gas heating (see Figure 8). This conclusion depends of course on the current natural gas prices. If the plantation manager/owner does not have the wood storage space available, than the clear advantage of the lower production costs for the wood chips from the own SRC plantation is lost due to the investments in storage building. The necessity of having bigger storage & drying place in case of SRC is a consequence of the wood delivery occurring only once per 3 years (after the harvest), while in case of wood chips from the market the stock reaching for one heating year is necessary.

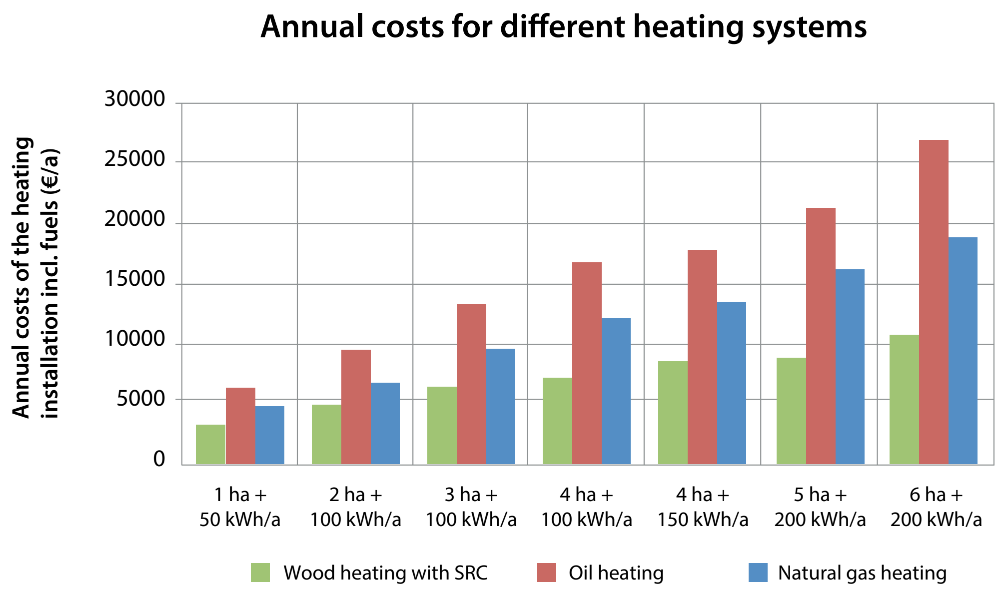

Figure 8: Annual cost differences for SRC wood, heating oil and natural gas based heating systems (incl. the heating system and fuel prices)

The results show a clear financial advantage if using wood chips heating system instead natural gas or heating oil based ones. However, without any financial support, the wood chips from SRC might create a competitive product to the conventional wood chips from the market only if enough storage space is available, without necessary investing in new constructions. A solution to that problem could be to search for **local synergies** e.g. shared use of the local wood storage spaces with the forest authorities or other farmers or creating a kind of subsidy on the national or European level, supporting investment in wood storage for this kind of initiatives.

It is obvious, that production of wood chips from the SRC creates a more complex endeavor when comparing to buying wood chips from the market. The owner is exposed to many unforeseeable risks linked to the weather conditions (e.g. drought) or danger of plant pests occurring. These factors may prevent potential stakeholders from investing in own SRC plantations, if they can securely buy comparable amount of wood at a comparable price from the market without any further efforts. The possible solution could be creating a sort of **insurance fund** on the national or regional level, which could compensate the stakeholders for loses due to fortuitous events. This could create the necessary trust into those supply chain concepts and reduce the risks on the side of plantation owners.

Another important aspect, which is not directly captured in the figures, is the local availability of the **harvesting machine**. This creates one of the main problems for the regions starting with the development of SRC plantation. In many cases the costs of renting and transport of the harvest machine (sometimes over hundreds of kilometers) to the plantation site can even out all the financial gains and hamper development.

Additionally to the above mentioned general calculations, POM and Inagro developed an online calculation tool to advice the potential stakeholders interested in planting SRC at their industrial or agricultural sites. The calculation tool is transparent, easy and quick, and gives a full overview of the parameters that define the profitability of planting SRC. The tool is in Dutch, to make it more easily accessible to the local public and is available from the link below.

www.korteomloophout.be

Within the tool some parameters have been fixed, others should be filled out by the person consulting the tool. The tool shows that profitability highly depends on the availability of a drying area. It also shows that selling the wood chips fresh, is unlikely to be profitable, whereas using it in your own combustion installation, can be very profitable when compared to the Flemish business-as-usual scenario using heating oil as a fuel.

3.1.5.3 Results for Miscanthus

During the desktop study POM performed on Miscanthus, an economical assessment was also made. This resulted in the cash flow as shown in Table 6 and in Figure 9.

Table 6: Example of cash flow tabel Miscanthus (developed by POM)

Year	Cash flow	Description
0	-€ 3 566	Planting cost
1	€ 0	
2	- € 12 427 (VLIF -28%) - € 11 261 (Ecologiepremie GO -28%) - € 9 661 (Ecologiepremie KMO -36%)	Storage + cost biomass boiler + harvest Avoided cost heating oil boiler Avoided oil cost
3	+ € 5 136	Harvest + maintenance biomass boiler Avoided maintenance cost heating oil boiler Avoided maintenance cost heating oil boiler
4-19	+ € 5.416 - + €11.779	Idem
20	+ € 11.892	Idem + removal Miscanthus

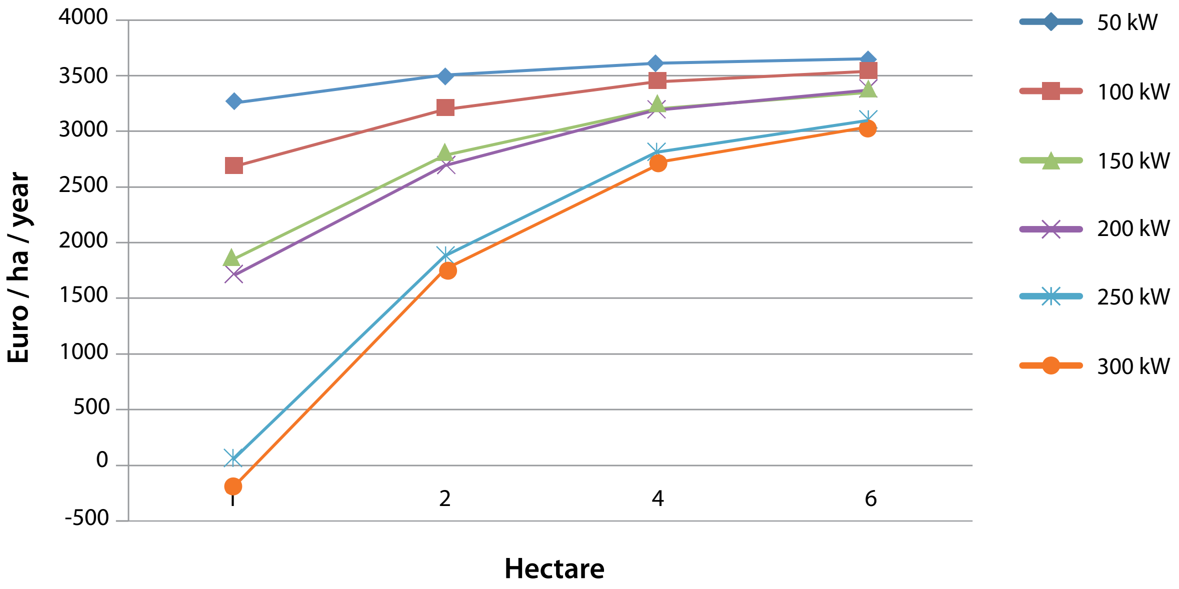

Figure 9: Example of net return graph for agriculture (developed by POM)

3.1.6 Environmental assessment

This chapter summarizes the results of the Life Cycle Assessment conducted at Luxembourg Institute of Science and Technology (LIST) through comparing the environmental performance for seven SRC pilot sites implemented in the Flemish part of Belgium. Different mixes of willow/poplar clones and native tree species were planted on the analyzed sites. Trees cultivated in the trials are expected to be harvested every three years (except a 7-year rotation for the native species and 5 –year rotation for poplars) over a time span of 21 year and in a further step (not included in the site comparison) used for heat production in small scale wood boilers. The characteristics of the sites analyzed through LCA are given in Table 7.

Table 7: Overview of the seven short rotation coppice sites analyzed in the study

Location	Cultivated area [ha]	Type of land	Planted trees [in %]	Plantation density [plants/ha]	Added Value
Harelbeke	± 0.75	industrial	100% poplar clones (AF2, AF8, Skado)	5 231	Activation of unused industrial land
Meulebeke	± 1.14	industrial	100% willow clones (Tora, Klara, Tordis, Olof)	12 370	Activation of unused industrial land
Oostkamp	± 1.03	agricultural	83% willow clones (Tora, Klara, Tordis, Olof) 17% local species (Black alder, Common hazel, Goat willow)	14 115	Increase in biodiversity
Poeke	± 1.05	agricultural	100% willow clones (Klara, Tora, Tordis, Olof)	13 714	Multifunctional land use for agroforestry and chickens breeding
Roeselare	± 1.74	industrial	100% willow clones (Klara,Tora, Tordis, Olof, Inger, local clone)	9 418	Activation of unused industrial land
Wevelgem	± 0.53	industrial	100% poplar clones (AF2, AF8, Skado, Grimminge)	5 043	Activation of unused industrial land
Zonnebeke	± 1.44	agricultural	84% willow clones (Tora, Klara, Tordis) 13% local species (Black alder, Common hazel, White willow) 3% poplar clones (AF2, AF8, Skado, Grimminge)	9 855	Increase in biodiversity

3.1.6.1 Data inventory and included processes

The analysis included production of the cuttings to be planted (all the necessary agricultural processes, crop management storage and transport), cultivation of SRC (field preparation, planting, field management, harvest, fertilizing), plantation removal as well as storage and natural drying of the wood. Additional information regarding the details of the study can be found in Rugani *et al.* (2016).

The foreground data related to all field operations were retrieved from Inagro. Based on the number and type of planted trees, the analysis was complemented by literature yield data for different tree species, since some of the plantations were only approaching the first rotation as the report was created. For the experimental sites established on former industrial land (see Table 5), an additional operation of killing and ripping of grassland was included. With regard to the background information, all data was retrieved from the ecoinvent® database v2.2 (EcoInvent, 2010). Other data sources were also used to build the emission inventory for some selected processes, e.g. field emissions from slurry (Basset-Mens and van der Werf, 2005).

The ReCiPe method (Goedkoop *et al.*, 2009) was used to perform the Life Cycle Impact Assessment (LCIA) of the SRC systems using the SimaPro® 7.3 (PRéConsultants, 2014) software. The analysis included a broad range of impact categories, such as: climate change, ozone depletion, terrestrial acidification, freshwater eutrophication, marine eutrophication, human toxicity, photochemical oxidant formation, particulate matter formation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, ionising radiation, agricultural land occupation, urban land occupation, natural land transformation, water depletion, metal depletion, fossil depletion. Additionally, an extended and more accurate accounting for carbon flows was performed by simulating the carbon dynamics over the 21 years using a specific carbon accounting modelling tool, i.e. CO2FIX (Masera *et al.*, 2003; Schelhaas *et al.*, 2004).

3.1.6.2 Predicted yields and carbon sequestration

According to the simulation in CO2FIX, the average yields for the 21 years period among the 7 mixed sites will reach 8.6 ± 4.3 DM t/ha/year. The highest average yields per site (14-15 DM t/ha/year), can be potentially expected on the sites at Oostkamp and Zonnebeke where native species are cultivated. For the plots with pure poplar plantations in 5-year rotation mode (Harelbeke and Wevelgem) the average yields of 7.3 ± 0.2 DM t/ha/year can be expected, while for pure willow plantations (Meulebeke and Poeke) the lowest average yields of 5.4 ± 1.0 DM t/ha/year are forecasted. The potential for carbon sequestration is strictly linked to the yield trends and follows the same patterns regarding the particular cultivation sites. Interestingly, the largest share of the sequestered carbon (52% on average) is allocated to belowground biomass and soil along the plots, while 48% on average is allocated to stems and branches. Even if the carbon allocated in branches and stems is exported from the plantation and after combustion returns as the CO_2, thanks to belowground biomass and soil pools nearly 7 tonnes of C per ha can be permanently sequestered after 21 years of the plantation.

3.1.6.3 Processes with the highest environmental impacts

The LCA results reveal that some plantations are less environmentally efficient than the others. This strongly depends on the whole production chain but also the type of trees cultivated, rotation frequency and the distribution density. In general if comparing 1 loose m^3 of woods coming from willow-based plantations and poplar plantations the higher impacts are generated by the latter ones, mainly due to the lower total production efficiency and the double effort of planting and removing trees during the 21 years of plantation life span. Moreover, the analysis of impacts generated from 1ha of plantation shows, that:

- poplar based plantations indicate the highest impacts for the majority of impact categories, in particular for all toxicity categories and terrestrial acidification linked to diesel and glyphosate use
- willow-based plantations show the highest impacts on acidification, marine eutrophication and particle matter formation - all linked to ammonia emissions during cuttings production
- the higher cutting density, the higher impacts on agricultural land occupation due to land required for the cuttings production.

More extended discussion on these aspects can be found in Rugani *et al.* (2016). In general, the following critical processes (i.e. being a source of the highest environmental impacts in certain categories) could be identified for the SRC case studies:

- Cooling of the cuttings over longer periods prior to the planting– contributed to high electricity use which, due to the composition of the Belgium energy mix (based on non-renewable fuels such as lignite), contributed to high impacts on freshwater eutrophication, and freshwater and terrestrial ecotoxicity (the critical processes are linked to the extraction of non-renewable fuels)
- Killing grass with glyphosate – relevant only for the industrial sites but had strong direct impacts on freshwater eutrophication, and freshwater and terrestrial ecotoxicity
- Production of cuttings – generated high impacts in the category of terrestrial acidification (mainly caused by emissions of ammonia and nitrogen oxides occurring in the fertilization process with pig slurry)
- Field operations and removal of the plantation – generated high impacts in the category of metal depletion due to the extraction and use of metals for the production of machineries and in the category of ozone depletion due to emissions of bromotrifluoro-methane during the production of diesel used in field operations (especially the tractor is assumed to consume a large amount of diesel in the removal step).

The patterns of impacts distribution per process related to field operations and plantation removal (as exemplarily shown in Figure 10 for the Oostkamp plantation), were similar across all the five willow-based case studies. The major impacts for these plantations were generated during cuttings production, as well as harvest and plantation removal phases. For the two poplar plantations the contributions from field preparation, planting of rods and plantation removal phases increased, while the importance of the impacts linked to the harvest stage was slightly reduced. Such changes of the impact pattern are the consequence of the harvesting in five-year cycle (for willows 3-year rotation) but also result from the shorter life span of the plantation, which has to be removed and replanted every 10 years.

In general, the consumption of diesel for field activities in SRC affected not only the climate change impacts (which are compensated by the avoided CO_2 emissions as the use phase of the wood chips is not included), but influences additionally other categories e.g. the particulate matter formation and fossil depletion. In order to better quantify the influence and variability of the diesel consumption occurring during the harvesting operation (the only regularly appearing process including use of diesel), a complementary sensitivity analysis was performed. The results revealed that even by diminishing the consumption of diesel by 20% (which would require a substantial management effort for the farmers every three years) the overall environmental impact profile seems not to change considerably.

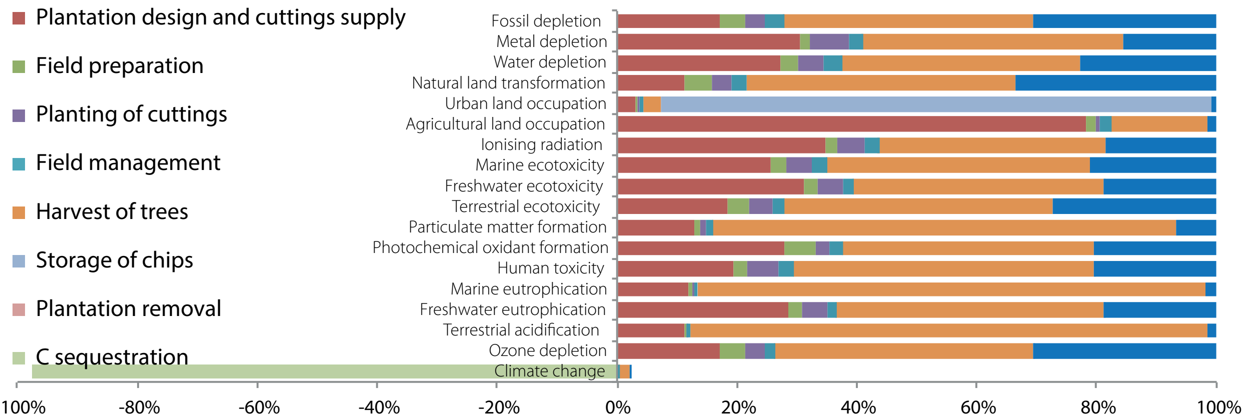

Figure 10: Typical profile of the impacts distribution per process for the production of wood chips from the SRC plantation, here for the Oostkamp site

3.1.6.4 SRC wood vs. forest wood

In order to evaluate the potential environmental benefits of using SRC wood chips for energy purposes, the three existing energy production models in EcoInvent® ((heat production in a small scale bolier, heat and electricity production in an ORC cogeneration unit and production of methanol serving as fuel for person transportation) have been modified by exchanging the input biomass streams from forest wood chips to SRC-based wood chips.

Based on the wood chips characteristics calculated for all the seven sites, the impact profile of the "average" SRC wood chips was described. This wood chips flow was incorporated in the supply-chain of the above described processes to be compared with the classic wood chips from forest wood.

In general, for the intermediate results it was observed that the use of wood chips from SRC in the different energy production systems, independent of the energetic valorization, generates similar response in some specific impact categories. Thus, due to enhanced use of diesel, the impacts on ozone depletion, fossil depletion and particular matter formation were always higher for SRC wood than for forest wood, independent of the type of energetic conversion. Similar trends were observed for terrestrial acidification and marine eutrophication, mainly due to the process of plantation fertilizing with pig slurry. The replacement of forest wood chips with SRC chips in the supply system of energy production seems not to have any significant influence on human toxicity nor on terrestrial, freshwater and marine ecotoxicity. On the other hand, some clear environmental benefits linked to the reduced land use could be observe and expressed by the relatively low impact scores obtained for urban and agricultural land occupation, and natural land transformation. Additionally, even though to lesser extent, the water depletion could also be reduced by implementing SRC wood in the energy production supply-chain. For transportation and heat production at 50kW unit, major benefits were recorded with regard to the climate change potential, for which the use of the average wood chips from SRC contributed to 70 kg of avoided CO_2-eq. for the transport of 1 person over 100 km or 27 kg of avoided CO_2-eq. per 1 MWh of generated heat.

The overall environmental impacts for the production of energy from forest wood and SRC wood are expressed through comparison of so called single score indicators, created by normalization and weighting of the impacts for above analyzed environmental indicators (expressed in different units and not directly comparable). These comparisons, in respect to their individual functional units (FU), are given in Figure 11.

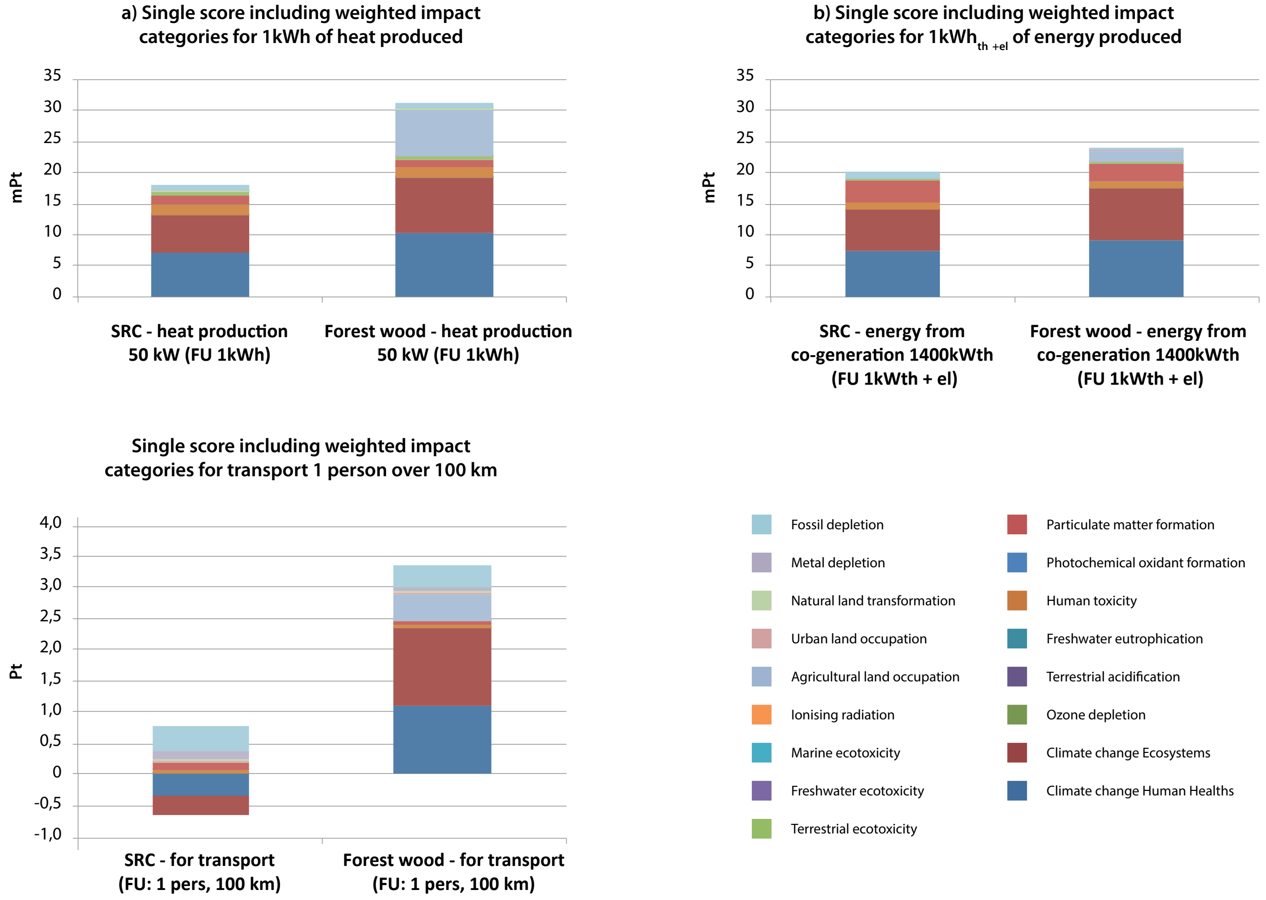

Figure 11: Results of the environmental assessment of the different energy production processes: (a) Production of 1kWh heat in a 50kW unit, (b) Production of 1kWhth+el energy in a 1400kWth co-generation ORC plant and (c) Energy for transport of 1 person over 100 km in methanol fueled car. The comparison includes the use of SRC wood and forest wood as the input material; 1Pt is a comparative unit representative for one thousandth of the yearly environmental load of one average European inhabitant.

The single score results showed clearly, that the use of SRC wood instead of forest wood allows avoiding substantial environmental impacts. Here the highest impact reduction can be reached if using SRC for transportation (89%), followed by the use in small scale heating installations (46%) and in industrial scale ORC co-generation plants (15%).

3.1.6.5 Summary

Cultivation of SRC shows a great potential in terms of carbon sequestration. As proven by the model, the highest sequestration potential is linked to the belowground biomass. In general, the multiple land use, aimed in the ARBOR project, allows activating new biomass streams, which, if used for energy production, contribute to substantial reductions in environmental impacts, mainly due to high impact avoiding potential for the climate change related processes. Moreover, the critical processes, contributing to the highest environmental impacts could be identified (e.g. storage of cuttings or use of glyphosate) and therefore pointed out as those with the highest optimization potential to reach an improvement in the overall environmental performance of the SRC systems.

3.1.7 Transfer to other regions

3.1.7.1 Luxembourg

The SRC areas in Luxemburg have a status of forest land, but following the European Directive EG 73/2009 are considered as 'eligible hectares' for the single payment scheme for farmers. The European Directive EG 1120/2009 was introduced in Luxemburg through the Règlement grand-ducal from 25.11.2011, which defined willow, poplar, maple, alder, birch and locust as species suitable for cultivation in the short rotation mode. The maximal length of one rotation period was set as 12 years. After the change of CAP SRC are accepted as EFAs within the greening measures with the weighting factor 0.3.

For the moment there is only one SRC site in Luxemburg, where Tordis willows have been cultivated since 2006 on the 1,1 ha land in the 3-year rotation mode. This site was created before the Luxemburgish SRC legislation was in force and consequently encountered several problems at the initial stage due to this fact. In general, here are several difficulties, which hamper the development of SRC in the country:

- shortage of agricultural land;
- unknown potential of alternative land to be used (e.g. like the industrial land use in the Flemish SRC case study) ;
- missing financial support for non-farmers – the single payment scheme is eligible but only for farmers planting SRC on agricultural land;
- unavailability of affordable harvest machine;
- preference of authorities to support use of indigenous species (clones), which are difficult to acquire;
- no strategy on the governmental level regarding SRC.

Financial support schemes

In Luxemburg there are support programmes foreseen for the energy production/heating with a wood boiler:

- For private persons (PRIMe House programme): depending on the fuel type (pellets, logs, chips) and the size of the building (one or multi-family house) an investment incentive between 25 and 40% can be paid with a ceiling between 2 500 and 20 000 € for the installations with integrated power and combustion control and automatic feeding and ignition system. There are no restrictions regarding the size of wood boiler installations.

- For communities (Environmental protection fund): an investment incentive of 33% of the installation costs is provided.

Furthermore, for CHP plants put into operation after the first of January 2008, independent whether belonging to private person, company or community, there are power feed-in tariffs guaranteed for 15 years of operation, depending on the size of the plant:

- For ≤1 MW: 145 €/MWh in 2008 but reduced by 0.3625 €/MWh with every further year
- For >1 - 5 MW: 125 €/MWh in 2008 but reduced by 0.3125 €/MWh with every further year

For the CHP plants put into operation after 01.01.2014 the new feed-in tariffs are in force:

- For ≤1 MW: 163 €/MWh in 2014 but reduced by 0.3625 €/MWh with every further year
- For >1 - 5 MW: 143 €/MWh in 2014 but reduced by 0.3125 €/MWh with every further year

Additionally, for all the plants (independent of the year of putting into operation) a heat bonus of 30 € per MWh of commercially used heat can be paid if the proportion of the commercialized heat is min. 35% of the total produced heat in the first three years of the installation and min. 75% from the fourth year on. For the installations which manage to comercialize between 65% and 75% of their heat production a heat bonus of 15 € per MWh of commercially used heat can be paid.

For the years 2007-2013 Luxemburgish authorities created a financial support programme for investments related to the energetic use of wood, e.g. storage and drying spaces for wood. The subsidies reached 30-45% of the investment costs depending on the status of the applying company/stakeholder and were eligible either for agricultural companies or forest land owners (possessing at least 0.5 ha of forest land). At the time of this report this support program is already closed but there is a follow-up programme in preparation for the period 2014-2020. It is planned, that the financial support will only be guaranteed for the agricultural companies with a predefined minimal size. Depending on the status and the size of the company, the future investment subsidies are planned to be set at the level of 25-40% with a maximum eligible investment costs between 250.000€ and 1.700.000€. Since the programme is currently in development, the above mentioned figures and assumptions can still be modified.

Wood market

In general there are no problems with availability of wood chips on the Luxemburgish market. The current cash & carry price for G30 chips with the moisture content of 20-25% is 27€/m^3 exclusive 6% TVA. The transport costs within the distance of 50 km depending on the type of transport vehicle (dumpcart or pump track) range between 30 € and 40 € exclusive 6% TVA.

3.1.7.2 Ireland

SRC Willow does not fall under the remit of the 1946 Forestry Act in the Republic of Ireland, and is therefore not subject to its felling and replanting requirements. There are a number of approaches to harvesting: direct chip harvesting, whole rod harvesting, and billeting. Harvesting is seen as a co-operative or contractors operation because of the specialised nature of the machines and the justification of their cost on relatively small individual holdings. It is unlikely that any single option will be the correct choice across the board. The availability of drying and or storage facilities, the requirements of the supply chain, site conditions etc. will determine choice.

SRC plantations are in operation in Teagasc facilities. These plantations are used to help establish the SRC market in Ireland through demonstration to farmers, suitability and hardness studies, and cultivation & harvesting best practice trials. This facility and SRC crops are focused towards education & development of the SRC market in Ireland, encompassing all areas of SRC use, from cultivation & harvesting, through soil remediation and recovery all the way to influencing policy decisions. The majority (if not the entirety) of SRC plantations in Ireland operate with the goal of producing SRC for bioenergy purposes. A small number of operations are utilising or supplying alternative SRC strains, such as Rural Generation in Derry (suppliers of British willow varieties) and NPS in Waterford (suppliers of Swedish willow varieties). A number of other companies are active in the area including Biotricity, Bord na Móna, Farrelly Willow and Kelly Nursery.

Financial support schemes

The Bioenergy Scheme for willow and miscanthus (2014) provides establishment grants to farmers to grow miscanthus and willow for the production of biomass suitable for use as a renewable source of energy. The Scheme aims to increase the production of willow and miscanthus in Ireland and to encourage alternative land use options. It is open to applicants who are landowners or have leasehold title to the land and have responsibility for farming the land on which it is proposed to carry out the plantation. Commonage shares, rented lands and grazing rights are not eligible for payment under the Scheme.

Aid is payable on 50% of the approved costs associated with establishing the crop, subject to a maximum payment rate of €1 300 per hectare. Eligible costs include those associated with ground preparation, fencing and vegetation control, the purchase of planting stock and planting. Areas planted with willow and miscanthus also qualify for the Single Farm Payment and payments under the REPS and Disadvantaged Areas Scheme, subject to some restrictions on the areas planted.

In order to receive the financial support, following conditions need to be fulfilled:

- Applications for establishment grants are subject to a pre-planting approval process;
- Applications will be prioritised with regard to the Selection Criteria set out in the Scheme's Terms and Conditions;
- The minimum allowable area per applicant is 3 hectares and the maximum is 30 hectares;
- Applicants must submit evidence of linkages with end-users to use the biomass crop as a source of bioenergy;
- Items invoiced, delivered or purchased, and payments made, prior to the issue of Pre-Planting approval are not eligible for grant aid.

Subsidy grants are available for the upgrading of a boiler to a more energy efficient version however further incentives are expected in the coming weeks with the publication of Irelands National Bioenergy Strategy. The publication will be forwarded once made available to the public.

Wood market

Currently, there are approximately 3 000 ha of SRC willow and miscanthus planted in the Republic of Ireland. However, in 2013 Teagasc estimate that 500 ha of miscanthus have been removed due to lack of incentives for the uptake of its use. The Irish Government are set to publish the National Bioenergy Strategy Plan in the coming weeks. It is hoped that this will include a renewable heat incentive among other supports which will help accelerate the uptake of bioenergy in Ireland.

The price of wood chip varies considerably depending on the moisture content and delivery distance from forest to end use, but is approximately €131 euro per tonne delivered at 35% moisture (SEAI 2013). The following link outlines all recorded prices for fuel in Ireland for both domestic and commercial purposes.

http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/

The general trends appear to be that the use of woodchips is decreasing while the use of wood pellet is increasing. However the percentage of roundwood harvest being used for bioenergy purposes has increased from 31.5% to 36% in the period 2010 -2012.

3.1.7.3 Germany

According to the German Federal Forest Act, there is a negative list for the definition of Forest Areas: areas which are cultivated with trees for the reason of timely wood harvesting and a rotation time under 20 years are not defined under the Forest term definition. Also areas that are used for agricultural practices (agro-forest areas) are not defined as forest. Consequently, the cultivation of SRC on agricultural areas is considered as an agricultural site.

Currently, there is about 10 000 ha of SRC planted in Germany (FNR 2014). There are installations on contaminated land to improve the soil (HUGO – RAG), on mining areas to (re-)cultivate the land, near rivers or on plane fields to stop/ reduce the erosion (Agroforst). The legal framework is currently hindering the plantation and harvesting of SRC at riparian areas as it is prohibited according to Water Protection Act to plant non-location-typical plants at water buffer stripes/ riparian areas. Policy recommendations are published by German Environmental Agency (Deutsches Umweltbundesamt) and can be consulted on the websites as listed below.

http://mediathek.fnr.de/catalog/product/gallery/id/4/image/981/

http://www.rag-montan-immobilien.de/referenzprojekte/umwelt/biomassepark-hugo/

http://www.agroforstenergie.de/_publikationen/vortraege/V_34_Vetter_2012_3.Forum_Projekt-AFE.pdf

Financial support schemes

In Germany there are support measures for the cultivation of SRC:

1. According to the German Nature Conservation Act or Federal Building Act, unavoidable damage to the nature and/or the landscape caused by intervention has to be compensated in priority (compensatory measures). If compensation measures cannot be done, the causer has to compensate in other ways (alternative measures). In the Federal State Saarland the causer can provide financial compensation equal to the lost value of the natural system in accordance to § 30 SNG. With that money SRC measures from the Ecological Account Register could get financed if the ecological functions will be offset by that measure.

2. Some Federal States (9/16) did promote voluntary the planting of SRC via Federal Country Incentive programmes. In the Federal State of Saarland an incentive program (KlimaPlus Saar) was in place for installation with 100 EURO/ hectare with a minimum size of 0,5 hectare up to 7,5 hectare. The program stopped 2014. The recent trend shows that most of the programmes are closed down.

   http://energiepflanzen.fnr.de/pflanzen/mehrjaehrige/energieholz/kup-foerderung/

In addition, there are support programmes foreseen for the energy production/heating with a wood boiler:

1. According to German Renewable Energy Act 2011, SRC belongs to biomass and is defined under category as energy crops with extra renumeration. Additional if it is cultivated on nature conservation areas an extra fee is paid-off. The latest amendment of EEG 2014 provides just basic payments for SRC. The electricity production from SRC is tariffed in EEG but there is no extra or additional tariff for SRC from buffer stripes.

2. Germany is announcing diverse financial investment subsidies mainly via the "Kreditanstalt für Wiederaufbau (KfW) (low rates) or annual changing market incentive programs (direct investment), eg BAFA.

3. Currently running program of KfW-Bank: Energieeffizient Sanieren – KfW-Programm 152 : Up to 50 000 Euro credit the German Banc "Kreditanstalt für Wiederaufbau (KfW) is funding single measures, as exchange of the heating system for energy efficiency criteria.

Wood market

Wood chips from SRCs are mostly used for regional heating or combined heat and power concepts. The market is anyhow small and whole wood chip market is not yet relevant

The adequate machineries for planting and harvesting SRC are specialized technologies. The commissioning of these machines or services is rather a question of availability, as the harvesting times are limited and less machine drivers are on market.

3.2 Biomass from buffer strips

3.2.1 Legal assessment

Buffer strips are an important measure to protect water resources and biodiversity. They are a proved method against pollution from agricultural sources like minerals and chemicals, but only exist by the grace of subsidies. In the Netherlands, most of the arrangements related to buffer strips is developed and executed not by national government but by provinces, municipalities or waterboards. There is one legislative framework on buffer strips, so called SNL (Subsidie Natuur en Landschap, eng. Nature and Landscape Grant). In this grant scheme, financial support is given to the farmers for management of nature. The bufferstrips are in this case used for fauna enrichment e.g. as birds habitat. Only in the province of Zeeland there are 550 ha of these type of fauna-strips. The other bufferstrips arrangements are carried out by more local governments like the provinces or the waterboards. At the moment (2014) there are no possibilities for new bufferstrip projects because of lack of financial means.

The protection of birds cannot be easily combined with the harvest of biomass. But if a synergetic solution could be found then 'nature' bufferstrips and biomass strips could co-exist. Currently, harvesting of the biomass from buffer strips is prohibited , however if interesting low-impact biomasss use solutions could be found, this situation could certainly change.

3.2.2 Pilot description

The ARBOR pilots are located in the South West of the Netherlands in the vicinity of the Belgian border. The aim of the pilot was to evaluate if it is possible to combine water protection functions with biomass production for energy or valorisation paths.

The pilots were developed with the intention to illustrate different types of strips and usage, and include following locations:

- 'Pannekeet' measuring 9 m by 493m
- 'Waesberghe' measuring 9 m x 658m
- 'Schaapstal' measuring 9 m x 518m
- 'Colijnsplaat' with 3 areas measuring 3m x 200 m

The demonstration plots are 9 m wide, and cover a total area of 0.5 ha up to 1.5 ha each. They consist of a mix of grass varieties and several cereals. Other crops that were used for demonstration purposes are sugarbeets, sunflower, alfalfa, sorghum and Sida cordifolia. For the moment the buffers are not allowed to be harvested. However, in the theoretically analysed scenarios (see Chapters 3.2.5 and 3.2.6) the total surface of the buffer strips covered with grass and cereal mixes (pilots Pannekeet, Waesberghe and Schaapstal) is harvested and valorized either through anaerobic digestion or material use for agricultural purposes.

3.2.3 Pilot based findings

It was found that mobilizing biomass from buffer strips may indeed help to secure local biomass streams, but the choice of the culture grown and targeted biomass based products have a strong influence on the final costs and environmental impacts. If the biomass from the strip is left unused, additional costs are generated as compared to the cultivation, since the market value of the produced biomass was lower than the costs of additional agricultural actions necessary for its harvesting. For more details on the economic aspects of mobilizing biomass from bufferstrips, we refer to chapter 3.2.5.

It is important to mention that the harvested yields as well as the potential price of the products (also depending on quality) may change from year to year and underlies regional differences. This may strongly influence the profitability of the whole endeavour but also the environmental performance of the analysed concepts. In general the results in their current form show that the biomass streams from buffer strips can only be activated, if certain buffer strips subsidy schemes will be sustained despite the biomass use (see chapter 3.2.5).

At this moment the great bottleneck is the prohibition of harvesting and selling the biomass, which did not change after the CAP reform. One of the main conditions for getting the compensation for the land use for bufferstrips is that the land will be out of production. This is still the case in all the known regulations on bufferstrips. The new CAP includes bufferstrips as EFAa in the greening measures, however the amount of subsidies that farmers can receive depends on the weighting factors as defined on the country level.

3.2.4 Future implementation in South West Netherlands

In the future, everything will depend on the new possibilities within the CAP (pillar 2). The latest tensions between Russia and Ukraine stir the debate about energy policy and self-sufficiency of the EU. The recognition of the dependence of energy supply of the EU from Russia is getting stronger. This gives new arguments into using this 'wasted land' of bufferstrips and contributing to the EU CO_2 goal. If the CAP could be changed in a way that it gives member states the opportunity of using buffer strips as a biomass source then a new discussion will be raised in the whole Europe. Moreover in the context of buffer strips valorisation, not only anaerobic digestion but also bio-refinery e.g. for gaining protein-rich fodder for agriculture (currently imported from South America) could be an interesting option.

3.2.5 Economic assessment

3.2.5.1 Scenarios and assumptions

The economic assessment was conducted at Luxembourg Institute of Science and Technology (LIST) based on the data delivered by DLV Plant for the existing 9-m wide buffer strips along water bodies (consisting of 3-m wide cereal strip and 6 m wide grass strip) but also on other sources of agriculture data and literature. The study included scenarios 1-3 as described in Chapter 3.2.2, being greening, energetic use and agricultural use. Intensive agriculture was not considered in the economic assessemnt, since this scenario was used only to illustrate the importance of buffer strips from the environmental perspective.

The analysis included all the costs linked to field management works (fuel costs, fixed machine costs and maintenance), materials (seeds and herbicides) and manpower. No subsidies were included in the study. Certain difficulty was created by the fact, that the buffer strips are not actively harvested in the moment. Since the buffer strip is cultivated in extensive way, the potential yields are not comparable with the conventional farming outputs. Based on the estimations of the buffer strip owner, the following yields were estimated: 3 tonnes of grain, 2 tonnes of straw and 3 tonnes of hay per buffer strip. These yields were used as calculation base for Scenario 3, but also to calculate the fresh mass harvest for Scenario 2. In the calculation of the harvested yields for grass in Scenario 2 it was assumed, that the difference between the harvested fresh grass and produced hay is linked only to reduction of the water content. Such assumption was not possible for cereals in Scenario 2, since they have to be harvested at different stages for ensiling (early dough stage) as compared to the grain and straw use purposes (harvest maturity stage).

Here the time difference between the development stages can reach even 1-2 months, which include also development of the plant material and not only the water losses due to maturation. Consequently, the estimation of yields for cereals harvested for ensiling was based on the information about similar cultures taken from literature (KTBL, 2006). Additionally, for the ensiling process it was assumed, that there are no mass losses during ensiling, which means, that the total weight of the fresh grass or cereals equals the total weight of the silage. Following these assumptions in terms of DM content, 7.5 tonnes of fresh grass or silage are equivalent to 3 tonne of hay, while 17 tonnes of cereal whole plant silage are equivalent to 3 tonnes of grain and 2 tonnes of straw[3].

Due to the low quality, as compared to similar products but coming from intensive agriculture, the assumed prices for grain for fodder, straw, hay and silage based on the information from the farmer corresponded respectively to 86%, 27%, 30% and 43% of the regular price for such products.

3.2.5.2 Results

In the economic assessment two additional situations were compared:

- *Situation A*: in which the manpower costs are considered as an expense contributing to the total cultivation costs (applicable if additional personal needs to be hired) and
- *Situation B*: in which manpower costs are zero as all work is done by the farmer (no personal hiring costs).

However, it is important to mention, that in reality an "in-between situation" is the most probable option, which means, that some agricultural works are done by the farmer himself, while the others e.g. harvesting are done by external hired personal. The total calculated cultivation costs and possible revenues for different cropping scenarios (1, 2 and 3) and different manpower accounting situations (A and B) are presented in Table 8 and Table 9.

	Scenario 1 Greening €/ha	Scenario 2 Energetic use €/ha	Scenario 3 Agricultural use €/ha
Total fuel costs	-62	-119	-90
Total fix and variable costs (excl. fuel)	-119	-308	-269
Total material costs	-164	-193	-164
Total manpower costs	-88	-134	-124
Total cultivation costs	**-434**	**-744**	**-647**
Additional costs compared to Greening	N/A	-311	-213
Total additional revenues from biomass use	N/A	+160	+210
Additional net costs compared to Greening	**N/A**	**-151**	**-3**
Total net cultivation costs	**-434**	**-584**	**-495**

Table 8: The total calculated cultivation costs and possible revenues if external workers need to be hired (Situation A)

Depending on accounting for situation A or B, the total cultivation costs of the buffer strips in the current mode (without biomass use) reach 346-434 €/ha. The highest contributing costs of 164€/ha are linked to acquiring of grass and cereal seeds and weed control agents. These costs stay equal for the analysed scenarios 1-3 but are additionally increased by expenditures linked to ensiling in Scenario 2.

The potential use of biomass (for energy or material purpose) generates additional treatment costs linked to the collecting and transport of biomass, which slightly differ between Scenario 2 and 3 due to the differences in maturity of the plant at harvest time and the nature of the final product. The costs of the undertaken additional agricultural actions, as compared to the Greening scenario, reach 213-311 €/ha including manpower (A) or 178-265 €/ha without manpower costs (B).

If the biomass is used either as silage for energy production purposes or hay, straw and grains, the total additional revenues of the farmer from biomass use, as compared to the Greening scenario, may reach 160-210 €/ha. This revenue allows covering the additional costs linked to colleting the biomass from the strip, only if the harvest is further used for agricultural purposes. In Scenario 3 the total net costs for such cultivation are nearly equal to the costs of the Greening scenario, if manpower is included, or even lower than the Greening scenario, in case of not including manpower costs (see Table 9).

	Scenario 1 Greening €/ha	Scenario 2 Energetic use €/ha	Scenario 3 Agricultural use €/ha
Total fuel costs	-62	-119	-90
Total fix and variable costs (excl. fuel)	-119	-308	-269
Total material costs	-164	-183	-164
Total cultivation costs	**-346**	**-611**	**-523**
Additional costs compared to Greening	N/A	-265	-178
Total additional revenues from biomass use	N/A	+160	+210
Additional net costs compared to Greening	**N/A**	**-105**	**32**
Total net cultivation costs	**-345**	**-451**	**-313**

Table 9: The total calculated cultivation costs and possible revenues if all the agricultural works are done by farmer (Situation B)

From the economic perspective, extensive cultivation of grass on a buffer strip and subsequent valorisation of the produced biomass streams as hay or grass silage generates much higher costs than cultivation of cereal mix and further valorisation of straw, grains and hay. For cereals cultivation, even generating additional revenues as compared to the greening scenario is possible. Additional analysis revealed that multiple harvesting of grass from the buffer strip (e.g. 2 times per vegetation period) in scenarios 2 and 3 would generate additional costs which are per harvest by 67%-87% higher than the potential revenues. Moreover, if grassy buffer stripes would be sown only once per 15 years, but harvested every year, a strong cost reduction by 252 €/ha could be observed for all scenarios, but the general trend of agricultural use as the financially most convenient scenario would stay the same. More details regarding additional grass and cereal scenarios can be found in Golkowska *et al*. 2015.

The final results are strongly influenced by 2 factors:

- the harvested yields assumed at a very low level due to extensive agricultural practice (i.e. no use of fertilizers, pesticides, etc.)
- the assumed low price for the products due to their low quality as compared to the similar products but coming from intensive agriculture.

In general, energetic use is more expensive than the agricultural one, mainly due to additional costs linked to the ensiling (ensiling installation), necessary to produce the final marketable product, but also due to the prices of seeds and of the final products.

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[3] But with different maturity stages and harvesting times

3.2.6 Environmental assessment

3.2.6.1 Description of the analysed case study

Based on the concept of the demonstration site of DLV Plant, on which grass (6-m wide strip) and cereal mix (3-m wide strp) are cultivated along water bodies, the Life Cycle Assessment (LCA) methodology was applied to evaluate the potential environmental benefits or drawbacks linked to biomass harvesting and use for energetic or animal feed purposes as well as potential dangers of abandoning buffer strips by the farmers and re-use for intensive agriculture. The analysis of the environmental impacts was performed by Luxembourg Institute of Science and Technology (LIST). The study included 4 scenarios:

- Scenario 1 (SC1): "Greening", use of buffer strip "as is", which means maintaining the existing vegetative cover of the strips (grass mixes and cereal mixes), mowing after the end of the summer and leaving the mown crop on the field for soil improvement.
- Scenario 2 (SC2): "Energetic use", similar to scenario 1, but the cereals (17 tonnes /ha) are harvested at earlier stage to produce the whole plant silage out of them, while also the fresh grass mix (7.5 tonnes/ha) is ensiled. The silage of both crops is sold for energy production through anaerobic digestion.
- Scenario 3 (SC3): "Agricultural use", similar to scenario 1, but after cereal harvest the straw (2 tonnes/ha) and grains (3 tonnes/ha) are collected separately, while the grass is dried and collected to be used as hay (3 tonnes/ha). Cereals, straw and hay are sold at market conditions.
- Scenario 4 (SC4): "Intensive cultivation", modelled as "worst case" scenario, to illustrate environmental consequences of abandoning buffer strips by the farmers. The scenario assumes regular intensive cultivation of mix of onions (47 tonnes/ha), potatoes (44 tonnes/ha), wheat (8.5 tonnes/ha) and sugar beets (74 tonnes/ha) as it took place before the buffer strip was created.

The LCA compared environmental impacts based on 1ha of buffer strip used for different purposed defined in Scenarios 1-4.

3.2.6.2 Data and methodology

The foreground data mainly with regard to the crop cultivation were delivered by DLV Plant or retrieved from data bases and literature (Ecoinvent centre, 2014; KTBL, 2006; Nielsen *et al*., 2006; Eurostat, 2015). Additionally, different data linked to the whole spectrum of the background processes was included (etc. seeds, machines, fertilizers, herbicides production, energy production) based on the information retrieved from Ecoinvent data base v.2.2 (ecoinvent centre, 2014). More technical details regarding the study can be found in Golkowska *et al*. (2015, 2016).

The study was conducted by using the ReCiPe methodology (Goedkoop *et al*., 2009) implemented in the modelling software SimaPro 7.3.3. (PRéConsultants, 2014), in which the LCI and LCIA results were calculated. The impacts on following environmental categories were considered: climate change (CC), ozone depletion (OD), terrestrial acidification (TA), freshwater eutrophication (FE), marine eutrophication (ME), human toxicity (HT), photochemical oxidant formation (POF), particulate matter formation (PMF), terrestrial ecotoxicity (TET), freshwater ecotoxicity (FET), marine ecotoxicity (MET), ionising radiation (IR), agricultural land occupation (ALO), urban land occupation (ULO), natural land transformation (NLT), water depletion (WD), metal depletion (MD), fossil depletion (FD). Additionally, the impacts created in all above mentioned categories were summarized to create so called single score indicator, which allows easier comparison of the overall effects but through normalization and weighting gives more significance to several impact categories e.g. climate change or particulate matter formation.

3.2.6.3 Results

In general, comparison of different buffer strip use types reveals, that the intensive agriculture (SC4) generates, depending on the impact category, 3 to even 70 times more impacts, than the greening scenario (SC1). The highest increase in impacts at the midpoint level could be observed for the marine eutrophication and terrestrial acidification, terrestrial ecotoxicity and agricultural land occupation (45-69 times higher impacts than for SC1), as well as for climate change, terrestrial acidification, freshwater eutrophication, freshwater ecotoxicity, marine ecotoxicity and water depletion (14-24 times higher impacts than for SC1). Interestingly, the strongest increase of the impacts can be seen for all the water related categories. This means that abandoning buffer strips and reconverting this land to the conventional agricultural land would have enormous negative consequences on the water quality. This is the reason why all the efforts need to be made to sustain the buffer strips in their current function of water protection.

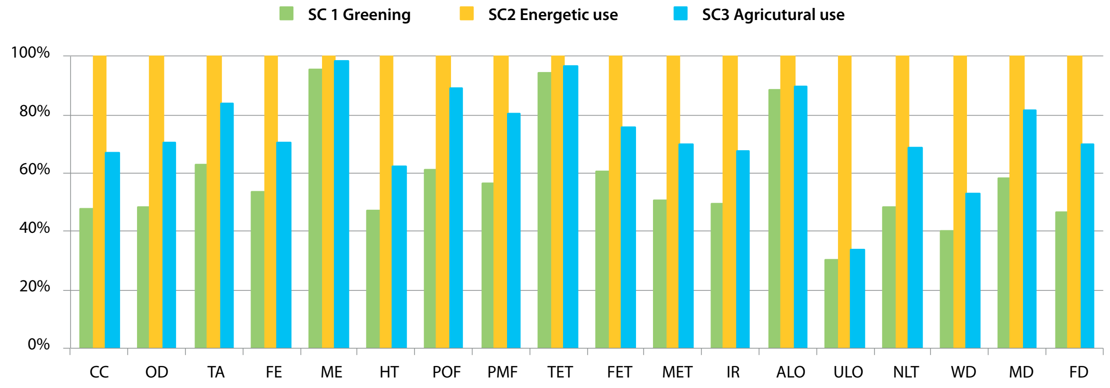


Figure 12: Relative midpoint results of the environmental assessment obtained by applying ReCiPe methodology for the different buffer strip use scenarios; CC- Climate change, OD - ozone depletion, TA- terrestrial acidification, FE- freshwater eutrophication, ME - marine eutrophication, HT- human toxicity, POF- photochemical oxidant formation, PMF- particulate matter formation, TET - terrestrial ecotoxicity, FET - freshwater ecotoxicity, MET - marine ecotoxicity, IR - ionising radiation, ALO - agricultural land occupation, ULO - urban land occupation, NLT- natural land transformation, WD - water depletion, MD - metal depletion, FD - fossil depletion.

Cultivation of the buffer strip (SC2 and SC3), even in extensive way, always generates additional impacts as compared to the greening (SC1). However, for all the impact categories the highest impacts were generated in SC2 (see Figure 12). Similarly, the single score indicator was by 77% higher for SC2 and by 33% higher for SC3 as compared to SC1. The higher impacts for SC2 were mainly linked to the differences in the harvesting phase which generates much more impacts if harvesting for silage production (combine harvester and chopping) as compared to grain and straw (combine harvesting, baling) or hay (mowing, tedding, raking, baling). If comparing the impact categories linked to water ecotoxicity and eutrophication, which are directly linked to the function of the buffer strip, similar trends were observed as for the single score indicator except for marine eutrophication, for which no significant increase of the impacts was observed neither in SC2 nor SC3 as compared to SC1. This indicates that extensive production of hay, grains and straw is more advisable from the general environmental and water protection perspective. However, even extensive production of silage for buffer strips generates much less impacts than classic intensive agriculture and could also be considered as interesting solution of buffer strip valorisation.

In Figure 13 the potential environmental damage profile associated with the production of electricity from buffer strips sourced silage (SC2) through anaerobic co-digestion is compared to the electricity production through anaerobic co-digestion based on conventional grass silage as well as to the damage profile of the classic Dutch electricity mix. Damages in each impact category are presented with their relative contribution to the total single-score indicator.

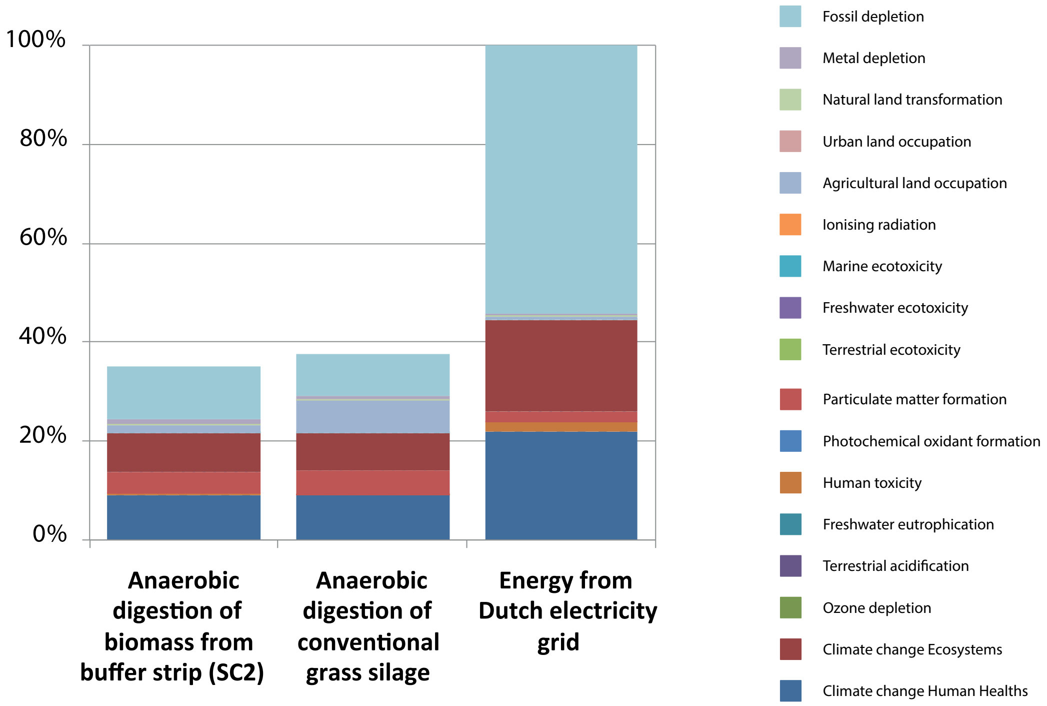


Figure 13: The potential environmental damage profile associated with the production of electricity from buffer strips sourced silage (SC2) as compared to two other electricity production processes

It is evident that producing electricity based on biomass from buffer strips allows avoiding more than 60% of potential damage as compared to the electricity from conventional energy mix. This positive effect can be reached mainly due to reduced fossil fuel consumption (fossil depletion), which enhances the climate change mitigation effect (Climate change Ecosystems and Human Health). On the contrary, biogas based electricity generates more impacts in category agricultural land occupation and particular matter formation. These impacts are typical for processes based on agricultural practices.

Minor differences are observed when comparing both processes of electricity production from biogas, i.e. using biomass from buffer strips vs. conventional grass in anaerobic digestion process. This means that extensively cultivated buffer strips can be a source of additional locally produced biomass which can be applied in anaerobic without producing additional negative impacts on the environment.

3.2.7 Transfer to other regions

3.2.7.1 Luxembourg

In luxembourg there are different support schemes in order to encourage the use of buffer strips:

- The permanent grassland located along the rivers with the average summer bed width of at least 2 m the greened buffer zones of 3 m width along the river banks are obliged to be retained and maintained. These areas are eligible for so called "landscape protection bonus" of 68-100€/ha, depending on the total land surface.
- Since 2009 (RGD 26.08.2009 – Agricultural environmental programme) in Luxemburg in the framework of "green corridors programme" buffer strips on permanent grass land of 3-12 or 5-20 m width (depending on the width of the water body) and those of 3-20 m on arable land are financially supported (750-1250€/ha) by the state.
- After the CAP reform from 2015, the arable buffer strips along water bodies belong to the so called "EFA areas" and can be supported through special greening bonus (81€/ha, calculation factor 1.5: 1.5m^2 per each 1 m^2).

These three forms of subsidies cannot overlap or in case the farmers participate in some or all of them, there are some corrections done by authorities.

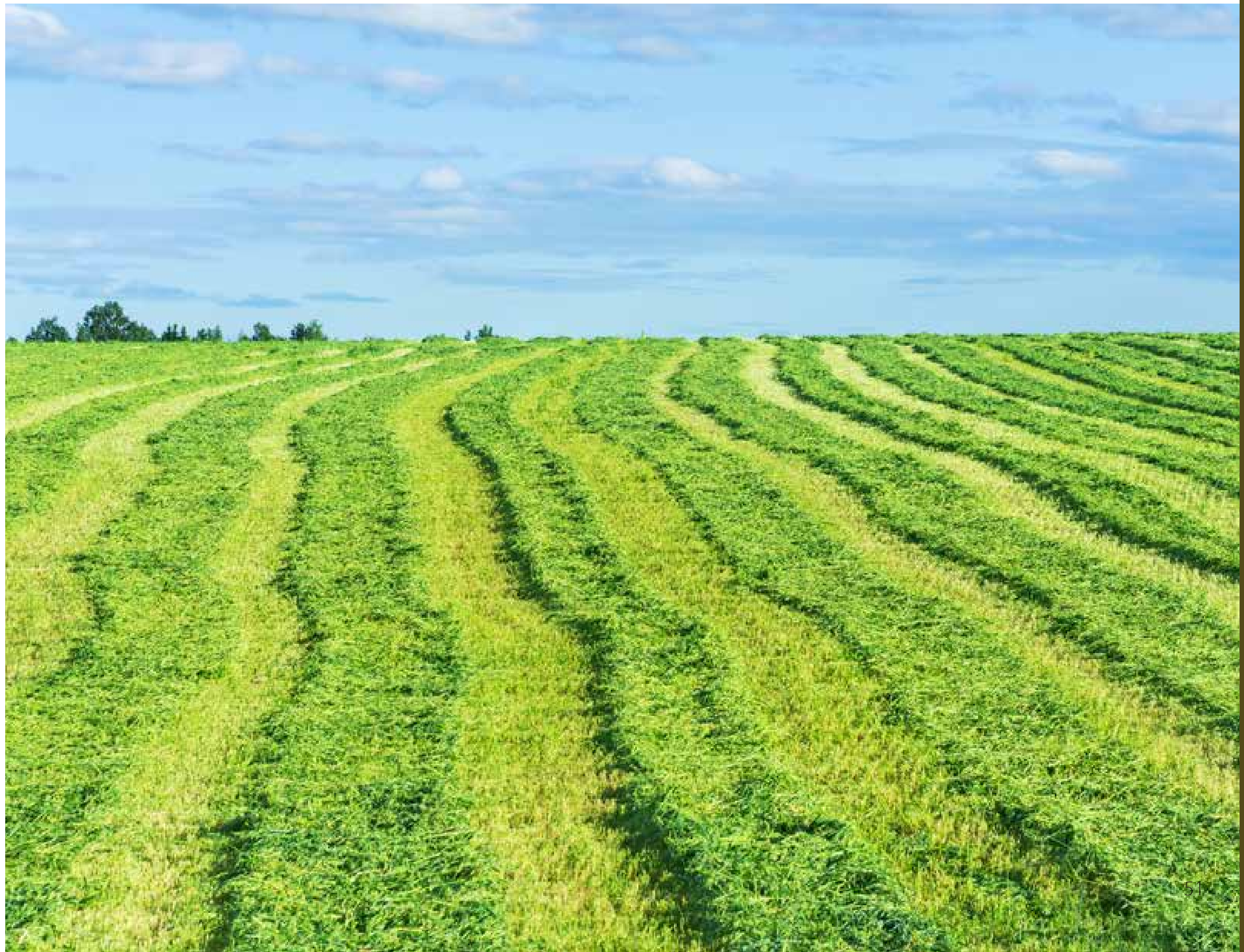
If supported within the state subsidies program, then only very limited "biomass production" is allowed. In general no tillage and reseed is possible. However the biomass is allowed to be mown once per year and used as fodder, but it is not clearly defined whether use for energy production purposes is allowed.

3.2.7.2 Germany

In Germany, many research projects on buffer strips are running. These installations are monitored as a source of biomass. Examples of „Fachagentur für Nachwachsende Rohstoffe (FNR)" projects are:

1. KUP am Fließgewässer - Streifenförmiger Anbau schnellwachsender Bäume entlang eines Fließgewässers zur Vermeidung von Stoffeinträgen - FÖRDERKENNZEICHEN: 22004711
   http://www.fnr.de/index.php?id=948&alles=1&status=Inhalt&zeitraum=formular&fkz=22004711&suchefkz=&sucheadresse=&von=01.04.1992&bis=13.06.2012&zeitraum=formular&untertitel=Bioenergie&was=&produktlinie=90&minz=84&maxz=693&zurueck=Stichwort

2. Kurzumtriebsplantagen zur nachhaltigen Biomassebereitstellung auf Deponieflächen/Altdeponien (KUPAD) - FÖRDERKENNZEICHEN: 22008411
   http://www.fnr.de/index.php?id=911&status=Inhalt&fkz=22008411



3.3 Biomass from marginal and contaminated land

3.3.1 Legal assessment

3.3.1.1 Status of biomass from contaminated land

The valorisation of biomass from contaminated lands is non-existing because of the unclear legal status it has. The Flemish regulatory organ (OVAM) has authority over the definition of raw materials and waste criteria. However, OVAM does not exactly specify to which category biomass originating from contaminated land belongs: is it considered as biomass or as waste?

Nevertheless, guidelines exist in the Flemish regulations in which waste is declared as 'a product which needs to be disposed, wants to dispose or has to dispose', following the European Regulations. In the ARBOR case study in the Campine region (eastern Flanders) the goal is to generate an income from the production of short rotation coppice and maize. In this way the focus lies on biomass production and safe land use rather than on sanitation of the land. In the latter case, the generated biomass is a by-product and needs to be disposed. For this reason, the harvested biomass on the Campine pilot should be regarded as biomass and not as waste, such that a raw material declaration could be requested to OVAM. In the document of OVAM 'What are waste materials' (OVAM, 2011), the indications to define if a product is waste or biomass are summarized below.

Indications that a material is biomass:

- The reuse of the material for the original purpose is certain, possibly after a small repair or simple treatment;
- The material is similar in nature, composition and its impact on people/environment is comparable or better than the primary raw material that it will replace;
- The material is intentionally produced with certain characteristics;
- The material is released as a side stream in the production of another product. The producer could also produce this product without producing this side stream, but has deliberately elected not to do so;
- Further direct use of the material is certain, in its totality and without special pre-treatment;
- The material undergoes a complete recycling or other treatment process.

Indications that a material is waste:

- The material must undergo further processing before it is suitable to replace a primary raw material;
- There is a possibility that the material is not usable;
- The material has a negative economic value;
- The manufacturer makes efforts to reduce the production of the material;
- The holder refuses to meet the necessary obligations (e.g. REACH) to classify a material as a raw material/product;
- The classification of the material or as a raw material/product results in a lower level of protection of the environment;
- There is no market for the relevant material;
- The material must be stored for its potential use, but its eventual application is uncertain;

The definition of biomass from contaminated land as a raw material is appropriate in case of energetic valorisation with techniques that do not have a negative impact on the environment. For example, the application of biomass from contaminated land in industrial burners to generate heat and electricity, on the condition that the burner is equiped with flue gas treatment and that the ash fractions containing the heavy metal contaminants are properly disposed. Another example is the application of excluding crops such as maize and grass for digestion and biogas production.

It can be concluded that regulations concerning biomass from contaminated land are depending on the valorisation route of the biomass (burning, digestion, etc.) rather than on the origin of the biomass. In this way, the focus on a chain approach of biomass and valorisation techniques to declare biomass from contaminated land as a raw material can generate an income for farmers and can reduce the impact on human health and environment.

3.3.1.2 Burning biomass from contaminated land

Burning of biomass from contaminated land is an economical option for the biomass valorisation in case short rotation coppice is grown on the contaminated land. The legal framework includes specific requirements regarding the input material before (cfr. contaminant concentrations), during (cfr. emission requirements) and after burning (cfr. disposal of ashes) of the biomass.

Concerning the input material requirements, the concentration of contaminants in the wood cannot exceed the thresholds as described in Table 10 when the wood is to be considered as 'treated but uncontaminated' wood waste.

Table 10: Compostion conditions (in mg/kg) for definition of (un)contaminated wood where A en B refer to the sampling procedure (VLAREM II 5.2.3 bis 4.8.)

	A	B
Arsene (As)	2	4
Cupper (Cu)	20	40
Lead (Pb)	90	180
Chrome (Cr)	30	60
Fluor (F)	30	60
Chlorine (Cl)	600	1 200
Pentachlorine	3	6
Benzo-a-pyrene	0,5	1

If the biomass is burned, the emission that are allowed without flue gas treatment and construction of chimney are given in Table 11. As cadmium enters the gas phase during burning (with a vaporisation temperature of 650°C) flue gas treatment should be installed as this emission value will be exceeded if an installation of several kW is run on wood from contaminated land.

Table 11: Emission threshold value (in kg/h) for burning of wood (VLAREM II 4.4.2.2.)

	Emission value
Nitrogen oxides	40
Sulphur dioxides	60
Particle matters	15
Lead	0,5
Cadmium	0,01
Thallium	0,01
Chloride	20
Hydrogenchlorides	20
hydrogenfluorides	1
Carbon monoxide	1,00

The ash fractions after burning will need to comply with the figures in Table 12 when these are inted to be used as a fertilizer. From previous research (Vervaeke *et al*., 2006) it can be deducted that Zn and Cd ash fractions from contaminated land are respectively 10 and 1100 ppm on average. These concentrations do not allow the ash fraction to be returned to the field as fertilizer and adequate treatment should be regarded.

Table 12: Composition and application conditions on the use of ashes or digestate as fertilizer or soil-enhancement (VLAREMA attachment 2.3.1.)

	Concentration (mg/kg DM)	Application (g/ha/year)
Arsenic (As)	150	300
Cadmium (Cd)	6	12
Chroom (Cr)	250	500
Cupper (Cu)	375	750
Mercury (Hg)	5	10
Lead (Pb)	300	600
Nickel (Ni)	50	100
Zinc (Zn)	900	1 w800

3.3.1.3 Digesting biomass from contaminated land

The crops maize, winterrye and english rye grass are annual crops which are best suited for digestion. Those crops are known as metal excluder and thus do not take high amounts of heavy metals. The threshold values for the use of digestate as a fertilizer can be found in Table 12. Nevertheless, the application of digestate as fertilizer will be hampered by the nitrogen and phosphorus requirement because of the limited application of Cd and Zn on the field.

3.3.2 Pilot description

The food versus energy debate has initiated a search for low impact energy crops that can fulfil additional functions besides biomass supply. Biomass production on soils that are not suited for agricultural use through contamination are examined. The Belgian and Dutch Campine region is a textbook example of an 700 square kilometre large area facing problems with diffuse metal contamination, mainly cadmium and zinc. Phytoextraction is a treatment strategy for diffusely contaminated soils that is based on the use of plants and associated microorganisms to remediate the soil. The big challenge with phytoextraction, however, remains the long remediation time. This could be overcome by valorising the harvested biomass in non-food applications, for example in the production of bio-energy. In this way, an income is generated for the farmer during the remediation period and the long remediation time is no longer a restriction.

Two trials were executed to assess the possibilities of biomass grown on contaminated land for bioenergy production, using two types of energy crops:

1. Field trial with short rotation coppice on marginal or contaminated land;
2. Field trial with maize and cover crops on marginal or contaminated land.

Short rotation coppice

The first trial focused on the use of short rotation coppice with 8 willow and 5 poplar clones and determined the biomass yield and phytoremediation potential in the sixth growth year (in 2012) of the plantation. The plantation is 2,25 ha large and located in the Campine Region (Lommel) in Belgium.

The willow clones used were Alba, Zwarte Driebast, Jorr, Loden, Christina, Belgisch Rood, Tora and Inger a combination of commercial available Swedish and Belgian clones. Whereas the poplar clones were Muur, Oudenburg, Vesten, Koster en Grimmige.

The willow and poplar clones were planted in a random order and in double rows. The distance between the double rows is 1,5 m were the distance between the two rows is 0,75 m, the distance between the plants in the row is 0,6 m.

Maize and cover crops (winter rye and ryegrass)

The second field trial was also situated in Lommel but here the focus was on annual energy crops (maize, winter rye and ryegrass), more specifically on the growth and metal accumulation potential and the opportunities for energetic valorisation.

Maize was the main crop and was sown after normal fertilization in April 2013 on 16 plots covering a total area of 0,8 ha. In September 2013 the first 8 plots were harvested while the remaining pilots were harvested in October. Simultaneously with the harvest of maize the cover crops ryegrass and winter rye were randomly distributed over the plots. As such, four plots were sown with ryegrass, three with winter rye and one was left fallow in September. In October two plots were left fallow and the other were evenly divided between winter rye and ryegrass. At the end of April 2014 the cover crops were harvested and after fertilization the maize was sown.

3.3.3 Pilot based findings

Concerning the pilots for growing short rotation coppice on marginal or contaminated land, following conclusions can be made:

1. The percentage of the plants of each clone that survived the six years period was calculated. From the results the best clones were selected to further determine the biomass yield and metal accumulation potential. The best poplar clones were Oudenburg (70 %) and Vesten (54 %). For the willow clones the survival ratio was much higher with Jorr (95 %), Loden and Torr (both 90%).
2. From the measurements of the stem diameter the biomass yield was calculated according to allometric relations. The biomass yield is divided into two categories: wood and leaves. For all clones the largest proportion of biomass is present in the wood fraction. Where the clones with the highest total biomass yield, including wood and leaves, are the willow clones Jorr (8,15 t DM/ha/yr), Loden (6,77 t DM/ha/yr), Tora (5,75 t DM/ha/yr) and the poplar clone Vesten (5,1 t DM/ha/yr).
3. If the focus is on phytoremediation the leave biomass plays an important role in the extraction of Cd and Zn, especially in the latter case. For Cd and Zn removal the best option is the willow clone Loden (250 g Cd/ha/yr and 8,1 kg Zn/ha/yr) followed by Tora and Jorr (resp. 160 and 135 g Cd/ha/yr and 6 and 6,1 kg Zn/ha/yr).
4. The short rotation coppice plantation in Lommel show that the combination of phytoremediation and the production of biomass for renewable energy production is possible. Depending on where the focus will be different clones should be selected.

5. If remediation of the contaminated land is the main objective, the clone Loden is the most suited candidate. Because of a high biomass yield and Cd concentration in the biomass it performs significantly better on phyto extraction potential than the other clones. Cadmium will be the limiting factor in regard to the remediation time which has been estimated on 82 year if a linear model is used and leaves are only harvested in the second year of each cycle.
6. Due to the large remediation time it could be wise to switch the focus to the production of bioenergy or phytoattenuation. For this strategy, the willow clone Jorr shows the best results regarding biomass yield.
7. The legal conditions to consider the wood chips as uncontaminated biomass (see Table 10) are fulfilled such that burning the wood chips falls under the regulations of burning uncontaminated wood. For the harvested short rotation coppice, the concentration of lead (Pb) is situated between 4 and 7 ppm.

Concerning the pilots growing maize and cover crops (winter rye and ryegrass) on marginal or contaminated land, following conclusions can be made:

1. From the biomass yield calculations of maize in clear differences could be seen between the harvest in September and October. The overall fresh matter yield is 85 and 80 t/ha while the dry matter content is 30 and 35 % for September and October respectively. It can be seen that the dry matter yield is higher for October than that of September moreover there is a clear allocation from the corn stover to the corncob and grain.
2. There was a clear difference in the biomass yield between ryegrass and winter rye and between the sowing dates, October and September. For winter rye sown in September 15,96 t FM per ha was harvested with an average of 27 % DM while for ryegrass this was 9,62 t FM/ha and 29 % DM. These figures are rather low if compared with other trials of cover crops but this is because of the fact that no fertilization was performed in February or March. The yield for cover crops sown in October was 2 to 3 times lower in fresh matter and slightly lower in dry matter content, resulting in very poor biomass harvests.
3. Until now no results are available for the metal content and accumulation potential of maize and cover crops of the field trial in Lommel.
4. Preliminary conclusion can be drawn from the current results regarding the harvest date of maize and the sowing and selection of the cover crop.
5. The conventional conversion technology for maize, winter rye and ryegrass is digestion. This technology prefers easy digestible sugars and can handle a high moisture content. For this reasons the early harvest of maize in September will result in a slightly higher biomass yield and a relative lower dry matter content which cause no problems for digestion. More important is that the harvest in September makes a longer growing period of the cover crop possible which leads to a biomass yield 2 to 3 times higher than when done in October. When looking towards the total biomass yield of cover crop and maize and subsequently the production of bioenergy it can be seen that the best strategy is the rotation of maize with winter rye in September.
6. The concentration of Cd and Zn in the silage of maize from contaminated land is respectively 1 and 257 mg/kg DM. The digestate in a semi-continuous batch test on the maize from contaminated land contains on average 3,2 mg Cd/ kg DM and 797 mg Zn/ kg DM. It can be seen that the digestate from the maize on contaminated land is slightly below the given values. Nevertheless, the application of digestate as fertilizer cannot fulfil the nitrogen and phosphorus requirement because of the limited application of Cd and Zn on the field.

3.3.4 Future implementation in Flanders

The valorisation of biomass on contaminated land is only possible if the contamination level is low enough to permit biomass growth and large enough to mechanize agriculture practices (sowing, fertilization, harvest) and profitable. Despite this restriction, bioenergy from contaminated land has a large potential.

The field trial in Lommel is part of the Kristalpark, a site intended for industrial activities but with large fallow areas suitable for growth of low impact biomass. This is just one of the examples situated in the Campine region (in the Netherlands and Belgium) where around 700 km^2 is contaminated with heavy metals and of which large parts are located in Flanders and more exactly in the provinces Antwerp and Limburg.

In addition, the development of brown fields requires high investments from government and private parties. For this reason it often takes a long time before a new function (residential, agriculture, industrial) can be given to the current brown field. In the meantime, the production of bioenergy could lead towards a better valorisation of those sites while adding benefits like reduced leaching and removal of contaminants from the soil.

3.3.5 Transfer to other regions

3.3.5.1 Belgium

In Flanders 62 091 ha of land is contaminated, of which 25 848 ha is attributed a high priority which implies that it must be remediated in the short term. In those 'high priority' sites the contribution of the different contaminants is shown in Figure 14. From these data, it can be seen that more than a quarter of the sites are contaminated with heavy metals, which makes heavy metals the second most important source of contamination, next to mineral oils.

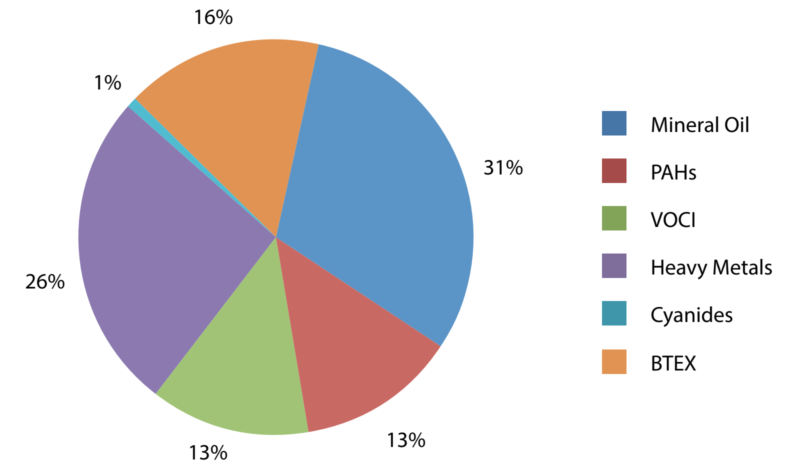


Figure 14: Site main contaminants with polycyclic aromatic hydrocarbon (PAH), chlorinated organic solvents (VOCI) and benzene-toluene-ethylbenzene-xylene (BTEX) (source: OVAM)

Phytoremediation has not been applied on a large scale in Flanders. If the focus is on the removal of heavy metals while simultaneously producing biomass suitable for energetic valorisation, the crops under consideration are willow and poplar. When extraction of heavy metals is not the main goal, growing maize is preferable because this crop is an excluder and as such the biomass can be used without risk of heavy metal contamination.

The harvested biomass needs to oblige with all the regulation concerning the heavy metal content of the input material for the valorisation process and during this process (such as combustion or digestion). If the aforementioned obligations are met, financial stimuli from the government can be acquired, which follow the same rules as for normal digestion or burning with regard to green electricity cerfiticates and green heat (see 3.1.1.4).

The institutions that are involved into past and current pilot project on biomass valorisation from phytoremediation and phytoremediation itself are the Laboratory Ecochem of Ghent University and the Centre for Environmental Studies of University Hasselt. More information on the pilot projects can be found on the websites below.

http://www.ugent.be/bw/tafc/en/research-groups/ecochem
http://www.uhasselt.be/cmk

3.3.5.2 Germany

About 4807 contaminated sites are located in Germany from which 532 in Saarland. A large part can be attributed to historical mining activities on which mostly heavy metal contaminants are present. About 10 % of the total agricultural land (arable and grassland) is potentially contaminated (Knapp *et al.*, 2008).

Several pilot studies have been executed in Germany on the use of biomass from contaminated land. In the case study from Sachsen the phytoattenuation strategy was followed. There they used an excluder crop winterrye to cope with the elevated levels of cadmium present in the soil. The winterrye was than digested to produce bioenergy. More information can be found in the document below.

http://www.bioenergie.uni-goettingen.de/fileadmin/user_upload/admin/Konferenz/Vortraege_24-01-12/Sauer_BiS-Tagung_Goe_24-01-12.pdf

Another pilot in the Sachsen region focuses on short rotation coppice and miscanthus. In this pilot the thermal valorization of the biomass was studies. Conclusions were that the biomass can be used to generate green heat but a special filter should be installed to treat the flue gasses. More information can be found on the website below.

https://publikationen.sachsen.de/bdb/artikel/14994

3.3.5.3 Luxembourg

Figures from 2006 show that in Luxembourg around 19 ha is already identified as contaminated sites but about is 500 ha is estimated to be contaminated (Panagos *et al*., 2013). Most of the contaminated sites are caused by elevated levels of mineral oils and PAH (around 90 %), only 6 percent of those sites are contaminated with heavy metals.

Two projects were linked to phytoremediation/attenuation in Luxembourg at the Public Research Centre Gabriel Lippmann. ENERREM investigated plants which could be used on water banks to prevent heavy metal leaching into water bodies. Next to this it also focus on plants with different heavy metals metabolism, fixing in the soil or extracting and accumulating in the plant tissues. The ECOLIRMED project researched which mechanism did occur to transfer heavy metals into plant tissues.

3.3.5.4 Ireland

A contaminated land inventory survey of Ireland by the Environmental Protection agency in 1999 was the most comprehensive study of contaminated sites in Ireland. Since 1999, environmental legislation and regulation have increased significantly, thus minimizing any potential growth in contaminated sites in Ireland. The estimation of contaminated sites can be seen in Table 13. This gives an estimated total of 2 000 – 2 500 contaminated sites in Ireland (Brogan *et al*., 1999).

Table 13: Contaminated site and industrial type identification in Ireland (after Brogan *et al*., 1999)

Historical sites (before 1999)	
Type of site	**Number of sites**
Old Gas Works	50-80
Closed Landfills	265
Closed Mine Sites	128 (38 with Tailings, 11 High risk)
Old Fertiliser Plants	4-6
Closed Tanneries	10-12
Operational sites since 1999	
Type of site	**Number of sites**
Existing Landfills	76 Authority 50 Private
Mining/Minerals Sites	7
Chemical Industry	150-160
Petroleum Import Terminals	22
Petrol Stations	900-1200
Tanneries	3
Dockyards	14-16
Military Sites	1
Railway Depots	80-100
Scrap Yards	180-200
Airports with Maintenance	2

Research project that are related with phytoremediation in Ireland are the FORSITE project, DIBANET, EPA Strive, ReUseWaste and projects from Ireland's national Technology Centre for Biorefining and Bioenergy (TCBB). Funding is available for research into phytoremediation in Ireland, via European (Horizon 2020) & Irish funding sources (IRCSET, SEAI, Science Foundation Ireland), to conduct PHD studies, postdoc research and larger group based research projects.

There are no specific financial stimuli in Ireland with regard to phytoremediation. Practical field based phytoremediation could be indirectly funded by other funding sources, which are mostly incentives for the growth of bioenergy crops (e.g. willow, Miscanthus, algae etc.) and projects similar to generation of biogas from landfill sites. The main theme running through these funding avenues is the government backed target to increase the generation of bioenergy in Ireland, which is a main driver for such research at present.

3.3.5.5 The Netherlands

In the Netherlands around 78 500 contaminated sites are identified and the potential number of contaminated sites is estimated at 180 000. Of those identified sites, about 39 % of the contaminants is due to heavy metals (Brogan *et al*., 1999).

The PhytoDec project from the Alterra institute of the Wageningen University quantified the cost versus benefits of the use of vegetation in the management of heavy metal polluted soils and dredged sediments. Next to this does the pilot project de Ceuvel in the district Buiksloterham, Amsterdam uses phytoremediation to remediate an old industrial site. Next to the environmental aspect the site also exerts a social and educational aspect as people can inhabit the living units on the site which 'float' on the contaminated soil and learn more about the process of phytoremediation. More information on the experimental site 'Broedplaats De Ceuvel' can be found on the website below.

http://deceuvel.tumblr.com/plan

3.3.5.6 United Kingdom

The area of potentially contaminated sites in the United Kingdom is estimated at 30 014 ha or 178 398 sites (Vangronsveld *et al*., 2009). Several field trial studies on phytoremedation were carried out in the UK, as illustrated in Table 14.

Table 14: Phytoremediation field trials in the UK (Vangronsveld *et al*., 2009)

Site	Contaminant	Type of site	Plant species
Rothamsted	Al, Cd, Cu, Pb, Zn,	Agricultural land	Grasses
Mersey Forest	Cd, Ni	landfill	Alnus glutinosa
Manchester		Sewage sludge	Crataegus monogyna, Salix caprea
Northampton	Cd		Vegetable crops
Cornwall	As	Agricultural land	Vegetable crops
Sugar Brook	As, Cd, Cu, Ni, Pb, Zn	Urban area	Betula

3.4 Biomass from cover crops

3.4.1 Legal assessment

Europe strives towards a sustainable food production and a livable rural area in the EU. Therefore an important factor in the agricultural policy are the greening measures (see chapter 2.1.1). The subsidy for greening measures is linked to the direct payment which the farmer receives as an income support. Approximately half the amount of the direct payment is comprised by these greening measures. To obtain this support the farmer is obliged to meet the three greening conditions:

- conservation of permanent grassland,
- crop diversification and
- creation of ecological areas.

These greening subisides compensate for the efforts of the farmer in the application of environmental friendly practices on his arable land.

Conservation of the area permanent grass: The total area of permanent grassland must be obtained and cannot be used as arable land.

Crop diversification: When the total arable land is more than 10 ha the farmer has to meet the condition of crop diversification. With this measure the farmer proofs that he tills different crops on his arable land. To fulfill the crop diversification at least two different crops have to be tilled, if the total arable land is between 10 – 30 ha. With the condition that the most extensive crop, covers no more than 75% of the total arable land. When the farmer has more than 30 ha arable land, he has to till at least three different crops, with a maximum of 75% of total arable land for the crop with the largest area and the two largest crops together don't comprise more than 95% of the arable land.

Ecological focus area: If the farm consists of more than 15 ha arable land, then it must suffice the measure of ecological focus area. At least 5% of the area arable land must be established as focus area. There are a few defined types of measurements which count as focus area: fallow, landscape elements, buffer strips, agroforestry, short rotation coppice, wooded arable area, Leguminosae and cover crops.

Table 15: Sow and harvest date of the cover crop differ between the different soil type regions

Soil type	Sow date	Harvest date
Clay & Sand	Before 01/09	After 15/10
Loam	Before 01/10	After 01/12
Sandy loam (& others)	Before 01/10	After 01/02

A cover crop may not be harvested or grazed before harvest date and the use of pesticides is forbidden in this period. The area for which an ecological focus measurement counts depends on the weighing factor. For cover crops this factor is 0.3, which means that 1 m^2 of cover crops counts for 0.3 m^2 as ecological focus measurement.

Only if the farmer meets these requirements he can obtain the direct support subsidy. An easy way to comply with these measures, is to till cover crops during the winter months. Furthermore it is recommended to mow the rye before incorporation into the soil. The harvested biomass can then be used as fodder, or as input for a digestion plant.

3.4.2 Pilot Description

Based on their growth characteristics cover crops can be divided in three categories: leafy crops, grassy crops and leguminous crops. Cover crops are grown to maintain and enhance soil fertility. They keep the soil covered until the next growing season after harvesting the main crop. In this way weed development is reduced, also the risks for nitrate leaching and erosion are lowered. Next to these advantages, when harvested, cover crops can also be a source of biomass production during winter. This way the yearly production of biomass on the field can be enlarged.

Two field trials were organized on biomass production with cover crops:

1. Field trial on different types of fertilizer.
2. Field trial on different varieties of rye.

These trials were situated at Moorslede, West-Flanders on a 2.67 ha field. The crop rotation is maize, main crop, and rye, cover crop. The main crop is tilled for production of corn, while the cover crop is a source of low impact biomass. The crop is sown shortly after the maize harvest on 30 October and harvested on the 5th of May. The sow density of rye was 400 seeds/m^2.
Next to these field trials also two biogas trials were held, one on lab scale and one on pilot scale.

Different types of fertilization

As stated in the case study report 'Nutrient recovery from digestate' (available on **http://www.arbornwe.eu/**) Flanders is obliged to process manure, in such a way that it is converted to a mineral fertilizer. The digestate processing techniques of co-digesters have the goal to recover a maximal amount of nutrients and produce dischargeable or re-useable water. With the recovering of nutrients from digestate it's important to determine the value as fertilizer. Therefore, a field trial with different types of fertilizations was set up with four treatments in four parallels (n=4): mineral N, scrubber water, liquid fraction digestate and urea. A plot with no fertilizer was used as blanc to compare the other types of fertilization. These different types of fertilizer are produced in Flanders at different full scale plants, by techniques such as acid air washers, membrane filtration and ammonia stripping. The scrubber water in this case comes from an air washer of a pig farm (Danis), liquid fraction digestate from the digestion plant AM Power and urea is extracted out of pig manure (farmer Pauweleyn).

Different varieties of rye

On the trial field different varieties of rye were tested on biomass production. This test was performed on five variants in four parallels (n=4). To check the influence of the duration of growing season there were two harvest moments: 23 April and 8 days later on 6 May. The different varieties tested were Speedogreen13, Turbogreen13, Borfuro , Protector and Jobaro[6].

Biogas lab and pilot trial

The biogas and methane production was measured according to the BMP-principle (biomethane potential). Therefore a small batch-test was set up with substrate. The biogas was continuously collected and analysed during the test period. In that matter the potential of methane can be determined, but also the evolution of the digestion process. The substrate of rye was measured in three parallels (n=3), together with two blancs (to determine the biogas production of inoculum). The organic reactor load (OCL) was 5g/l. The temperature was kept at 38°C during experiment.

The substrate of rye was mixed with inoculum to simulate the environment of the digester. This inoculum contains the micro-organisms necessary for digestion to biogas. It has also a buffer activity to obtain more stability in the symbiotic growth for the most important bacteria. The inoculum used was digestate from the pilot digester at Inagro. About 40 L of digestate was collected and incubated for a week at 38°C. During this incubation period the digestable products it still contains will be removed. Aftwerwards it was sieved, to obtain a homogenous mixture and was put in the reactor bottles. The characteristics of the obtained substrate are given in Table 16.

Every bottle was connected to a gas bag by means of a plastic tube to collect the produced amount of gas. Every 1-2 days these bags were replaced during measurement. A gas analyzator measured the amount of methane and carbondioxide. During the same period, biogas trials were carried out in the biogas digester installation of Inagro on pilot scale.

Table 16: Characteristics of the substrate on which the biogas measurements were carried out.

Substrate	FM (g)	DM (%)	ODM (%)	ORL (g/l)	DM (g)	ODM (g)
Rye	53	31,7	26,62	5,6	16,8	14,1

3.4.3 Pilot based findings

3.4.3.1 Effect of different fertilizers on the productivity

Urea and the blanc plot have significantly lower yields than the other fertilizers (see Figure 15). While mineral N fertilizer and scrubber water have the highest yield. The reason of the lower yields of liquid fraction digestate and urea can be explained by the fact that scrubber water and mineral fertilizer are applied at 10 March, while urea and liquid fraction are applied 2 weeks later at 24 March. So the plots fertilized with scrubber water and mineral fertilizer had an advantage in growing season. This can explain the lower DM yield of urea.

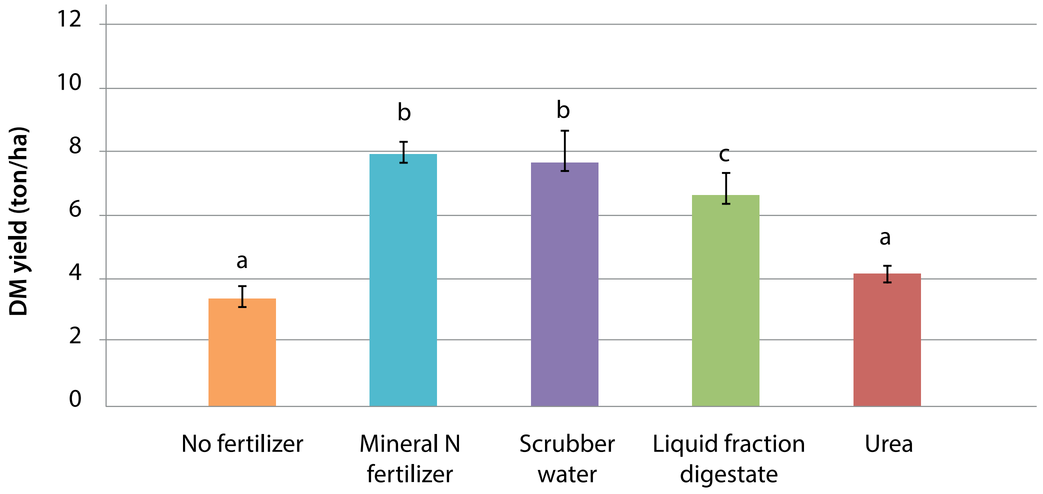


Figure 15: Dry matter (DM) yield of rye after fertilization with mineral N, scrubber water, LIF digestate and urea.

The time of fertilization is very important, as seen by application of mineral fertilizer and scrubber water. Although liquid fraction digestate is applied 2 weeks later, the yield is significant better than urea. So it can be assumed that the working coefficient will be better than urea.

In field conditions it's not always possible to fertilize at the desired time. This short framework of application time is a difficulty with the tillage of a cover crop in the winter, which can lead to yield losses. As seen with the application of the mineral fertilizer and srubber water, which are applied at the correct moment, the yield is significantly better.

3.4.3.2 Effect of different crop varieties on the productivity

Turbogreen has significantly the highest dry matter yield of 7.4 ton DM per ha (see Figure 16). While Jobaro has the lowest yield of 3 ton DM per ha. The germination ratio of Jobaro was 50 plants/m^2, which is much lower than the other four varieties,which was 300 plants/m^2.

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[4] Saatzucht
[5] Inagro
[6] ILVO & Freudenberger

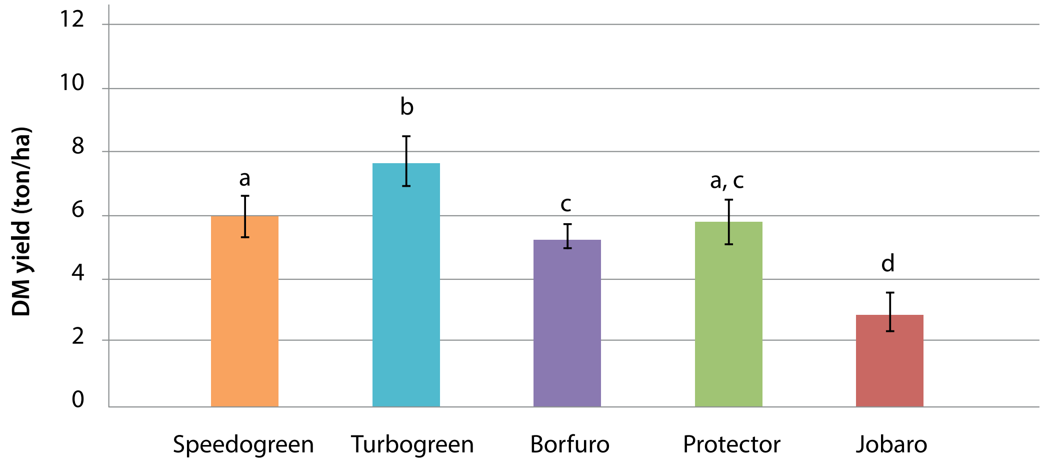


Figure 16: Productivity of rye for different types of rye varieties, for the measurements on 23 April 2014.

After harvest of the second date the yield of the different varieties were equal (see Figure 17), with exception of the yield of Jobaro which was significant lower than the other varieties. Speedogreen, Turbogreen, Borfuro and Protector have a biomass yield from respectively 8.5, 8.9, 8 and 8.9 ton DM/ha, while Jobaro produces only half of biomass, 3.9 ton DM/ha. The significantly lower yield of Jobaro can be explained by the low germination of the seed as mentioned earlier.

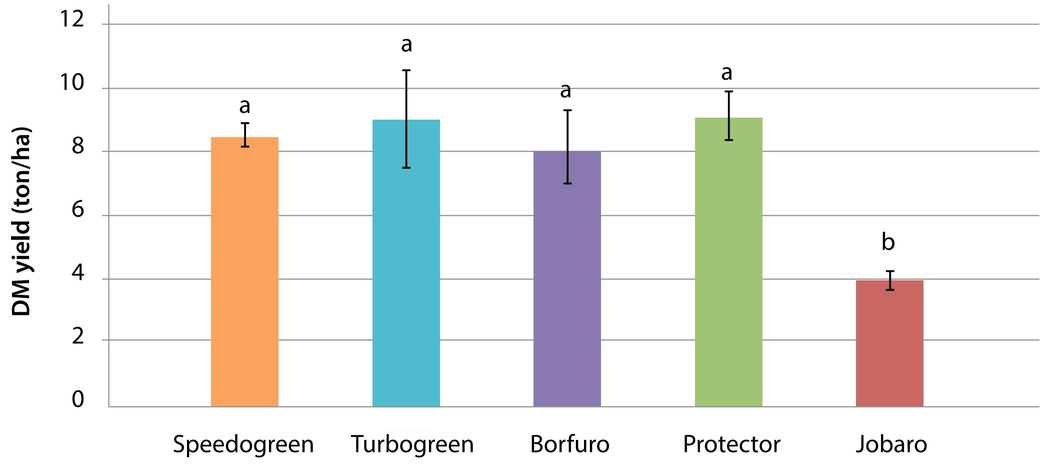


Figure 17: Productivity of rye for different types of rye varieties, for the measurements on 6 May 2014.

Based on the productivity measurements after the first and second harvest date, it can be stated that Turbogreen grows the fastest early in the season, as compared to the other varieties. The low biomass yield of Jobaro is due to the low germination rate. This can be explained by the fact that this variety is only recently developed. The seed was clearly bad in quality. With respect to the biomass potential, Turbogreen is the most interesting variety to use as cover crop in combination with a main crop. It is desirable to produce as much as possible biomass early in the season, so that the main crop can be sown at the correct time. In that case, the risk of yield losses in the main crop is minimized and the cover crop has produced big amounts of biomass for digestion.

3.4.3.3 Biogas lab trial results

The process of biogas production can be divided into three phases:

1. Phase 1: short and low gas production
2. Phase 2: after a few days the biogas yield rises exponentially to about a week later
3. Phase 3: the gas production lowers during the end phase

The measured volumes of biogas were corrected according to the standard conditions with the general gas law. In order to be able to compare results under different temperature and pressure. Brutto production is the production of the whole bottle, including biogas production of inoculum. The net production is biogas yield of substrate, without brutto biogas production of inoculum without substrate. Table 17 shows the gross and net biogas and methane yields during the incubation period of 40 days.

Table 17: Results of the biogas measurements on the rye sample.

	net biogas/FM	net biogas/ODM	net CH_4/FM	net CH_4/ODM	% CH_4
	(m^3/ton)	**(m^3/ton)**	**(m^3/ton)**	**(m^3/ton)**	
Rye	180.9	731.9	94.5	354.9	52.2

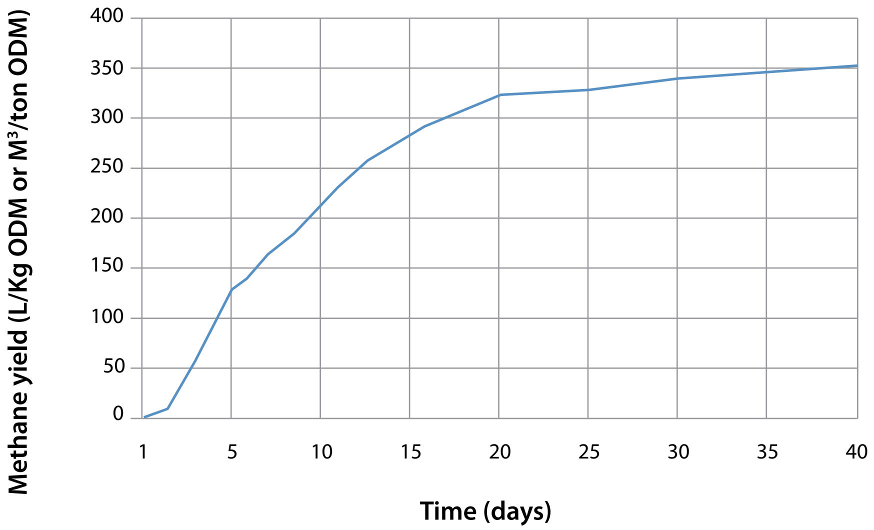


Figure 18: Evolution of the methane yield from the rye sample during the 40 day incubation period

During the same period, a biogas trial was carried out in the pilot biogas digester installation of Inagro at the pilot scale. Figure 18 shows the electricity production (kWh/day) from a reference period and the moment of rye feeding. The input is 1,6 ton/day, which consists of 1 ton pig manure and 0.6 ton maize. During the period of experiment 25% of the energy maize was replaced with rye. During the reference period the mean electricity production was 21 kWh/day, while during the test period it was 17,3 kWh/day (see Figure 18).

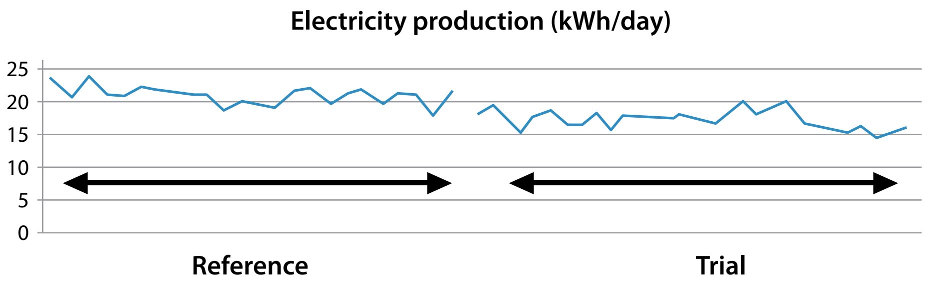


Figure 19: Evolution of the electricity production from the biogas digester installation during a reference period and during the moment of rye feeding (trial).

The methane content of biogas yield rye expressed in ODM is higher than energy maize, and is respectively 354 Nm^3 methane/ton for rye and 322 Nm^3 methane/ton for maize. However, rye has a lower DM content than maize. Methane production for maize is 115 Nm^3/ton FM and 94 Nm^3/ton for rye. This can also be concluded from the pilot trial with feeding of the digester with 25% rye instead of maize. The mean kWh production per day is lower (17,3 kWh/day) than during the reference period (21 kWh/day). We can also state that this influence is due to adaptation of the bacteria in the digester to another input material. It can be concluded that rye has potential to replace maize. Because rye can be tilled as a cover crop during winter it is more effective as an input material than maize, which can be used for food and feed.

3.4.4 Future implementation in Flanders

The main disadvantages of rye are the extra cost to maintain the crop, the rent of the parcel, the extra work that is necessary, harvesting in different steps,… On the other side, there is a profit when selling the rye to the digester. The advantage of this system is that the farmer has two yields of biomass in one year. Rye is ideal because it can be sowed pretty late in the season, after the harvest of maize, in the second half of October. Furthermore rye tolerates the winter cold. Nowadays there is no set market price for rye, but because the biogaspotential is similar to maize, we can refer to this, which is €35/ton.

The yield is mainly influenced by the soil type and the water supply in the soil. Experiments at Inagro have shown that, depending on the season conditions, the yield for the main crop (maize) can vary. A wet season delivers enough water in the soil for both the cover crop and maize, and thus higher yields. On the contrary, a dry year has negative influences on the maize yield, because of the during the growing period. The maize will have growth problems because of shortage of water. Rye has already used the stock of water in the soil. The weather conditions also influence the possibility for harvesting rye and sowing maize. A few days delay in the sowing date of maize influences the yield significantly. The farmer obtains the largest value from the main crop, so he will always give priority to maize.

3.4.5 Economic assessment

Economic assessment for the cover crop pilot was conducted at Luxemburg Institute of Science and Technology (LIST). The analysis is based on the cultivation of winter rye as a cover crop with maize as the main crop. The data linked to the cultivation were delivered by Inagro but also to limited extent on other sources of agricultural data and literature. The study aims at assessing costs of cover crop cultivation and ensiling as compared to the possible yields and revenues which can be achieved.

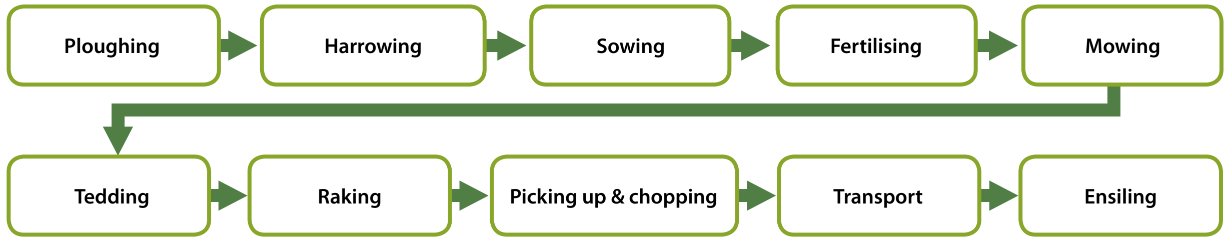


Figure 20: Processes included in the economic assessment of winter rye cultivation

The analysis includes all the costs linked to field management works (fuel costs, fixed machine costs and maintenance), materials & installations (seeds, fertilizers, silage facilities) and manpower. No subsidies were included in the calculations. Additionally for the ensiling process it was assumed, that there are no mass losses during ensiling, which means, that the total weight of the fresh rye equals the total weight of the silage. The current maize silage market price reaching nearly 35 €/tonne was used as a base for the calculation of the market value of the produced winter rye silage. The price of 29 €/tonne of winter rye silage was estimated based on the lower energy content of the rye silage (3,1 MJ/kgFM) vs. maize silage (3,78 MJ/kgFM).

In the economic assessment, two different situations were considered:

1. the manpower costs are considered as an expense contributing to the total cultivation costs (applicable if additional personal needs to be hired)
2. no manpower costs presuming that the agricultural works are done by the farmer.

However it is important to mention, that in reality an "in-between situation" is the most probable option, which means, that some agricultural works are done by the farmer himself, while others, e.g. cereals chopping, are done by hired external personal. The total calculated cultivation costs, together with different manpower accounting situations and possible revenues, are presented in Table 18.

Table 18: Total calculated cultivation costs and possible revenues
(If works done by farmer, no manpower costs considered)*

Cover crop investment costs & revenues	
Seeds, fertilizers, materials	171 €/ha
Fuel & machine costs	509 €/ha
Manpower	131 €/ha
Total costs without manpower	680 €/ha
Total costs	810 €/ha
Market value of the silage	912 €/ha
Revenues for farmer	102 €/ha
Max. possible revenues	232 €/ha

Depending on how the manpower is accounted for, the total cultivation costs of the cover crops reach 680-810€/ha. In both scenarios revenues of 102-232€/ha can be generated by the farmer. From this perspective cultivation of winter rye for energy production can be profitable to the farmer.

Nevertheless, it is important to keep in mind that cultivation of the cover crops is always a matter of balancing two cultures on one field. Depending on the vegetation year and weather conditions, higher or lower winter rye yields and different calorific values of the silage can be reached. If unfavorable weather conditions occur (e.g. too dry, too wet or too cold long in the spring) either the fertilizing or the harvest (or both) would have to be delayed, influencing sowing of the main culture. However, it can be presumed that farmer will rather tend to "protect" the main crop cultivation (maize) from the cover crops repercussions and in such situation would harvest cover crop earlier and at lower yields and calorific values (risking the lower income for the cover crop) rather than postponing sowing of the main crop. In this context the balancing of the two cultures needs always to be seen as additional risk to the farmer who, without any financial support, might not be willing to run this risk.

3.4.6 Envrionmental assessment

3.4.6.1 Description of the analysed case study

Based on the pilot of Inagro, in which maize is cultivated as main crop during summer and rye is grown as a cover crop during winter, the Life Cycle Assessment (LCA) methodology was applied to evaluate the potential environmental benefits or drawbacks linked to planting cover crops meant for energetic purposes. The analysis of the environmental impacts was performed by Luxembourg Institute of Science and Technology (LIST).

This study aimed at assessing environmental impacts of energy production through anaerobic co-digestion of maize silage with pig manure (scenario 1) as compared to co-digestion of maize and rye silage with pig manure (scenario 2). The characteristics of maize and rye silage used as basis for the LCA is given in Table 19. Additionally, based on the ecoinvent data base, these two scenarios were compared with energy generation from wood pellets (scenario 3) and natural gas (scenario 4). The basis for the comparison was the output energy unit of 1MJ energy (both heat and electricity).

Table 19: Characteristics of maize and rye silage used in the LCA assessment

		Maize silage (no cover crop) Scenario 1	Maize silage (main crop) Scenario 2	Rye silage (cover crop) Scenario 2
Yield [tonnes FM/ha]		80	79	32
DM content [%FM]		29	28	26
Specific methane potential	[lN/kgFM]	212	200	170
	[MJ/kgFM]	3.6	3.4	2.78

For the analysed scenario 2 the system consisting of maize and rye cultivation on one field as a main and cover crop respectively was considered. In scenario 1 maize was assumed to be cultivated on the same field, but without cover crop and the additional amounts of maize, necessary to counterbalance cover crops missing in co-digestion process, as compared to scenario 2, were assumed to be cultivated on additional land nearby. After harvesting, both maize and rye were ensilaged and subsequently co-digested with pig manure. The produced biogas was thereafter converted into energy in a small scale combined heat and power generation unit (CHP). The schema of the systems analysed in scenarios 1 and 2 is given in Figure 21.

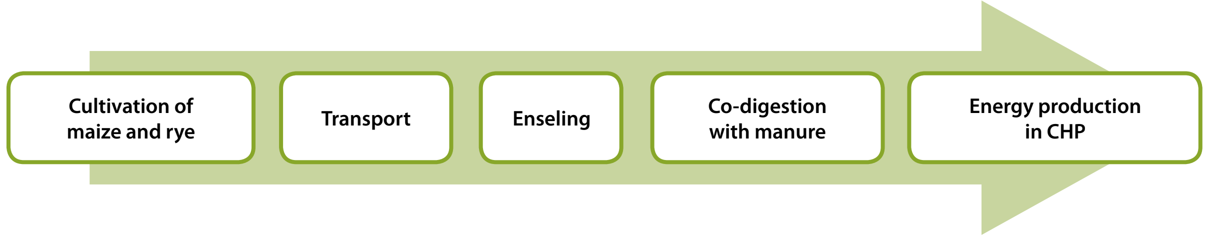


Figure 21: Chart flow of the energy production systems analysed in scenarios 1 and 2

Additionally, different data linked to the whole spectrum of the background processes was included (etc. seeds, machines, fertilizers, herbicides production) mainly based on the data retrieved from ecoinvent data base v.2.2 (ecoinvent centre, 2014). More technical details regarding the study can be found in Golkowska *et al*. (2015).

3.4.6.2 Methodology

The ILCD (International Reference Life Cycle Data System) recommendations of European Commission for performing the Life Cycle Impact Assessment (LCIA) were applied in priority (EC, 2010) and complemented by using the ReCiPe methodology (Goedkoop *et al*., 2009). These two LCIA methods were implemented in the modelling software SimaPro 7.3.3. (PRéConsultants, 2014), in which the LCI and LCIA results were calculated. The impacts on following environmental categories were considered: climate change, ozone depletion, terrestrial acidification, freshwater eutrophication, marine eutrophication, human toxicity, photochemical oxidant formation, particulate matter formation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, ionising radiation, agricultural land occupation, urban land occupation, natural land transformation, water depletion, metal depletion, fossil depletion. Additionally, the impacts created in all above mentioned categories were summarized to create so called single score indicator, which allows easier comparison of the overall effects but through normalization and weighting gives more significance to several impact categories e.g. climate change or particulate matter formation.

3.4.6.3 Results

When comparing the impacts in different categories for scenarios 1 and 2, the following positive trends could be observed for scenario 2:

- Significant decrease (by more than 50%) in marine eutrophication effect due to the reduction of nitrate leaching
- Slight reductions (by 5%) in terrestrial acidification effects for due to lower ammonia emissions to air
- Slightly reduced freshwater eutrophication effects (by 5%) due to lower phosphorous emissions to water
- Reductions for terrestrial and freshwater ecotoxicity (by 15%) due to lower heavy metal emissions to soil
- Reduced agricultural land occupation (by 15%) mainly due to parallel use of the same land for the main and cover crop cultivation
- Reduced nutrient load (for nitrogen and phosphorous) during cultivation of rye (80 kg N/ha and no P) as compared to maize (190 kg N/ha and P application via digestate use) resulting in lower emissions of nutrients and heavy metals

The disadvantages of rye cultivation for co-digestion in biogas plant resulted mainly from its lower yield (by 60%) and biogas potential (by 15%) as compared to maize. Consequently, for the production of the same amount of energy from rye larger land areas have to be cultivated as compared to maize. This generated additional impacts in the categories linked to the production of crops, such as, climate change, ozone depletion, human toxicity, ionising radiation, photochemical oxidant formation, marine ecotoxicity, natural land transformation, water, metal and fossil depletion. However, the impact increase in all listed categories did not exceed 13%.

The summarized and weighted results, expressed in the single score factors, are very similar for both scenarios 1 and 2 with a small impact increase of 1% for scenario 2 (see Figure 22). However, this difference is negligible and after considering the statistical uncertainties for both scenarios the difference can be considered as not significant. The main categories contributing to the single score are climate change, fossil depletion (both slightly better in scenario 1 without rye) as well as particulate matter formation and agricultural land occupation (both slightly better in scenario 2 with rye). The environmental impacts linked to pollutants emissions are generated mainly during crops cultivation, biogas production and energy production at CHP and constitute mainly local emissions. This is not the case for impacts linked to resources that mainly come from background processes, e.g. fuel for electricity production, agricultural machinery, etc. Apparently the marine eutrophication (for which the greatest environmental benefit were observed in scenario 2) is not represented in the single score indicator, due to the limitations of the ReCiPe method. The main advantage of scenario 2 is therefore not considered at the endpoint level of the results. According to the conducted sensitivity analysis the highest influence on the final results could be observed for variations of yield and biogas potential values of maize and rye, but possible modifications for these parameters after including the uncertainty intervals do not change the general interpretation of the single score results for scenarios 1 and 2.

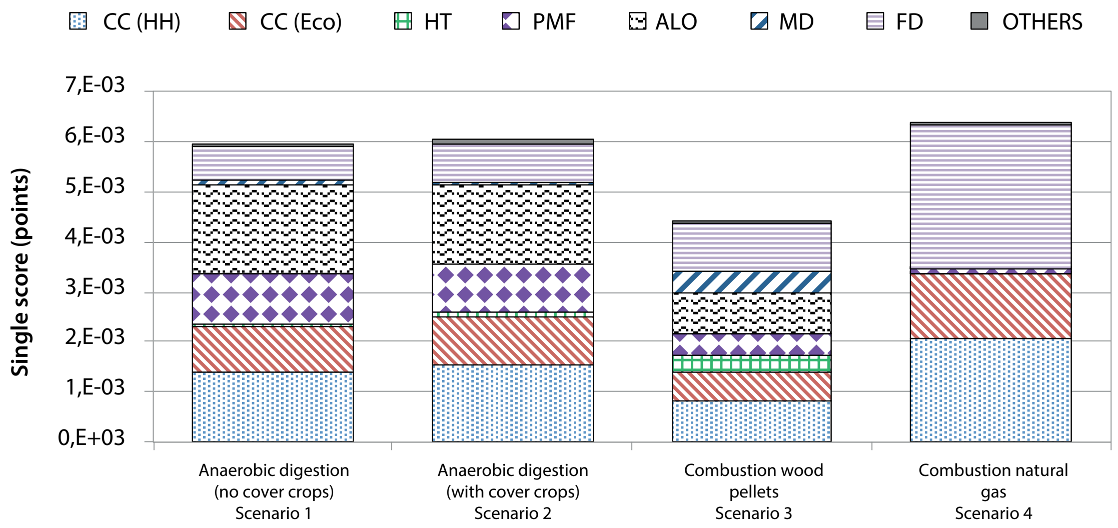


Figure 22: Results of the environmental assessment obtained by applying ReCiPe methodology for the different energy production processes based on the functional unit of 1MJ energy produced; 1Pt is a comparative unit representative for one thousandth of the yearly

production from wood pellets (scenario 3) and natural gas (scenario 4) at the single score level (see Figure 19), the anaerobic digestion leads to higher impacts (around 25%) than the wood pellets combustion, in particular due to increased impacts on climate change, particulate matter formation and agricultural land occupation. Impacts for two former categories for anaerobic digestion were mainly linked to the direct emissions of carbon dioxide, dinitrogen monoxide, ammonia and nitrogen oxides to the air at the CHP, digester and on the field. As compared to natural gas combustion both anaerobic digestion scenarios performed slightly better (single score values reduced by nearly 5%). However, the confidence intervals for all four scenarios are overlapping, meaning that, due to data linked uncertainties, the difference between all the systems is statistically not significant and therefore no ultimate judgement can be done about the technology generating the lowest environmental impacts.

Due to methodological limits certain environmental consequences of using cover crops (e.g. reduction of compaction, maintenance of soil organic matter) could not be quantified or not analysed at the single score level (e.g. marine eutrophication). Also the models used for nutrients and heavy metals fate in soil are quite simple and can be expected to be revised in the future. These limitations do not allow quantifying of certain cover crop linked advantages.

3.4.6.4 Summary

Cultivation of rye as a cover crop during winter and its use in co-digestion generates several advantages linked to optimized land use, applying less fertilizing agents and no herbicides use, reducing leaching effects and avoiding additional biomass transport, as compared to digestion of solely maize silage from summer culture. However, rye is characterised by lower yields and specific methane potential as compared to maize. Consequently, for the production of 1 MJ of energy, larger amount of rye silage is required, as compared to maize silage. This counter-balanced the general advantages of rye cultivation and co-digestion as compared to maize. Thus, according to the single score results, neither positive nor negative effects can be observed, meaning that cover crops next to generation of multiple benefits for the soil can be considered as additional biomass source securing local supplies without producing additional negative impacts on the environment.

3.4.7 Transfer to other regions

3.4.7.1 Luxembourg

If considering the total arable area in Luxembourg (131 049 ha) there are 13 410 ha used for the production of winter wheat, 4 570 ha for winter barley and 246 ha for winter rye (meant for baking industry). Further 582 ha are planted with winter and summer rye meant for fodder and 243 ha with summer and winter barley meant for brewing industry, however here no details are given on percentage of these cultures cultivated explicitly in winter. In general, in the framework of erosion protection subsidy there is a finacial support foreseen for cultivation of cover crops or catch crops (undersown) after main culture.The subsidy amount depends on the plough through/ harvest time. The cover or catch crops should be sown before 5-19 September, depending on the location within the country. The cover crop for harvest sown too late cannot be subsidised. This means in practice that e.g. maize, beetroot and potatoes cannot be followed by subsidized frost irresistant cover crop. However maize can be accompanied by a catch crop. There is also a possibility of cultivation of frost resistant cover crops/catch crops. Sowing of cereals or cultivation of "green manure" is not eligible for the erosin protecion subsidy. However all cover crops including rye type „Rheidol" are eligible if meant for erosion protection.

Subsidies height is linked to the plow through/harvest time: 80 €/ha are foreseen for freezing off cultures and the plow through after the 1st of January, while 120 €/ha can be received for frost resistant cultures and the plow through/harvest after the 1st of February. Moreover, after the CAP reform the arable land with cover or catch crops, which consist of mixed cultures, can be treated as ecological focus areas (EFA) with the surface weighting factor 0.3. For this reason farmers can count on extra financial support. The financial subsidies for EFA are foreseen to be at the level of €81/ha for 2015. This is financed by the distribution of a fixed amount of money each year between all the greening eligible (and submitted) applications. The financial means for all the greening bonus measures in Luxembourg for the coming 5 years are planned to reach annualy around 10 000 000€.

3.4.7.2 Germany

In Germany there is 4 742 328 ha arable land of which 767 957 ha were grown with cover crops during winter in 2010. This area was distributed in 656 083 ha for green manuring, 73 038 ha for fodder and 38 835 ha for energy use (BMELV Statistik; 2010). Plants are mainly clover (5%), grass and grain as whole and green crop harvesting (17%), legumes (2%), rape (63%), turnip (1%) and other cover crops (12%) (Data 2007). Cover Crops are counted for the "greening" in the CAP.

There is 38 835 ha cover crops mainly used in biogas plants. Research about this topic is carried out in following institutes:

- Universities: Universität Hohenheim, Universität Bonn, Universität Kassel-Witzenhausen, Universität Freising
- Federal agricultural research institutes: Thüringer Landesanstalt für Landwirtschaft, Landwirtschaftlichen Technologiezentrums Augustenberg, Landesanstalt für Landwirtschaft, Forsten und Gartenbau (LLFG), etc.
- Research institutes: Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e. V. Müncheberg
- Industrial companies: u.a. Feldsaaten Freudenberger; Planterra

http://www.freudenberger.net/zwischenfruchtanbau.html
http://www.planterra-saaten.de/informationen/zwischenfruchtanbau/

3.4.7.3 United Kingdom

No specific data is kept by the UK government on cover crops. The data collected each year by census of farmers takes the status of arable farms on the 1st of June – therefore any cover crops that have been employed are not collected.
Through the EFA part of the Basic Payment Scheme under the revised CAP, stimuli is possible to sow cover crops. Payments are made based on the total application numbers against the total fund amount. Different land areas are classed by quality for payment mechanisms however cover crops would only eligible when planted on prime agricultural land. Therefore farmers must have established the crop before 31st October and retain them until at least 15th January.

Research is done at:

- The UK governments Department for Environment Food and Rural Affairs
- Anaerobic Digestion & Bioresources Association
- The National Agronomy Centre
- Newcastle University
- Organic Study Centre and Duchy
- Harper Adams University

3.4.7.4 Ireland

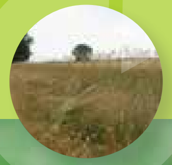
The extent of cover crop use on farmland is entirely up to the individual farmer. Most of the cover crops used will be purposed as fodder or ploughed back into the land.

The only potentially applicable financial stimuli for cover crops in Ireland is the Agri Environmental Options Scheme (AEOS). This scheme aims to tie land up into use for the improvement of conservation and land protection practices in farming, to protect wildlife habitats and endangered species, and to produce quality food in an environmentally friendly manner.

Payments of up to €5000 are available to qualifying farmers who agree to undertake a selected number of operations on their farm for a period of five years. The payment rate varies for each option available and for some options, e.g. hedge planting is divided into a basic payment plus a capital payment. In order to claim capital payments it will be necessary to provide receipts for items such as fence wire, stakes etc.
Anaerobic digestion has not been utilised in any significant way in Ireland to date. In most cases any cover crops used will have been used for animal fodder, composting or to add nutrients back into soils via ploughing into land.

There are no widely known institutes working in this area, mainly due to the fact cover crops aren't covered under the SFP Single Farm Payment. There may be some small scale investigation into cover crop usage in Ireland, but it will be limited to small scale research projects, student projects etc.

4 - Outcomes TAB on low impact biomass



The first session of the ARBOR Transnational Advisory Board on the 26th of April 2013 in Ghent dealt with 'Energetic valorization of low impact biomass from agriculture and nature protection areas'. TAB members were invited to participate at a visit to an 18 ha plantation of SRC (willow and poplar) and to an agroforestry plantation.

The TAB itself started with an introduction by Barry Caslin from Teagasc, the Irish Agriculture and Food Development Authority who gave an overview of Ireland's renewable energy targets and how to reach these. Mr. Caslin concluded that SRC could and should play an important role in this, but nevertheless, Ireland will be highly dependent on biomass imports to meet its targets. The following two presentations were given by Inagro, showing the results obtained and the activities planned on the activation of unused agricultural side-streams and SRC on agricultural land. Finally, there was a lively discussion with some controversial statements prepared by the Flemish partners, where people voted to express their opinion. Two different sessions were organised:

- Session 1: low impact biomass from agriculture, including short rotation coppice
- Session 2: biomass from nature protection areas, including buffer strips

The results of the discussion on both subjects are summarized below.

4.1 Results of the questionnary

4.1.1 Low impact biomass from agriculture

From a legal/administrative perspective, crop residues should be considered as a product not as waste (~ cf. Germany Circular Economy Law, 2012)

a) Yes, it should be considered as an agricultural product (66%)
b) Yes, but only under given conditions regarding control and registration (28%)
c) No, it should fall under waste legislation (6%)

In order to protect soil organic carbon – financial support is required to cover the costs for removal of crop residues and returning the carbon removed

a) Yes, additional costs not related to default agronomic practices should be Compensated (38%)
b) No, it is up to the farmer to create sufficient surplus value for harvested residues (63%)

The other societal added values of bio-energy (waste management, nutrient recovery, employment, etc.) are insufficiently financially valorised in comparison to 'energy-only' renewables (such as wind, solar, hydro)

a) Yes, other societal added values should also be financially appreciated (71%)
b) Other values should be valorised, but it is up to the market to generate these surplus values not the government (23%)
c) No, support schemes should reflect energy-benefits only (6%)

Bio-energy production processes providing added CO_2 e.g. abatement should be included in the ETS CO_2 trade system to generate financial additional incentives at European level

a) No, incentives are already covered by measures at regional / national level (14%)
b) Yes, as a general principle CO_2 abatement should be considered as a whole and valorised via ETS in addition to national / regional measure (34%)
c) Yes, but only to the extent that added abatement can be proven in addition to the reduction realised by merely the fossil fuel substitution (52%)

The new Common Agricultural Policy (CAP) should include short rotation coppice (SRC) as a 'greening' measure.

a) Yes (81%)
b) No (19%)

It should be possible to attain subsidies for locally produced SRC to be able to compete with market prices for wood chips (e.g. via CAP reform)

a) Yes (58%)
b) No (42%)

Subsidies for SRC should not be limited to farmers only.

a) No subsidies should be awarded at all (cfr previous question) (7%)
b) Subsidies should be limited to farmers (21%)
c) Subsidies should not be limited to farmers (72%)

Additional stimulation should be provided for application of SRC on marginal / residual land e.g. contaminated soils, road sides (including rail and water ways, temporarily unused industrial ground)

a) Yes (76%)
b) No (24%)

4.1.2 Biomass from nature protection areas

The usage of materials from nature-conservation-areas for bioenergy generation is an economic opportunity (even if small) for the funding of nature-conservation measures.

a) Yes, that's already working well in some areas in our country (17%)
b) Yes, it can be, but the conditions are not yet suitable (76%)
c) No, I do not agree (7%)

Organising and stimulating collection, logistics and upgrading greenery cuttings can stimulate the creation of low-educated jobs

a) Yes (89%)
b) No (11%)

Energetic valorisation of more 'difficult' biomass (e.g. road side clippings) should receive additional financial incentives (~ German system)

a) Yes (69%)
b) No (31%)

Slight intensification of the handling of nature-conservation areas (e.g. as second cut later in the year) is acceptable to increase the yield from these areas.

a) Yes, this could increase the economic income while maintaining its initial Function (34%)
b) No, we should concentrate the activities on nature conservation and not change best practices for other purposes (66%)

The energetic use of materials from landscape-conservation might, in long-term, open doors for further intensified management of these areas and thereby endangers its initial function.

a) Yes (47%)
b) No (53%)

4.2 Conclusions

Some general conclusions regarding bio-energy opposed to other types of renewable energy: the majority agreed that societal added values of bio-energy should be financially appreciated, and more in particular, the person/ organisation responsible for the added value should be the beneficiary. However, people largely agreed that subsidies should be made available for start-up schemes, but the schemes themselves should be self-sufficient.

With regards to crop residues, the majority voted in favour of the acknowledgement of these residues as a product, rather than a waste, mainly to prevent additional constraints (legal, financial, etc.). The issue of removing soil organic carbon by harvesting energy crops should be tackled by the farmer himself, by creating sufficient surplus value for the harvested residues and with this surplus return the carbon removed.

Most people agreed that the CAP should include SRC as a „greening measure", as long as this does not necessary mean subsidies for SRC and is restricted to indigenous species. People who were opposed argued that SRC doesn't have a clearly identified added value for biodiversity, which is one of the goals of the greening measure. Extra subsidies for planting SRC for farmers, companies in industrial zones or on marginal land, were highly controversial and evoked a lot of discussion. Some people argued that a subsidy during the initial years (establishment grant) is reasonable, while others indicated that this can lead to a distortion on the market prices for locally sourced wood chip. However, most people agreed that additional stimulation is reasonable for phytoremediation purposes.
In general, these questions resulted in a lot of discussion as to the whole need for subsidies and the importance that seems to be put on it.

Concerning the usage of materials from nature-conservation-areas for bioenergy generation, there was agreement on the fact that this holds an economic opportunity and that it can create low-educated jobs, but the opinions on how to improve the economic conditions were quite diverse. Increasing the financial incentives for difficult biomass was questionned because in some case this type of biomass is already collected and funded. Also an intensification of the areas to increase the biomass yield is not fully considered as an appropriate measure as it holds the risk of overexploitation, depletion of nutrients and additional costs. However, it is clear that there is a need for a framework in order to regulate further intensified management.

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