**LIFE Environment and Resource Efficiency project**

**"Nutrient recycling circular economy model for large cities – water treatment sludge and ashes to biomass to bio-energy "**

**Project Acronym: NutriBiomass4LIFE**
**Project Number: LIFE17 ENV/LT/000310**

# Business plan for nutrient recycling and biomass plantation business

**Report prepared by**

**UAB "Pageldynių plantacija"**

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## Preface

The purpose of this document is to present business plan for poplar plantation establishment and nutrient recycling in such plantations (B5).

For the implementation of the NutriBiomass4LIFE project, a subsidy is awarded from the EU LIFE program, the EU's funding instrument for environment and climate action. The funding of the project also come from the Swedish Energy Agency and Ministry of Environment of the Republic of Lithuania.

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## II. About the NutriBiomass4LIFE Project

The Nutribiomass4LIFE project was launched on 1 July 2018 and will be running until the end of September 2023. Within the framework of this project, 6 beneficiaries from Lithuania and Sweden aim to create and demonstrate the first of its kind on the EU level full scale self-sustainable closed loop circular economy model for large cities' nutrient rich waste - municipal wastewater treatment sludge and biomass ashes – recycling into renewable energy for city's needs via environment friendly biomass plantation phytoremediation filter. The circular economy model is based upon Vilnius city, the capital of Lithuania (550 thousand population).

The specific objectives of the project included:

- promoting resource efficiency through reuse of nutrients (less usage of mineral fertilizer) and decrease in transportation distances and flows;
- promoting waste management pyramid priorities via changing path from landfilling and incineration of nutrient rich waste towards reuse in biomass growth improvement;
- mitigation of food chain contamination risks via changing path of nutrient rich waste from uncontrolled usage in food crop growing towards 100% legally compliant and monitored non-food biomass yield improvement;
- creating new best practices for dried MWTS digestate usage for non-food biomass;
- developing new business models to make biomass growing / forestry on marginal and less suitable to agriculture soils economically attractive via substantial biomass yield improvement;
- promoting soil organic content improvement via bio-solids applications;
- promoting renewable energy production;
- promoting afforestation of less suitable for agriculture / marginal lands;
- contributing significantly to climate change impact reduction by sequestrating significant volume of $CO_2$ in the whole circular economy model value chain, promoting renewable energy production, soil carbon content improvement;
- promoting of EU and national legislation and policies and contributing to their development by promoting safe and environment friendly reuse of nutrients from wastes.

### The Coordinating beneficiary:

1. UAB "Pageldynių plantacija" (Lithuania)

### Associated beneficiaries:

2. Forest and Landowners Association of Lithuania (Lithuania)
3. Lithuanian Research Centre for Agriculture and Forestry (Lithuania)
4. UAB "Kirtimu katiline" (Lithuania)
5. UAB "Vilniaus vandenys" (Lithuania)
6. Swedish University of Agricultural Sciences (Sweden)

For more information, please visit the project's website: www.nutribiomass.eu.

## III. List of Abbreviations and Partner Acronyms

| | |
|---|---|
| NutriBiomass4LIFE | EU LIFE project "Nutrient recycling circular economy model for large cities – water treatment sludge and ashes to biomass to bio-energy ", No. LIFE17 ENV/LT/000310 |
| ARR | afforestation and reforestation |
| CE | Circular economy |
| cm | centimetre, 1 m = 100 cm |
| $CO_2$ | Carbon dioxide |
| dmt | Dry matter ton (t) |
| DMWTSD | Dried granulated municipal waste-water treatment sludge digestate |
| EU | European Union |
| g | gram, 1 kg = 1000 g |
| kg | kilogram, 1 t = 1000 kg |
| ha | hectare, 1 ha = 1000 square meters |
| IMF | Improved forest management |
| IRR | Internal rate of return |
| km | kilometre, 1 km = 1000 m |
| l | liter, 1000 l = 1 cub. m |
| LVL | laminated veneer lumber |
| m | meter, 1 m = 100 cm |
| mm | millimetre, 1 m = 1000 mm |
| MAI | Mean annual increment |
| MWTS | municipal waste-water treatment sludge |
| N.A. | Not available |
| NPV | Net present value |
| PP | UAB "Pageldyniu plantacija" |
| REDD | Reducing emissions from deforestation and forest degradation in developing countries |
| Pg | Peta gram, 1 Pg=$10^{15}$ grams |
| SLU | Swedish university of agricultural sciences |
| SSD | Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (Sewage Sludge Directive) |
| t | metric ton, 1 t = 1000 kg |
| VCC | Voluntary carbon credits |
| vs. | versus |
| VV | UAB "Vilniaus vandenys", Vilnius city municipal water supply and sewage water treatment company |

## Introduction

## Purpose and Aim

The purpose of this document is present business plan for poplar plantation establishment and nutrient recycling in such biomass plantations (B4).

## Structure

The document is divided into the following chapters:

- Chapter 1 “The key success factors for the poplar plantation establishment” describes the key factors for successful poplar plantation establishment: water availability, suitable soil, selection of suitable clones and good establishment and weed management in the first year.
- Chapter 2 “Poplar clones” presents poplar clones which are suggested for planting in Lithuania and neighbouring markets for successful poplar plantations establishment.
- Chapter 3 “Investment and cost assumptions” describes investment into land and poplar plantation establishment and management cost.
- Chapter 4 “Revenue assumptions” discuses biomass yield assumptions, expected product mix and pricing, land appreciation and carbon removal revenue assumptions.
- Chapter 5 “Financial result” discloses key financial results of poplar plantation establishment and nutrient recycling business plan.
- Chapter 6 “Sensitivity analysis” provides comparison of major business scenarios.
- Chapter 7 “Comparison of investment in other markets” compares investment results from investment into Lithuanian, Latvian and Swedish markets.
- Chapter “Conclusions” provides key results of poplar plantation establishment and nutrient recycling business plan.
- “Annex” provides financial model for biomass plantations establishment.

# 1 The key success factors for the poplar plantation establishment

The success of planting hybrid poplar plantations basically depends on several main conditions:

- Water availability
- Suitable soil
- Selection of suitable clones
- Proper establishment and weed management

## 1.1 Availability of water

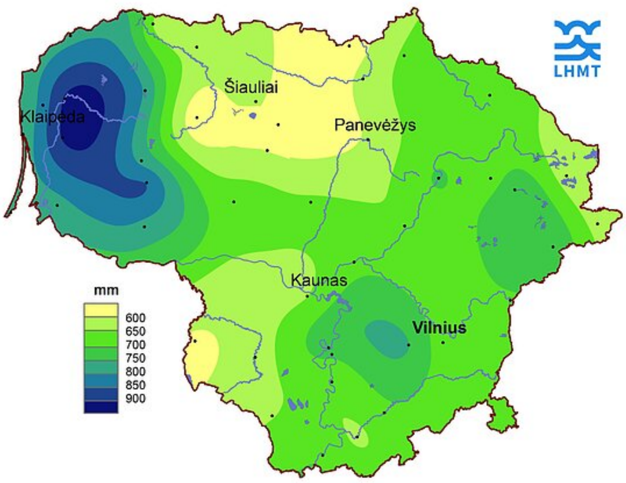
Hybrid poplars are fast-growing trees whose natural habitats are riverbanks. That is, the availability of water is the most important factor ensuring the successful establishment and fast growth of poplars. Water availability is especially important in the first year, which largely determines the further growth rate of poplar plantations.

Water availability is determined by:

- Precipitation during the growing season
- Groundwater level
- Soil granulometric composition
- Terrain
- Competing vegetation
- Properties of poplar clones

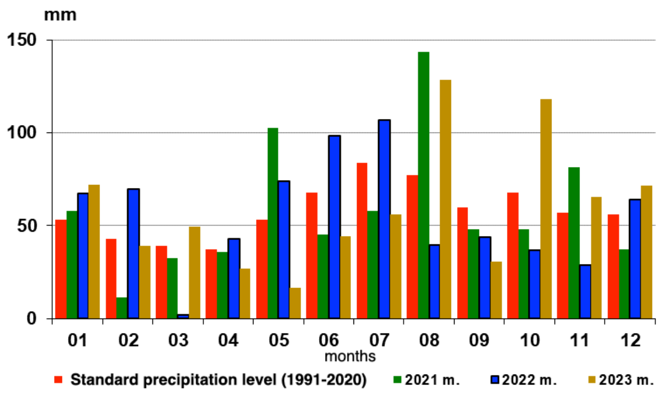
Historically, Lithuania with annual precipitation level of 675 mm is considered to be in the zone of excess moisture, and for this reason, the absolute majority of agricultural land has old drainage systems.

**Picture 1-1. Annual precipitation levels in Lithuania, mm**



Although historic annual precipitation is favourable for poplar growing, the changing climate puts additional challenges as precipitation during spring decreases and more often we suffer a prolonged droughts during vegetation periods.

**Picture 1-2. Monthly precipitation levels in Lithuania, mm**

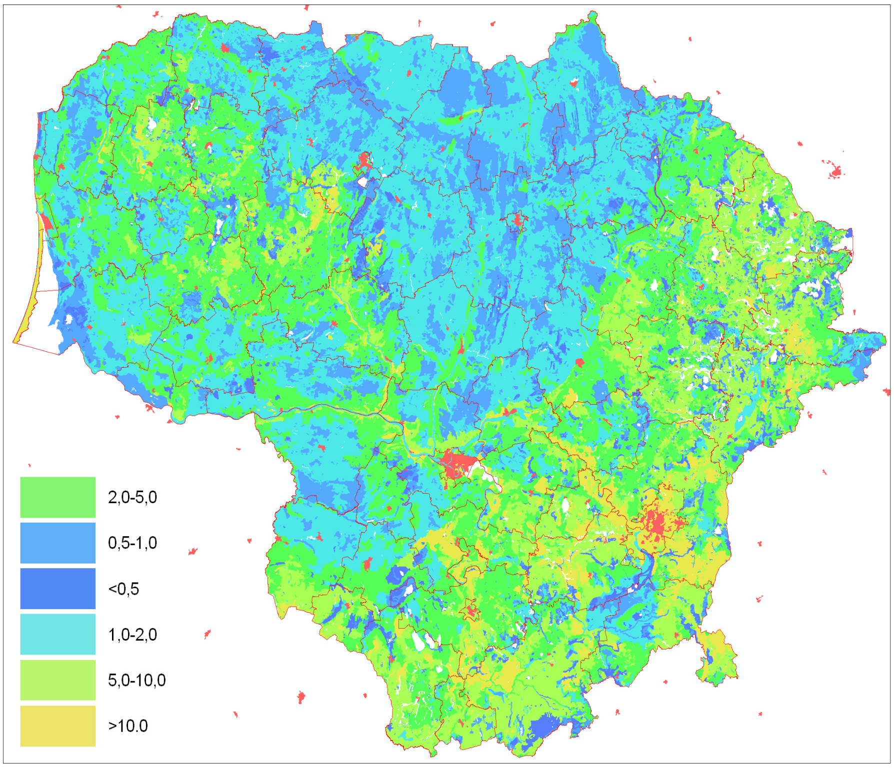



Since 2015 Climate change phenomena, which is becoming increasingly noticeable in Lithuania, have a more positive effect on poplar plantations, because the yield of poplars increases due to the warming climate, increasing amount of solar radiation, and tropical nights. On the other hand, longer and more frequent droughts pose an additional risk to the growth rates of newly planted poplar plantations and the survival in the first year of growth. This risk can be managed by planting poplar plantations deeper, choosing the right soil and successfully managing competing vegetation.

It is generally assumed that the earlier in spring poplar plantation is established, the higher their viability will be in the first year, because spring is associated with higher soil moisture. However, climate change also introduces corrections here - practical results during last several years have shown that poplars established very early (late March - early April) can even dry out if the spring is cold and very dry. In some years, seedlings planted later (e.g. in June) may grow even better if the planting coincides with the rainy season. Regardless of such cases, it is still recommended to plant poplars in the spring, when the groundwater is at a highest level.

Since poplar roots are shallow, poplar plantation should ideally be established when the groundwater is 1-2 m deep. According to the ground level map of Lithuania, the most favourable area is north-central Lithuania, where there is the most productive zone of intensive agriculture – crop growing. However, poplar plantations cannot economically compete with intensive crop farming, and accordingly cannot compete for the most productive lands. By choosing appropriate soils that maintain moisture, poplar plantations can be successfully established and grown both in Western and Eastern Lithuania, where the groundwater level is much lower.

**Picture 1-3. Groundwater level map of Lithuania, m**




Source: Lithuanian Geological Service

During periods of long-lasting droughts, when groundwater enters deeper layers, poplar growth can stop completely, trees can drop their leaves, thus protecting themselves from the devastating effects of long-term droughts. Despite poplars need water for their growth, soils have to be well drained, not flooded.

Choosing the right granulometric composition of the soil can significantly reduce the risk of long-term droughts, especially during in the first-year of poplar establishment. Despite the fact, that the groundwater can be well below 2 m, heavier soils, especially when heavier granulometric composition prevails in the base soil layer, are safe enough for the cultivation of poplar plantations because they maintain moisture in the soil. Although poplars traditionally grow on light sandy soils at the banks of rivers, in order to reduce the risk of devastating effects of drought, sandy soils for poplar breeding should be avoided when the groundwater is deeper than 2 m. Sandy soils (Arneosols) are defined as those soils, the soil part of which consists of sand.

When the terrain of the poplar plantation is flat, an even growth of biomass over the entire area of the plot can be expected. However, in both eastern and western parts of Lithuania, where there are areas less favourable for traditional farming and which are economically attractive for poplar plantation establishment compared to traditional farming, uneven terrain prevails. Normally, fertile soils, washed down from the higher elevations, accumulates in lowlands, and in addition, the ground water is higher in the lowlands, so the growth of poplar plantations in the lowlands is much faster.

Removing competing vegetation, especially in the first year, is very important for two reasons:

1. Poplars are open sun plants, so they must not be overshadowed by competing vegetation. This problem can be partially solved by planting long poles or tall containerized seedlings, but in especially fertile and humid lowlands, still that will not be a solution.
2. Weeds compete for the water from the soil surface and use up nutrients that are vital to the establishment of poplar plantations in the first year. Competing vegetation is especially dangerous in infertile soils that are characterized by high water permeability (sands) and especially in times of drought, as the first-year poplar seedlings cannot obtain water from the deeper layers.

It should also be noted that the water availability in the top soil layer also depends on the former use of land. In intensively used arable land, the water capillary systems are destroyed, so poplar plantations planted in arable land with a lighter granulometric composition (sands) due to lack of water grow worse than in abandoned land or grasslands. However, if the soil granulometric composition is heavier (loam or clay), the difference in water availability between arable and non-arable land is not significant.

Different poplar clones also vary in drought tolerance. Among the clones grown in Lithuania, the ones that are the most resistant to droughts are those that start vegetation at the earliest - that is, they burst when the soil has enough moisture and there is no competing vegetation. This is characteristic of the northern clones - all Snowtiger clones except Snowtiger 3. Meanwhile, Snowtiger 3 and OP42, whose vegetation starts later but lasts longer, are less resistant to lack of moisture and are suitable for growing in soils with good moisture conditions. In any case, the growth of all poplar clones is highly dependent on the moisture content of the soil, although poplars do not grow in soils that are constantly flooded or that are flooded for long periods of time during the growing season.

## 1.2 Suitable soil

The more fertile the soil, the more poplar growth is likely. Soil fertility is related to both the soil's ability to retain moisture and the amount of nutrients it contains. The most fertile soils in Lithuania are Cambisols, which are the most suitable for intensive crop growing, but Cambisols are rarely found in both the Eastern and Western parts of Lithuania.

The most fertile soils, which are often found in less favourable areas for farming, are Luvisols and poplar plantations grow very well in them. Albeluvisols are also suitable for growing poplar plantations.

Such infertile soils, which are unsuitable for traditional agriculture, such as Glaysols, are usually very suitable for poplar cultivation, since most of them are temporarily waterlogged, and water is the main pre--condition for the rapid growth of poplars.

Planosols and Fluvisols soils are less common soils, in which poplar yield is lower, especially due to the lack of moisture.

Sandy soils (Arenosols) are the least suitable soils for poplar establishment due to the lack of nutrients and primarily moisture. If the groundwater of the sandy soil is high (1-2 m above the ground surface) - usually such sandy soils are located near water bodies (rivers or lakes) on the coasts, then the sandy soils are also suitable for growing of poplar plantations. Otherwise, sandy soils should be avoided for the planting of poplar plantations, because in Lithuania we are dealing with more and more frequent and longer droughts.

You also need to pay attention to the acidity of the soil - very acidic soils are not suitable for poplars. Suitable soils for the growth of poplar plantations are when the pH of the soil is higher than 5.5. The most acidic soils are upland peat soils, which are completely unsuitable for growing of poplar plantations due to their acidity. Sandy soils are also more acidic.

Poplars require mineral soil to grow, so another category of soil that should be strictly avoided for poplar establishment is deep Histosols. Upland peat soils are unsuitable due to their acidity, so in this case we are talking about drained lowland peat soils. Although lowland peat soils have a favorable moisture content and a high nitrogen content, which are the main catalysts for poplar growth, deep drained lowland peat soils are unsuitable for poplar cultivation for the following reasons:

- Nutrient imbalances. Lowland peat soils contain a lot of mineral and organic nitrogen, while other micro and macro elements can be at high deficiency. Since the growth of poplar plantations requires a balanced amount of micro and macro elements, due to a large nutrient imbalance, when nitrogen promotes very fast growth, the plants can be severely stressed and often die.
- Late growing season start and extended growing season ending. Drained lowland peat soils are usually moist and located in lower areas, so in the spring the peat soils are cold for a long time and this stops the beginning of poplar vegetation. On the other hand, in late summer or early autumn, the first frosts always come to lowland peat soils. Since lowland peat soils contain a lot of nitrogen and poplar vegetation starts later in spring, correspondingly, the vegetation in lowland peat soils is significantly longer, and autumn frosts arrive in them the earliest. Therefore, poplars usually freeze in the fall or may freeze completely (especially in the first year) in lowland peat soils.

If the lowland peat soils are shallow - that is, the peaty layer is only in the arable layer, and the base soil layer consists of mineral soil (especially clay or loam) - such soils are suitable for growing poplars.

As a rule, peat soils should be avoided for poplar establishment, but both in eastern and western Lithuania, soil types vary greatly due to the changing elevations, so it is not uncommon, especially in larger plots, to have inserts of peat soils. In such a case, it is advisable to plant exclusively Snowtiger clones (except Snowtiger 3) in the peat soil inserts, which are characterized by an earlier start of vegetation and an earlier end of vegetation.

## 1.3 Suitable poplar clones

Various commercial varieties of poplar plantations were planted and tested in Lithuania. The following varieties are the most suitable for commercial activities in Lithuania:

- **Snowtiger clones**. Snowtiger clones are suitable for growing in all soils and are more suitable for early droughts due to the earlier vegetation.
- **OP42 clone.** OP42 is the most widely used poplar clone in the Baltic Sea region. In Lithuania, you should avoid planting poplars in lowlands and peaty soils because OP42 may freeze. Also, OP42 is less resistant to drought in the first year of growth.
- **Italian AF clones**. Of the Italian AF clones, we can only recommend AF34, which has proven to be resistant to winter frost damage due to its strong bark structure, is very productive and

straight. AF34 is characterized by a long vegetation, so there is a risk of severe frosts or complete freezing in the first year if we get early frosts, so it is completely unsuitable for growing in lowlands and peaty soils.

- **German MAX clones.** German MAX clones are only suitable for very short rotation plantations - up to 5 years and are intended exclusively for biomass energy production.
- **Other clones.** There are other– Swedish Forest research institute Ekebo poplar clones, US Minnesota university poplar clones, which undergo testing in Lithuania.

## 1.4 Proper establishment and weed management

The main indicator that signals whether we will have a particularly productive hybrid poplar plantation is what height the poplar plants have reached at the end of the first year. If at the end of the first year the poplar plantation planted with long poles reached a height of 2-4 m, you can be sure that there will have a particularly productive poplar plantation.

Proper planting of poplar plantations is ensured by:

- Optimal soil
- Proper selection of poplar clones
- High quality poplar seedlings
- High-quality soil preparation
- High-quality weed control

In the first year of establishment, the cultivation of poplar plantations should be viewed as an intensive agricultural activity. Only in further years poplar plantation management become much closer to forestry with more extensive management.

**That is, the more we invest in the first year, the better the result will be at the end.**

# 2 Poplar clones

In the last 10 years, various commercial varieties of poplar plantations have been planted and tested in Lithuania:

- Swedish Snowtiger clones
- OP42 clones
- Italian AF clones
- German MAX clones
- German Matrix clones
- Swedish Ekebo clones
- Belgian clones
- US NRI (Minnesota) clones

All the clones listed above, except the German MAX clones, are intended for longer rotation growing poplar stem wood, while the German MAX clones are intended exclusively for short rotation biomass energy production.

## 2.1 Snowtiger clones

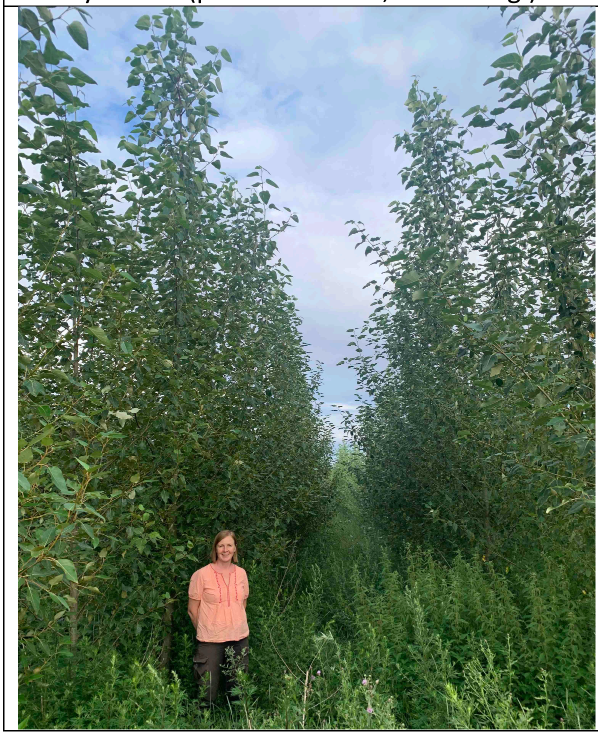
Snowtiger clones are among the most productive in Lithuanian conditions, suitable for all types of soil. The Snowtiger poplar clonal trials were established in Lithuania in 2014 under EUROSTARS E! 8443 project "High productive and climate adapted poplar clones for the energy and forestry sector in Baltic Sea Region".

SnowTiger poplar clonal mixture consists of planting material bred specifically for Northern European climates by crossing North American *Populus P. trichocarpa* (♀) × *P. trichocarpa* (♂) elite trees. The planting material is suitable for the breeding of plantation of highly productive woody biomass used in the energy, pulp and plywood production sectors and for environmental purposes.

The SnowTiger clonal mixture consists of four main clones ST2, ST3, ST4 and ST6. There are also ST10, ST22, ST34 and ST108 clones, but their production volumes are quite limited. All Snowtiger poplar clones are male (♂).

Compared to very popular OP42, Snowtiger clones are straighter, with thin branches, more suitable for plywood production, and more resistant to frost and drought.

**Picture 2-1. Snowtiger poplar clones in Lithuania**

| Four-year-old (planted in 2020, Vilnius reg.) | Ten-year-old (planted in 2014, Anykščiai reg.) |
|---|---|
|  |  |

## 2.2 OP42 clones

The OP42 clone was developed at Oxford Paper Company, Pennsylvania (US) 100 years ago by crossing Populus maximowiczii (♀) × P. trichocarpa (♂) elite trees.

Today it is the most widely used poplar clone in the Baltic Sea region, while in the US this clone is quite rare because many new, more productive clones have been bred. OP42 clones were bred for longer rotation, cellulose production. Because of its branching, it is less suitable for plywood production.

OP42 poplars are characterized by a later and longer growing season, which can cause younger trees to freeze and become crooked in the fall. After 4-5 years, when the trees reach a height of 8-10 meters, the probability of frosts is low.

It is a reliable, time-tested clone, suitable for Lithuania, but due to frost damage, planting in lowlands and peaty soils should be avoided. Since the OP42 clones are old, they are not licensed.

**Picture 2-2. OP42 poplar clones in Lithuania**

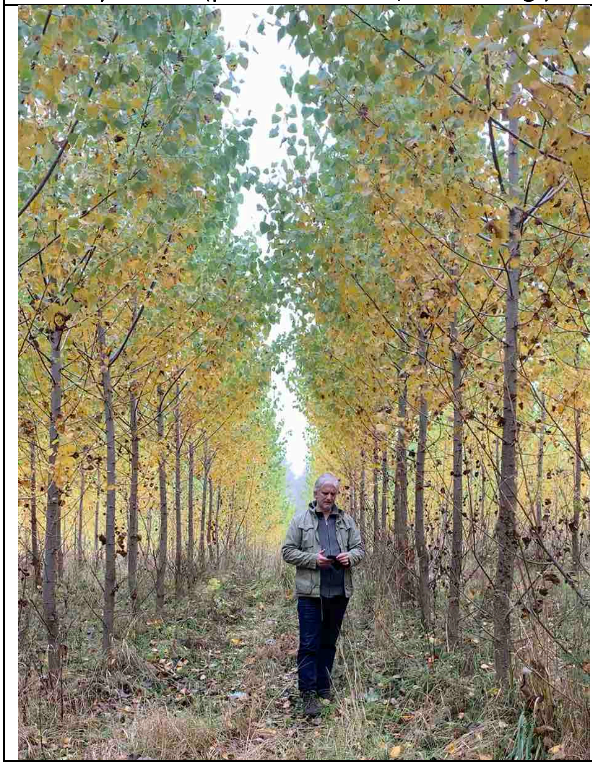
| Four-year-old (planted in 2020, Vilnius reg.) | Ten-year-old (planted in 2014, Anykščiai reg.) |
| --- | --- |
|  |  |

## 2.3 Italian AF34 poplar clones

Italian AF clones are the most widespread in Europe. AF clones, predominantly *Populus deltoides* × *P. nigra* hybrids, are very productive in warmer climates because they have a much longer vegetation season, which can last until mid-October. Their vegetation starts when the climate and soil warm up, so in Lithuania, due to the cold spring, their vegetation can start very late - sometimes even in the beginning of May.

For the NutriBiomass4LIFE project AF34 (which is a close relative of the AF7 clone) was selected. AF34 is a *P. deltoides* (♀) × *P. nigra* (♂) hybrid (*P. Canadensis*) bred by the Italian Alasia family 20 years ago. AF34 is mainly grown in Southern Europe, and due to its straightness is grown for a longer rotation (15 years) for the plywood industry. In Lithuania, it was selected for its fast growth and relatively good resistance to cold during wintertime. The bark of AF34 is completely resistant to severe frosts, but due to its long vegetation, one-two-year-old trees can be severely damaged by early autumn frosts. In later years of growth, the risk of frost is low. All AF seedlings are grown in Italy from where they are imported.

**Picture 2-3. AF34 poplar clones in Lithuania**

| Three-year-old (planted in 2020, Vilnius reg.) | Ten-year-old (planted in 2014, Anykščiai reg.) |
|---|---|
|  |  |

One more risk, which is associated with AF34 clone and emerged during implementation of NutriBiomass4LIFE project, is susceptibility to bacterial infection (canker) after pruning or damage of stem. This risk emerged after two years after pruning of some AF34 plantations with the purpose to grow higher quality wood. This risk has to be observed and assessed over longer term. Therefore, pruning of AF34 clones is postponed.

## 2.4 German MAX clones

The German MAX clones (MAX1, MAX2 and MAX3) are Populus maximowiczii × P. nigra hybrids, bred exclusively for cultivation in short rotation (up to 5 years) and for biomass energy. The German MAX clones are not suitable for growing for longer rotation stemwood due to their crookedness, branching and often broken tops.

MAX clones for biomass are planted very densely - over 10,000 units/ha. They can be more productive compared to willows, but poplar seedlings are more expensive than willows, so willows are much more popular as energy plants in our region. MAX clones are mainly grown in Germany. Because MAX clones are old, MAX clones are not licensed.

## 2.5 German Matrix clones

The German Matrix (Matrix 24 and Matrix 49) Populus maximowiczii × P. trichocarpa hybrids are newer clones compared to the MAX clones and are suitable for growing in a longer rotation for stemwood.

Matrix clones are characterized by a longer rotation, so Matrix clones are not suitable for Lithuanian conditions due to the risk of early autumn frosts.

The new German clones FastWood1 and FastWood2 (Populus maximowiczii × P. trichocarpa hybrids) have a shorter growing season than the Matrix clones, but still also vulnerable to early autumn frosts.

## 2.6 Swedish Ekebo clones

The Swedish Forest Institute offers a collection of Ekebo poplar clones, the majority of which is clone OP42. Two non-OP42 clones are selected from this collection: SvSFPo6 and SvSFPo4. SvSFPo6 is a *Populus maximowiczii × P. trichocarpa* hybrid, a close relative of OP42. SvSFPo4 is a *Populus balsamifera × P. trichocarpa* hybrid.

SvSFPo6 and SvSFPo4 are suitable for cultivation in Lithuanian conditions and the first tests showed that their productivity is close to OP42.

## 2.7 Belgian clones

Various Belgian clones have been tested in Lithuania: Oudenberg and Vestern (*Populus deltoides × P. nigra* hybrids) and new Denker, Skado, Bakan, Balebek (*Populus maximowiczii × P. trichocarpa hybrids*) are risky in Lithuanian conditions due to long vegetation and the risk of early frosts. They are suitable for regions with marine climate.

## 2.8 US NRI (Minnesota) clones

37 US NRI (University of Minnesota) clones are being tested in Lithuania, most of which consist of (*Populus deltoides × P. nigra* hybrids). These clones are characterized by high productivity and are resistant to frost, because they are bred for the continental climate of Minnesota, which is close enough to the climatic conditions of Lithuania. It is very likely that these clones will also be very productive and suitable for Lithuanian conditions.

## 2.9 Types of seedlings

Both unrooted (long poles) and rooted (grown in containers) poplar seedlings are used in Lithuania.

In Lithuania, poplar plantations are established with long poles (150-180 cm long), while seedlings grown in containers proved to be suitable for replanting purposes if survival of established plantation is lower than 90%. Long poles are not suitable for replanting purposes, because it is not possible to use machinery for replanting in already established plantation. Long poles are the fastest growing planting material and are also the most resistant to weed competition because weeds cannot overshadow them.

Long poles are 150-180 cm one or two-year-old canes that are planted with a machine at a depth of 60 cm. In order to reduce the risk of drying out, the diameter of the long pole at the top should be at least 1 cm. Especially long poles - 2.5-3 m can be planted by drilling up to 1 m. deep pits.

During spring, poplar seedlings are stored at cold storage at minus 1-2$^{o}$C temperature.

**Picture 2-4. Cold storage of long poles**

Long poles of poplar hybrids of different crossing combinations have different vitality and the ability to initiate vegetation both from existing and dormant buds, so it is necessary to acquire required quality of seedlings for the establishment and growth of poplar plantations to be optimal.

*Populus maximowiczii and Populus trichocarpa* hybrids (e.g. OP42) or interspecies hybrids (e.g. Snowtiger) are characterized by the fact that the start of vegetation from one year buds is very fast (up to 2 weeks), while from dormant buds it is relatively slow (can take from 3 weeks to several months).

Long poles of Swontiger, OP42, Ekebo clones are prepared to have one year old buds at the top - so that the vegetation does not come from dormant buds, as it takes a long time. E.g. in the case of Snowtiger 3 clone, viability from dormant buds alone is very poor.

One-year-old poles of Swontiger, OP42, Ekebo are covered with formed surface buds, which all burst at the same time during the start of the growing season. Formation of leaves from multiple buds require a lot of moisture when the roots are also just starting to develop and that may lead to quick dry-out of one-year old poles.

The optimal long poles of Swontiger, OP42, Ekebo clones for poplar plantation establishment are two-year-old plants, leaving a 5-10 cm one-year old tip at the top with 2-3 surface buds. Such poles are the most vital and grow from them is the fastest, although their preparation is the most expensive - from the second year of the live branch, all grown branches must be cut.

**Picture 2-5. The beginning of the growth of long poles, Vilnius district**

| One year old seedlings of OP42 | Two year old seedlings of Snowtiger |
|---|---|
|  |  |

Italian AF clones and US Minnesota clones (*Populus deltoides × P. nigra hybrids*) long poles are typically prepared without surface buds usually from one, sometimes two-year-old plants. In the case when long poles are prepared from two-year-old plantings, it is necessary to cut off small branches from the side of the poles.

**Picture 2-6. The beginning of the growth of long poles of AF34 clones, Vilnius district**

## 2.10 Seedlings grown in containers

Poplar seedlings grown in containers are usually used to replant unsuccessfully established plantation/seedlings, as successful replanting with long branches is difficult due to inability to use panting machinery inside of already established plantation. In case of replanting of plantations, necessary to replant missing plants no later than in the fall of the same year/or the spring of the following year, because later replanted seedlings will not be able to compete with rapidly growing vegetation and will be overshadowed.

# 3 Investment and cost assumptions

Business plan financial calculations are presented in the spreadsheet in the annex and is composed by several key input groups:

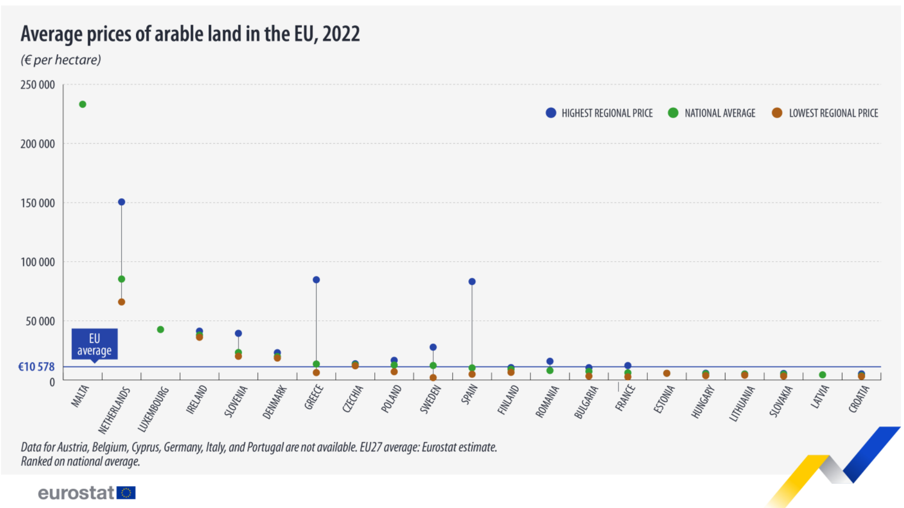
- Land costs (rows 13-17)
- Soil preparation costs (rows 19-22)
- Planting costs (rows 24-26)
- Weed control costs (rows 28-30)
- Pruning costs (rows 32-34)
- Fertilization costs and revenues (rows 36-40)
- Management costs (row 42)
- Biomass sales revenues (rows 46-61)
- Land value appreciation (row 63)
- Revenues from $CO_2$ removal (rows 65-75)

## 3.1 Land costs

While calculating economics of poplar plantation establishment, land costs have to be taken into account as land availability is one of the key success factors for plantation establishment and the most significant cost item.

Based on Eurostat data, average arable land prices in 2022 in the EU were 10 578 eur/ha (te value does not include data from Austria, Belgium, Cyprus, Germany, Italy and Portugal, thus it can be assumed that all-inclusive EU average arable land prices are even higher). In Lithuania average price of arable land in 2022 was 5012 eur/ha.

**Picture 3-1. Average prices of arable land in the EU, 2022**



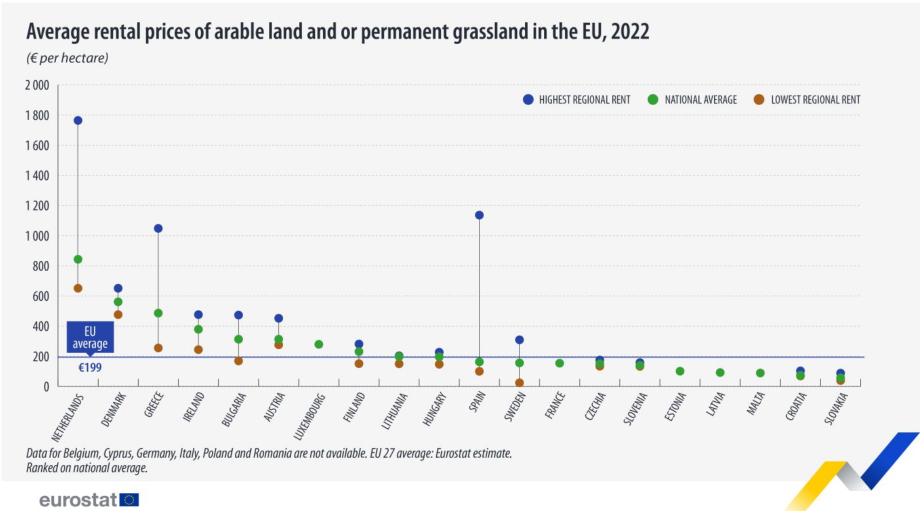
Buying arable land was usually more expensive than buying permanent grasslands. The average price of one hectare of arable land in the EU was about 2 200 eur/ha more than the average price of one hectare of permanent grassland in 2022 (at 8 393eur/ha). In Lithuania average price of grasslands in 2022 was 3585 eur/ha.

Not all land is owned by the farmer working it. Many farmers rent their land, as either a short or long-term business decision. The cost of renting land is another factor that farmers have to absorb in their business. Mirroring the variation in arable land prices, annual rental prices of one hectare of agricultural land (average of arable land and permanent grassland) also vary starkly between countries and regions within countries.

In 2022 the EU average price of arable land was 45 times more than the average annual rental price of 233 eur/ha. In Lithuania average rent price of arable land in 2022 was higher than the EU average and was 241 eur/ha.

In 2022 the EU average price of arable land and permanent grasslands was 199 eur/ha, while in Lithuania - 198 eur/ha. In Lithuania average rent price of grasslands in 2022 was 164 eur/ha.

**Picture 3-2. Average rental prices of arable land and permanent grasslands in the EU, 2022**




Despite investment into poplar plantation establishment are significantly higher comparing to annual conventional agricultural cultivation costs, land costs are even much higher. Land costs may differ, depending on the ownership and possession of the land. In Lithuania, the following land costs may be considered while planning investment in poplar plantation establishment:

- If plantation is established by existing landowner, landowner has to consider alternative usage revenues – lease of the land, other agricultural use (if appropriate) or sale of the land.
- If investment is made into land for poplar plantation establishment, typically low productivity land in ANC area costs **4000 eur/ha (cell F14).**
- If plantation is established on leased land – land rent costs are assumed **200 eur/ha (cell F17).** Considering long term lease requirement– contracts are usually indexed for inflation. Long term land lease option for plantation establishment is economically more beneficial than investment into land acquisition, but very rare for 20-year duration.

- Land brokerage costs (acquisition or rent) are assumed at 150 eur/ha **(cell F15).**
- Lithuanian land (property) tax is assumed at appr. **1 eur/ha (cell F16).**
- **Land costs are the major variation scenario when calculating business plans for different markets (e.g. Latvia, Sweden) as other cost and revenue scenarios are similar.**

## 3.2 Soil preparation costs

Soil preparation costs consists of:

- Weed disking before plowing (if required) costs
- Plowing costs
- Cultivation after plowing costs

Soil preparation plays a very important role as root development of poplars requires loose soil and good soil aeration conditions for optimal poplar growth. If there is a compacted pad formed in the soil, it should be broken up with a deep grinder.

It is assumed that weed disking before plowing can be performed at 6 ha/day area. Disking before plowing costs are composed of 12 l diesel /h tractor fuel consumption (diesel price @ 1,5 eur/l), plus 150 eur / day / tractor driver wage, 200 eur /day tractor ((lease/maintenance) costs and 20% overhead costs. Total costs for disking before plowing are **100 eur/ha (*cell F20*).** If land plots are smaller, then disking costs will be higher, as smaller area will be disked per day. Disking before plowing costs are not included in basic scenario costs calculations as in most cases land preparation is done before planting in spring, therefore disking before plowing is not required.

Since the poplar seedlings are planted deep enough (60 cm deep), the soil should be plowed accordingly - 35-40 cm deep. Deep plowing is also necessary, because poplar plantations are often established on agricultural soil that have not been actively used for agriculture for a long time, where the soil has been undisturbed and compacted for a long time, and the aeration in the soil is poor.

Such deep plowing is quite expensive and slow - only an average 3 ha can be plowed. The soil can be plowed both in the fall and in the spring before planting of poplars. If soil is plowed in spring, just before poplar establishment, such plowing has initial pre-emerging weed protection, because herbicides are not used for weed control while establishing poplars. In case of plowing of not-used for agriculture land in autumn, disking of weeds before plowing may be needed.

It is assumed that deep plowing (35-40 cm deep) can be performed at 3 ha/day area. Plowing costs are composed of 12 l diesel /h tractor fuel consumption (diesel price @ 1,5 eur/l), plus 150 eur / day / tractor driver wage, 200 eur /day tractor ((lease/maintenance) costs and 20% overhead costs. Total costs for deep plowing are **200 eur/ha (*cell F21*)**.

After plowing, before planting the soil is cultivated to flatten the soil. It is assumed that cultivation after plowing can be performed at 6 ha/day area. Cultivation after plowing costs are composed of 12 l diesel /h tractor fuel consumption (diesel price @ 1,5 eur/l), plus 150 eur / day / tractor driver wage, 200 eur /day tractor ((lease/maintenance) costs and 20% overhead costs. Total costs for cultivation after plowing are **100 eur/ha (*cell F22*)**.

**Picture 3-3. Soil preparation – plowing and cultivation**

Total soil preparation costs (not including disking before plowing) for poplar planting are **300 eur/ha**.

## 3.3 Planting costs

Planting costs are composed of seedling costs and actual planting costs.

Poplars are planted in spring and may be established till end of June. Planting of poles is possible in late autumn as well, but as vegetation of poplars is long, seedlings for planting may be ready only in November. Planting of poplars in November-December is very problematic due to wet soils.

Planting of long poles is done with special machine, planting long poles 60 cm deep. 2 ha / day of plantations are established using long poles, at 1600 plants /ha density.

**Picture 3-4. Planting long poplar poles**

For poplar plantation establishment in Lithuania, it is recommended to use OP42 and Snowtiger poplar clones. At the beginning the growth of OP42 and Snowtiger clones is slower than AF34 but taking longer rotation (20 years) OP42 and Snowtiger are less risky and biomass yield is compatible to AF34.

It is recommended to plant two-year-old OP42 and Snowtiger long poles with 5-10 cm one year-old shoot on top with one or two fresh buds. Such long poles are more vital and drought resistant, but their production is more expensive, as two-year-old poles have to be cleaned from small branches during pole for seedling preparation. Therefore, costs of such poles are 1,1 eur/unit. Taking into account, that planting density of poplars is 1600 plants/ha, **total plant costs are 1760 eur/ha (*cell E10 x cell F25*).**

It is assumed that long pole planting with special machine can be performed at 2 ha/day area. Planting costs are composed of 11 l diesel /h tractor fuel consumption (diesel price @ 1,5 eur/l), plus 150 eur / day / tractor driver wage, 200 eur /day tractor ((lease/maintenance) costs, plus two planting workers each @ 120 eur/day and 20% overhead costs. Total costs for planting are **440 eur/ha (*cell F26*)**.

Total poplar plantation establishment/planting (including seedling and planting) costs are **2200 eur/ha.**

## 3.4 Weed control costs

Weed control (competing vegetation) is very important to ensure the vitality and rapid growth of planted poplar plantations in the first year, especially during droughts. In the second year, weed control is not compulsory, after poplars reached 1.5-2 m. height in the first year, but is recommended.

Herbicides are not used for weed control in NutriBiomass4LIFE plantations, therefor weed control of planted poplars is carried out in a mechanical way - disking between planted poplar rows. In the first year, if poplars are planted early (March-April) and especially if the soil for planting was prepared from the fall, it is recommended to carry out weed control by disking twice a year (e.g. at the end of May and mid-July). It is estimated, weed control by disking can be performed at an area of 6 ha per day.

**Picture 3-5. Mechanical weed control – disking**

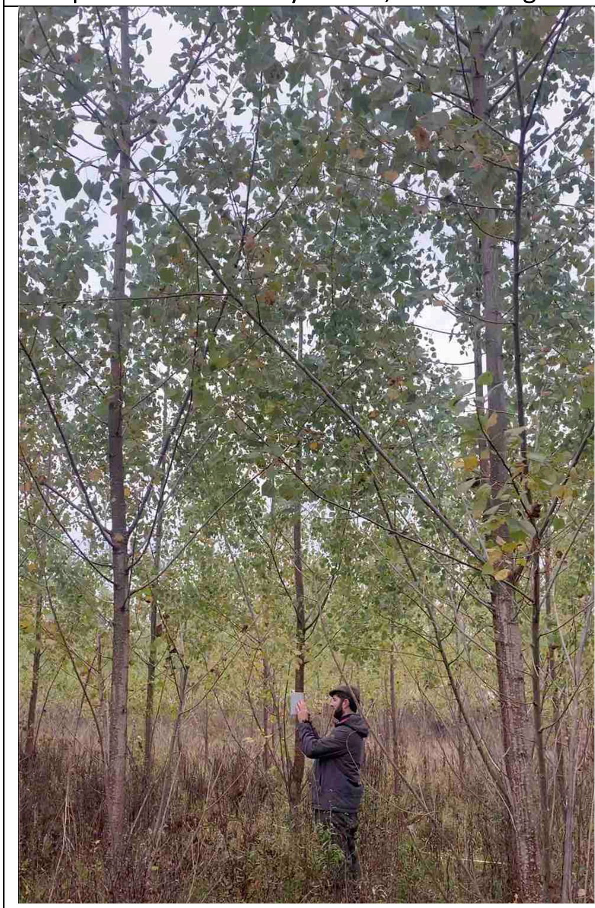
It is assumed that weed control (disking) can be performed at 6 ha/day area. Weed control (disking) costs are composed of 12 l diesel /h tractor fuel consumption (diesel price @ 1,5 eur/l), plus 150 eur / day / tractor driver wage, 200 eur /day tractor ((lease/maintenance) costs and 20% overhead costs. Total one-time costs for weed control (disking) are **100 eur/ha (*cells F29 and F30*)**.

**Overall first year poplar plantations establishment (land preparation, seedlings, planting, weed control) costs total 2600 eur /ha.**

## 3.5 Pruning costs

Pruning is necessary if poplars are established by long poles and are grown for higher quality roundwood in longer rotation. Poplars, established with long poles, usually start vegetation from a few buds, so the goal of pruning is to limit the growth of competing shoots, concentrating all the energy of the plant on the leading shoot. Such pruning should be done in the second year when the leading shoot reaches 1-1.5 years. (it is important that deer would not reach the upper bud) and if there is no high risk of browsing by moose. If the risk of moose browsing is high, pruning can be done in the third year.

**Picture 3-6. The beginning of the growth of long poles, Vilnius district**

| Not-pruned AF34 four year old, Moletai reg. | Pruned AF34 four year old, Moletai reg. |
| --- | --- |
|  |  |

Pruning of long poles is done in the following way:

- A diagonal cut cuts off the top of a long pole (usually dead) above the leading shoot so that the leading shoot can easily overgrow it to form a straight tree.
- Competing branches below the leading shoot are cut leaving 1/3 of their length (when pruning is carried out in the second year). If competing branches grow from the same bud as the leading shoot, they are removed right next to the tree stem, leaving only the leading shoot.
- When pruning is carried out in the third or fourth year, when trees reached a height of 6 meters or more, competing branches up to 2.5 meters high can be removed right next to the stem.

The second pruning to form stems for veneer logs is carried out in the seventh-ninth year, that is, after thinning, by removing branches near the stem at a height of up to 8 meters.

Pruning costs very much depend on the timing (how old are plantations) of pruning:

- When pruning is done at the end of first year of growth or beginning of the second year – pruning costs appr **150 eur/ha** – pruning of all 1600 trees/ha.
- When pruning is done at third year of growth or beginning of the fourth year – pruning costs appr **240 eur/ha (cell F33)–** but pruning is done only on each the second line, or 800 trees/ha.
- When pruning is done after thinning at year seven to ten – pruning costs appr **450 eur/ha (cell F34)** – and pruning is done on 700-800 trees/ha.

## 3.6 Fertilization

Poplar plantations, which are usually established on low productivity, nutrient deficient soils, can be fertilized with nutrient rich waste – sewage sludge digestate and biomass ashes, to increase biomass yields. Nutrient rich waste – sewage sludge digestate and biomass ashes – can be used for fertilization because poplars can act as phytoremediation crops, which absorb heavy metals and nutrients in more efficient way than agricultural crops. Nitrogen rich sewage sludge has an immediate effect on biomass yield improvement, while application of biomass has long term effect on soil improvement as nitrogen concentration in biomass ashes is negligent. It is estimated that fertilization with sewage sludge may increase biomass yield by **12-20% (cell F37).**

In Lithuania it is allowed to use **11 dmt/ha (cell F39)** row of sewage sludge and 1-3 t/ha of biomass ashes once in three year for fertilization of biomass plantations.

**Picture 3-7. Fertilization of poplar plantations with sewage sludge**

SSD and national regulation on MWTS application in agriculture/forestry requires costly comprehensive analysis of soil heavy metals of each 5 ha of area considered for fertilization. Additionally, national regulation, in case of application of MWTS in biomass plantations, require implementation of soil and water monitoring program.

Taking into account rates of reuse of DMWTSD in biomass plantations and soil sampling and analysis costs – it is estimated that initial soil analysis and water monitoring analysis cost about **2,75 eur/t** of DMWTSD applied in biomass plantations (calculated as heavy metal analysis in soil – 85 eur/5ha sample and sample collection 50 eur/5ha plus heavy metal and nutrient analysis in monitoring water – 110 eur/50ha sample and sample collection 50 eur/50ha adjusted for 11 t/ha application rate).

Transportation costs of DMWTSD are dependent, whether DMWTSD are supplied packed in big bags or unpacked in container. If DMWTSD is supplied packed in big-bags, transportation volume is about 14,6 t/truck (NutriBiomass4LIFE case) and the average price per truck is about 200 eur/truck or 13,7 eur/t. Additionally we have to add big-bag (1,5 cub m) costs – *6* eur/t. Thus, total transportation costs of DMWTSD packet in big bag costs are **19,7 eur/ha**.

Costs of DMWTSD spreading in the poplar field are composed of unloading, spreading and disking (insertion into soil) costs. It is assumed, that 74 t /day of DMWTSD can be reused for fertilization with one set of machinery (two tractors). Spreading costs are composed of 3,03 l diesel /t of DMWTSD recycled (diesel price @ 1,5 eur/l), plus 300 eur / day / two tractor drivers wages and 200 eur /day tractor ((lease/maintenance) costs. Total spreading in biomass field costs are **11,3 eur/t** DMWTSD.

**Overall costs for recycling of DMWTSD in biomass fields total about 33 eur /t DMWTSD, including soil analysis costs (cell F38). Two time per one rotation fertilization with DMWTSD is assumed to achieve 12% yield increment for poplars in 20 years. Fertilization is optional in the business plan calculations and not included in the basic scenario as current policy measures support incineration and it is not economically feasible to compete with incineration of sewage sludge.**

### 3.7 Management cost assumptions

There are some additional operational costs which can be considered as management costs. Management costs include visiting and supervision of plantations, IFCC certification costs, etc. Management costs are assumed @ **20/eur ha annually (cell F42).**

## 4 Revenue assumptions

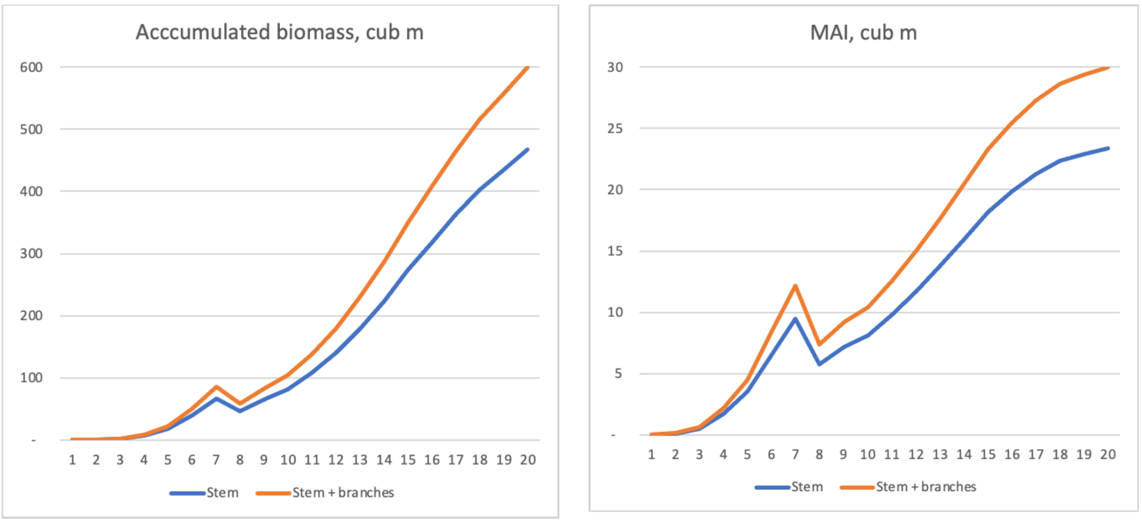
Established poplar plantations for 20 year rotation can become a significant roundwood resource. Potential buyers for poplar roundwood will be:

- IKEA plant at Kazlu Ruda, which produces particleboard for furniture industry;
- New Homanit panel mill near Vilnius, which starts MDF and HDF production for furniture and construction industries at the beginning of 2024;
- Sodra Morrum pulp mill (South of Sweden), which produces textile fiber – poplars are perfect material for textile fiber production;
- VMG group – bended plywood furniture production mill near Klaipeda and new LVL mill in Akmene. The company expresses interest to use poplars for bended plywood furniture production, while poplar veneer usage for LVL production has to be tested.
- Plywood producer – Likmere mill in Ukmerge – currently veneer from poplars is not produced at Likmere mill, as there is huge demand for birch plywood but in future this may change when raw material will be available at sufficient quantities.

### 4.1 Biomass yield assumptions

Biomass yield is based on the poplar yield model developed by SLU, for 20-year-old poplars (OP42 clone), planted in Southern Sweden. This model assumes poplar yield unfertilized. According to initial Lithuanian data (4-year-old) under Lithuanian conditions poplars grow faster, but we lack long term data for the model. It is assumed that unfertilized poplar biomass will reach 31 cub m MAI in 20 year and will accumulate 650 cub. m. in 20 years (including 50 cub m thinning harvesting).

**Picture 4-1. Poplar yield (unfertilized) curve**




## 4.2 Net revenues from biomass sales

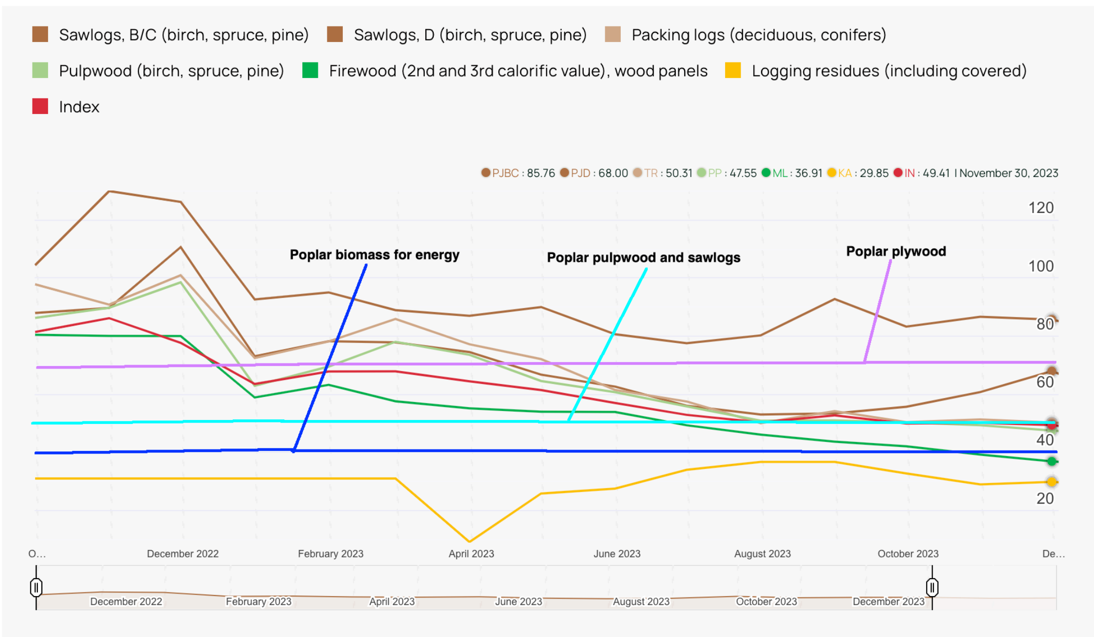
Poplar wood sales prices in the financial model are provided net, for standing wood, which are calculated as gross prices at the roadside minus harvesting and forwarding costs.

### 4.2.1 Poplar wood gross revenue assumptions

The prices of wood experienced significant fluctuations over recent years. Business model of poplars are based on current wood prices on the road side (gross prices) and expected mix of output:

- 40% roundwood is assumed to be sold as pulpwood and sawlogs @ **50 eur/cub. m**
- 60 % of roundwood is assumed to be sold as veneer logs @ **70 eur/cub. m**
- Branches and tops will consist 28,2% of total roundwood and is assumed to be sold as energy wood @ **46 eur/cub. m.**

**Picture 4-2. Assumed poplar roadside prices comparing to wood exchange prices at Baltpool (EUR/cub m)**



### 4.2.2 Thinning and final harvesting cost assumptions

NutriBiomass4LIFE plantations, established at 1600 plants/ha density will have to be thinned at 6-9th year of growth.

If plantations are grown for a 20-year rotation to produce high value veneer logs, it is reasonable to have no more than 600 trees in the plantation during the final felling.

Thinning is done by harvesting each the second row of poplars with light excavator ant mounted tree shear to it, which collects and loads harvested trees near remaining rows of poplars. This allows to collect and forward harvested biomass with light forestry trailers. Light machinery is preferably to be used for harvesting and thinning in order to avoid poplar root damage and soil compaction.

**Picture 4-3. Thinning at age of 7 years (AF7 clone), Vilnius region.**


Poplar biomass harvested during thinning can be used for energy chip production or as roundwood in wood panel production.

**Picture 4-4. Poplar thinning biomass**

Thinning costs consist of poplar harvesting and forwarding to the road-side costs. In winter 2022/2023 poplar thinning was performed by the contractor at a price **16 eur/cub m**, which included both harvesting and transportation to the roadside services.

It is calculated that thinning-harvesting can be performed with light excavator ant mounted tree shear at 70 cub m/day harvesting output. Poplar thinning-harvesting costs are composed of 10 l diesel /h of light excavator fuel consumption (diesel price @ 1,5 eur/l), plus 150 eur / day / light excavator driver wage, 200 eur /day light excavator ((lease/maintenance) costs and 20% overhead costs. Total thinning-harvesting costs are **7,7 eur/cub m**.

It is calculated that biomass transportation to the roadside costs are based at 65 cub m/day transportation to the roadside volume. Poplar transportation to the roadside costs are composed of 7 l diesel /h tractor consumption (diesel price @ 1,5 eur/l), plus 150 eur / day / tractor driver wage, 200 eur /day tractor ((lease/maintenance) costs and 20% overhead costs. Total transportation of biomass to road -side costs are **8,3 eur/cub m**.

Total thinning (including forwarding to the roadside) costs are **16 eur/cub m**.

Final harvesting costs of poplars are lower than of thinning and are compatible to forest clean cutting as traditional forest harvesting machines are used. Final forest clean cutting and transportation to the roadside cost appr. **12 eur/cub m**, taking into account that poplars are more uniform and typically with lower transportation distances to the roadside, it is assumed that final poplar harvesting costs will be **10 eur/cub m.**

### 4.2.3 Biomass net revenue assumptions

Poplar wood sales prices in the financial model are assumed net, for standing wood, which are calculated as gross prices at the roadside minus harvesting and forwarding costs:

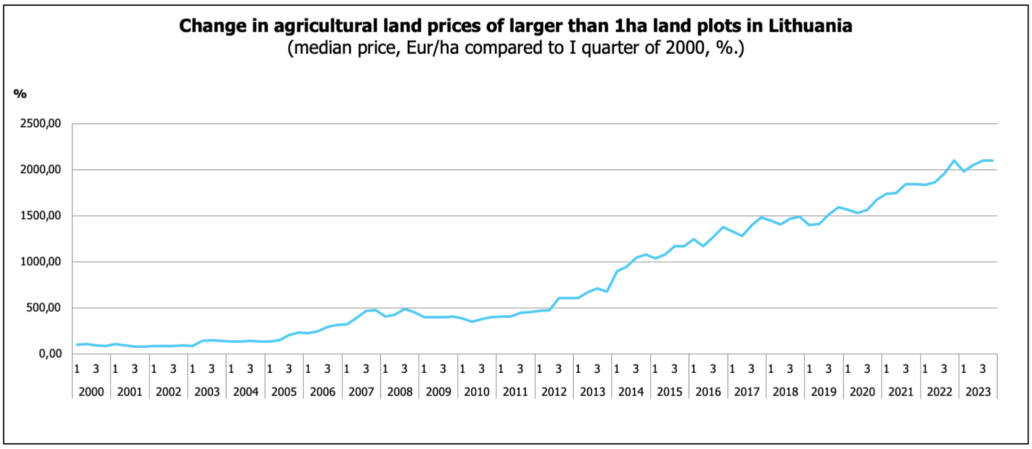
- For pulpwood and sawlogs - **40 eur/cub. m (cell F58)**
- For veneer logs - **60 eur/cub. m (cell F59)**
- For branches and tops (energy wood) - **30 eur/cub. m (cell F57 and F60).**

## 4.3 Land value appreciation assumptions

Land value is the most substantial investment for poplar plantation establishment. If we take 20 year horizon, investment into land depreciates substantially when we discount it, therefore land appreciation value has to be assumed.

In Lithuania agricultural land prices experienced significant increase – compared to I quarter of 2000, at the end of 2023 agricultural land prices increased 2100%, or 13,5% annually. The agricultural land value appreciation can be noticed even over last ten years -- compared to I quarter of 2014, at the end of 2023 agricultural land prices increased 233%, or 9% annually.

**Picture 4-5. Change in agricultural land prices of larger than 1ha land plots in Lithuania**



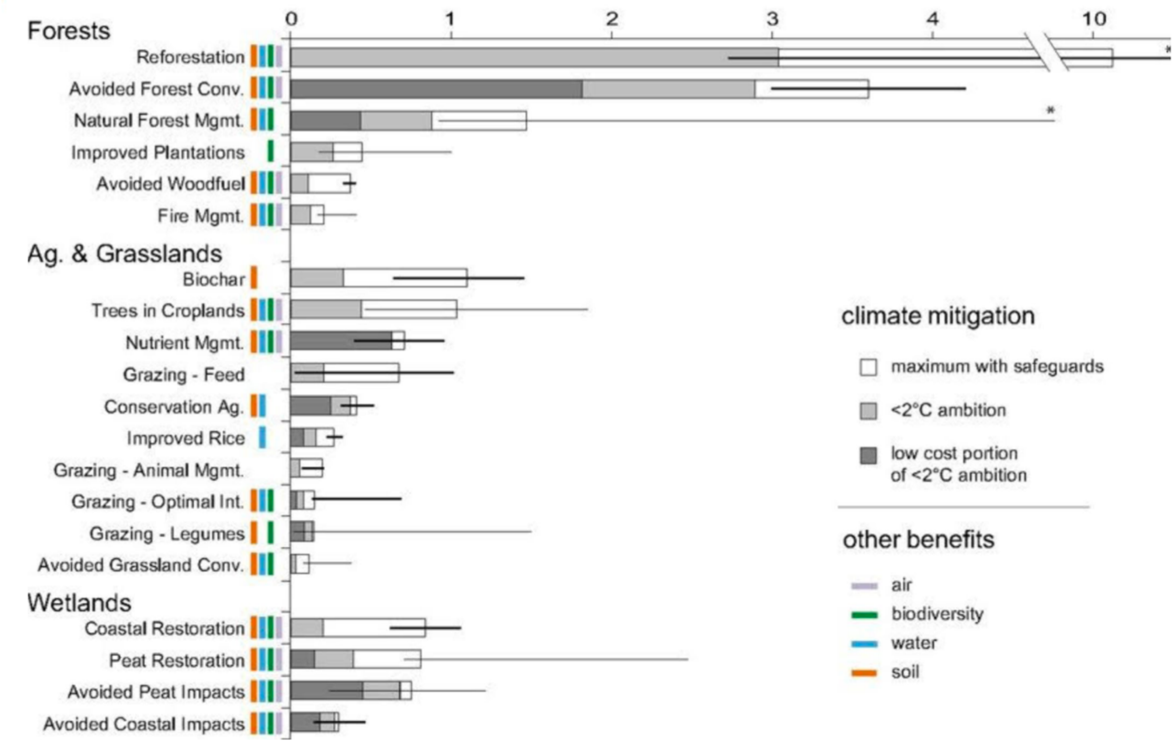

Despite significant historic agricultural land value appreciation in Lithuania and more than 2 times lower price than EU average, we assume conservative **3% annual land value** appreciation in the next 20 years **(cell F63).**

## 4.4 Revenues from $CO_2$ removal

Forest have been always perceived as perfect nature based carbon sink which is easy to understand, easy to measure and observe by carbon buyers, therefore forest based carbon credits have for a long time most favored by the markets. The absolute majority of forest related carbon credits have been associated with Reducing Emissions from Deforestation and Forest Degradation (REDD) projects, which are implemented in developing markets. Other Forest instruments that are getting their way in developed markets include ARR (afforestation and reforestation) and IFM (improved forest management.

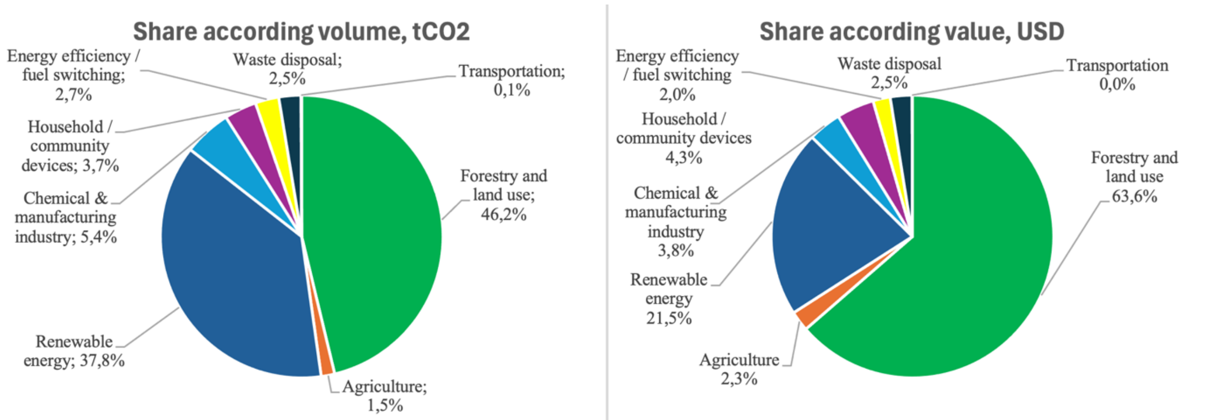
It s estimated that overall nature based climate solutions globally in 2030 may have PgCO2e yr-1 i.e. up to 30% of global emissions mitigation potential that has to ensure <2C degree ambition. Out of all nature based solutions forest are undoubtfully key climate mitigation instrument.

**Picture 4-6. Climate change mitigation potential in 2030 (PgCO2e yr-1)**




Voluntary carbon markets can play a pivotal role bridging the gap of funding to utilize climate change mitigation potential. Voluntary carbon market value already reached 2 billion USD in 2022 and in order to meet <2C degree climate change ambition it is expected to raise to 1 trillion USD in 2050. Besides social motivation to combat climate change, the key drivers for rapid development of voluntary carbon markets are related to legal and voluntary disclosure obligation of businesses through CSRD, SFDR, CDR other reporting standard implementation.

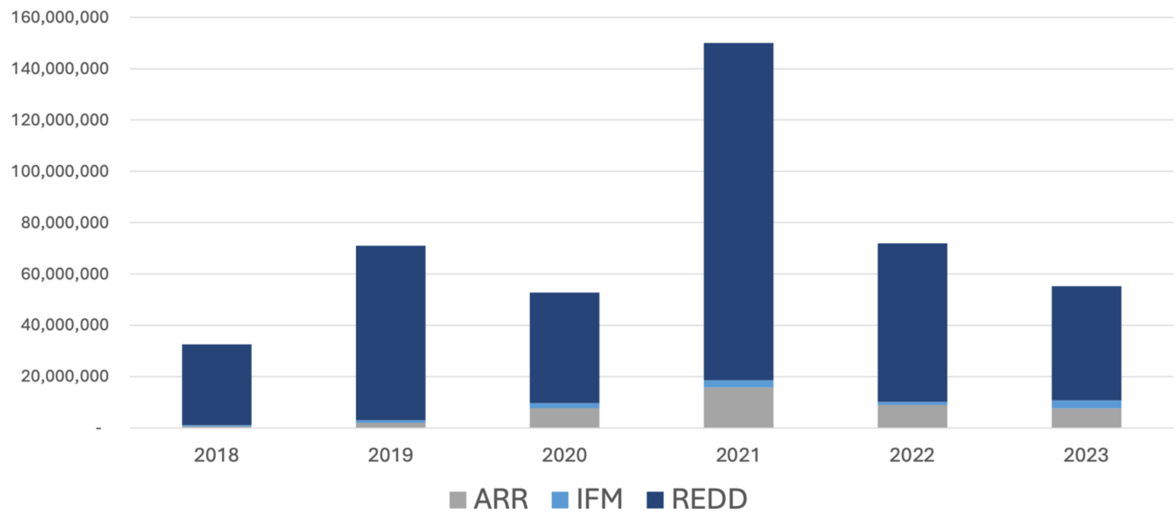
**Picture 4-7. Voluntary carbon credits share according sources in 2023**




Forest based voluntary carbon credits in 2022 had 46,2% in global VCC volume and even higher share in the value – 63,3%, because all nature based VCC were priced the highest.

Among Forest based VCC, REDD based VCC strongly prevailed, but new tools such ARR and IFM are picking up as well. Especially strong growth is in afforestation VCCs, while improved forest management still at a low level because methodologies are still under development. As biodiversity issues are getting more attention it can be expected that conservation forestry (IFM) VCCs will be on the rise.

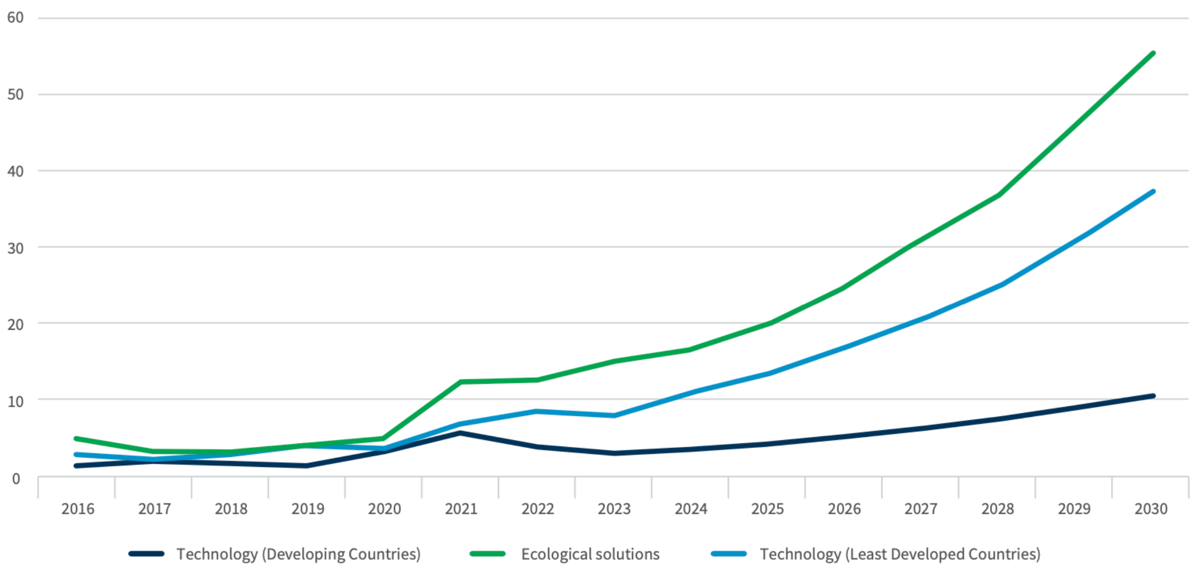
**Picture 4-8. Forest VCC issuance according to different forest measures**




Till 2020 global VCC market was dominated by oversupply, but starting 2021 when demand increased several times, the amount of VVC not yet redeemed is diminishing each year.

Strong fundamentals of growing corporate demand, combined with new regulations and standards that will make it harder to generate carbon credits, will flip market conditions from oversupplied to undersupplied in the near term. This would put significant upward pressure on prices, especially for nature-based credits, some of which will be generated in the developed countries.

**Picture 4-9. VCC price forecast, tCO2e(USD)**



Poplar plantations are the most efficient and powerful carbon removal tool in agriculture, when calculating carbon removals. Poplar growing on agricultural land as $CO_2$ removal activities may come to assist businesses to achieve their carbon neutrality goals, especially related to their scope three emissions, which contribute to 25% of total global $CO_2$ emissions.

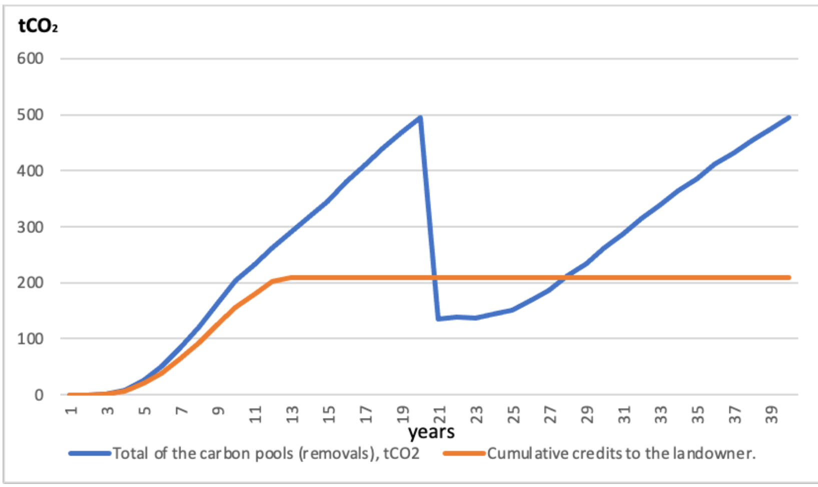
Today exist several global possibilities to benefit from carbon removal activities and issue of carbon credits, associated with afforestation, including establishment of longer-term rotation poplar plantations. The most globally recognized and reliable carbon removal certification schemes include VERRA, Gold Standard, American Carbon Registry, Climate Action Reserve and Cercarbono.

In 2023 EU Commission came with Carbon Removal Certification Framework (CRCF) proposal, which targets to regulate carbon removal activities on the EU level and potentially open possibilities to businesses/farmers/forest owners to cash out from carbon removal activities. Although CRCF include carbon farming activities, still it is not yet clear whether when and how it will be engaged and how tree growers could benefit that.

Nevertheless, today poplar plantation growers may benefit from global carbon removal practices by joining VERRA or Gold Standard certification schemes through intermediaries under the following conditions:

- Poplars are newly established and grown for rotations not shorter than 20 years.
- At least two rotations of poplars have to be grown – meaning that total tree growth duration on agricultural land should be not shorter than 40 years.
- 10% of generated carbon credits are transferred to intermediary, which develops certified carbon credit project and covers all costs for project development and carbon credit validation – meaning landowner, which establishes poplars, does not need to incur any upfront project development and other carbon issue costs.
- Poplar plantations over the first 13 years can generate to landowner 210 carbon credits (after buffer and intermediaries commissions) without counting SOC increase.
- The price for carbon removal is assumed at 30 eur/t $CO_2$. **(cell F75)**

**Picture 4-10. Carbon credit calculations for poplar plantations based on VERA methodology**



## 5 Financial result

Poplar plantation establishment has a long economic horizon (20-year rotation). The absolute majority of investment (land and poplar plantations establishment) typically are incurred at the beginning of the cycle, while major revenues from biomass sales can be expected at the end of the cycle - after 20 years only. Additional revenues can be expected from carbon removal – sales of carbon credits, which in 13 years can compensate poplar plantations establishment costs.

**Overall costs for establishment of poplar plantation is about 2700 eur/ha.** Much higher investment are related to the land itself, e.g. in Lithuania's case – 4000 eur/ha. Financial calculations show that poplar plantation establishment business case can generate about **9,3% of internal rate of return (IRR)** considering land investment as well. Additional revenues from $CO_2$ removal (sale of carbon credits) can improve profitability of poplar growing business case to achieve **12,3 % internal rate of return (IRR) and 2719 eur/ha net present value (NPV @ 9,5% discount rate).**

Financial calculations show that investment into poplar plantation establishment and carbon removal can generate sound return to investors. Despite high IRR, such an investment is not highly attractive by farmers as poplar establishment cannot ensure stable annual revenues and the major revenues still are expected in 20 years. Nevertheless, poplar plantation establishment investment may be very attractive investment opportunity for long term institutional investment as this offer green and carbon removal investment. Such an investment is also may be interesting to landowners (especially younger ones who inherited land), who live in cities and agriculture is not their major activity, but who are interested in making climate beneficial investment. Such an investment is in particular interesting for landowners who already own land and doe not use it or get insignificant revenues from land lease. But the limiting factor for such investors may be significant investment of 2700 eur/ha in poplar plantation establishment as banks in Lithuania still do not provide long term funding for carbon removal activities, such as establishment of trees.

It is estimated that fertilization with dry sewage sludge digestate if landowners compensate all transportation and spreading of DMWTSD costs (i.e. 33 eur/ha) additionally can increase **IRR by +0,3%** or generate **463 eur/ha NPV @ 9,5% discount rate.**

**Pay-back** of the investment is long as it is related with long biological cycle of tree growth and investment in the infinite value of asset – land. Estimates simple payback of the basic scenario is **13 year**s, while discounted – is **20 years** (full one cycle).

**Break-even point** (discounted NPV=0), calculated on the basis of MAI (mean annual increment of 20 year cycle) is MAI (stem, 20 years) – **15,7 cub m /ha**, or MAI (total biomass, 20 years) - **20,1 cub m /ha**

## 6 Sensitivity analysis

The basic business case is calculated for scenario for land acquisition, including carbon removal revenues, not-fertilized with DMWTSD and with pruning for veneer logs.

Sensitivity scenarios of the business case are calculated for the following scenarios:

- Land acquisition vs. land rent
- Carbon removal revenues vs. no carbon removal revenues

- Pruning for veneer logs vs. no pruning
- Not-fertilized vs. fertilized with dry sewage sludge digestate

## 6.1 Land acquisition vs. land rent

Land rent is much more financially favourable scenario comparing to land acquisition because the ratio of land rent to land acquisition price is much lower comparing to discount rate used. Comparing to the basic scenario land vs. land acquisition scenario provides substantial +3,1% increase in IRR and 714 eur/ha increase in NPV.

The reason, why land rent scenario is not a basic scenario is that long term land rent in Lithuania (20 year duration) is hardly available, particularly for planting of trees. Additionally, in case of land rent scenario total 40 year commitment from land lessor is required if carbon removal revenues are considered – either 40 land rent period or 20 year land rent period plus 20 year additional commitment from land lessor to grow second rotation of poplars.

The financial results of **land rent** + carbon credits + veneer logs + no-fertilization scenario are as follows:

- IRR = 15,4%
- NPV (discounted 9,5%) = 3433 eur/ha
- Simple payback - 9 years
- Discounted (9,5%) payback – 20 years
- Break-even point (discounted 9,5%): MAI (stem, 20 years) – 13,7 cub m /ha, or MAI (total biomass, 20 years) - 17,6 cub m /ha.

## 6.2 Carbon removal revenues vs. no carbon removal revenues

Carbon removal revenues add significant cash flows to the business model of poplar growing and even that is a strong precondition for profitable investment into tree growing. Comparing to the basic scenario elimination of carbon revenues scenario has lover IRR by -3 % in and lower NPV by minus 2902 eur/ha.

The financial results of land acquisition + **no-carbon credits** + veneer logs + no-fertilization scenario are as follows:

- IRR = 9,3%
- NPV (discounted 9,5%) = - 183 eur/ha
- Simple payback - 20 years
- Discounted (9,5%) payback – N.A.
- Break-even point (discounted 9,5%): MAI (stem, 20 years) – 24,2 cub m /ha, or MAI (total biomass, 20 years) - 31,1 cub m /ha.

## 6.3 Pruning for veneer logs vs. no pruning

Pruning of poplars may provide much higher value roundwood products, such as veneer logs. Comparing to the basic scenario elimination of pruning costs and veneer log production scenario has lover IRR by -0,3 % in and lower NPV by minus 549 eur/ha.

Actual value of veneer log production scenario may be even higher because of higher process of veneer logs. The higher discount on veneer logs is applied because there is no poplar veneer producer in the region and veneer logs will have to be exported to southern European market. Alternatively local birch veneer producers may try to adjust their production capacities or poplar veneer may be used in local plywood furniture production.

The financial results of land acquisition + carbon credits + **no veneer logs** + no-fertilization scenario are as follows:

- IRR = 11,9%
- NPV (discounted 9,5%) = 2170 eur/ha
- Simple payback - 12 years
- Discounted (9,5%) payback – 20 years
- Break-even point (discounted 9,5%): MAI (stem, 20 years) – 16,5 cub m /ha, or MAI (total biomass, 20 years) - 21,2 cub m /ha.

## 6.4 Not-fertilized vs. fertilized with dry sewage sludge digestate

Fertilization with DMWTSD may increase biomass yield by 12%-20%. For the basic scenario it is assumed poplar yield will increase by 12% at the end of 20 years if plantation is fertilized two times per rotation. Comparing to the basic no-fertilization scenario land, fertilization scenario land scenario provides +0,3% increase in IRR and 416 eur/ha increase in NPV.

The financial results of land acquisition + carbon credits + veneer logs + fertilization scenario have the following financial results:

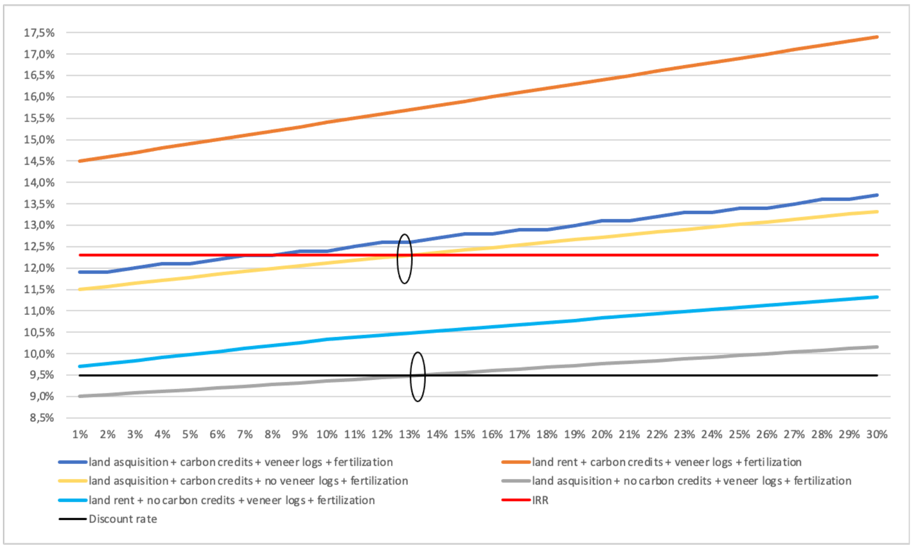
- IRR = 12,6%
- NPV (discounted 9,5%) = 3182 eur/ha
- Simple payback - 12 years
- Discounted (9,5%) payback – 20 years
- Break-even point (discounted 9,5%): MAI (stem, 20 years) – 17 cub m /ha, or MAI (total biomass, 20 years) - 21,8 cub m /ha.

Land acquisition + carbon credits + veneer logs + fertilization scenario is based on the assumption, that poplar growers assume all the fertilization costs by themselves – 33 eur/dmt of DMWTSD, what include full compensation of transportation and spreading costs. This is the scenario today many waste water treatment plants are offered by cement producer for DMWTSD incineration. Cement plants incinerating sewage sludge do not pay CO2 taxes and additionally receive free Emission allowances therefore cement producers have large profitability gap even to start paying for DMWTSD acquisition.

Financial results of poplar plantation fertilization with DMWTSD heavily depends upon biomass yield improvement. Results received from three-year fertilization trial during implementation of NutriBiomass4LIFE project showed 12% biomass yield improvement and that poplar biomass yield improvement tend to decrease over time, therefor it has to be repeated.

Break-even analysis (based on fertilized biomass yield improvement) shows that fertilization and yield improvement may increase returns, where in case of land rent scenario +1% change in biomass yield improvement due to fertilization improves IRR by +0,08%, while in case of land acquisition scenario +1% change in biomass yield improvement due to fertilization improves IRR by +0,04%.

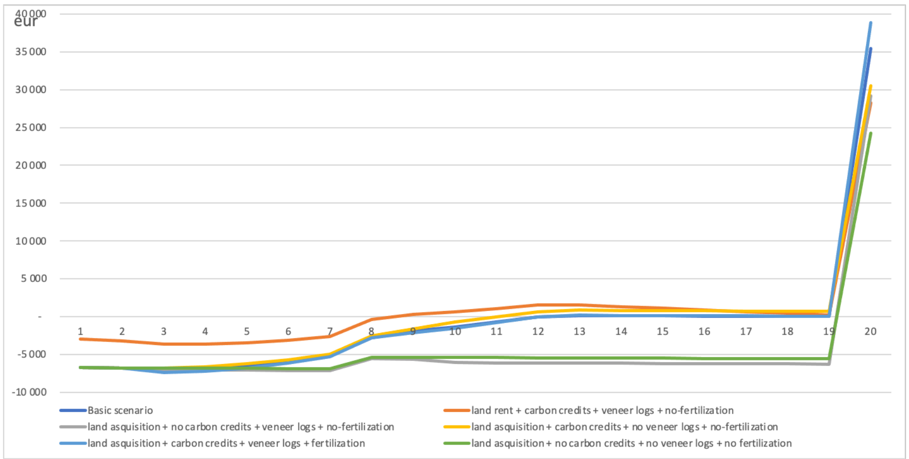
**Picture 6-1. Break-even point based of biomass yield improvement while fertilizing with DMWTSD**




## 6.5 Scenario comparison

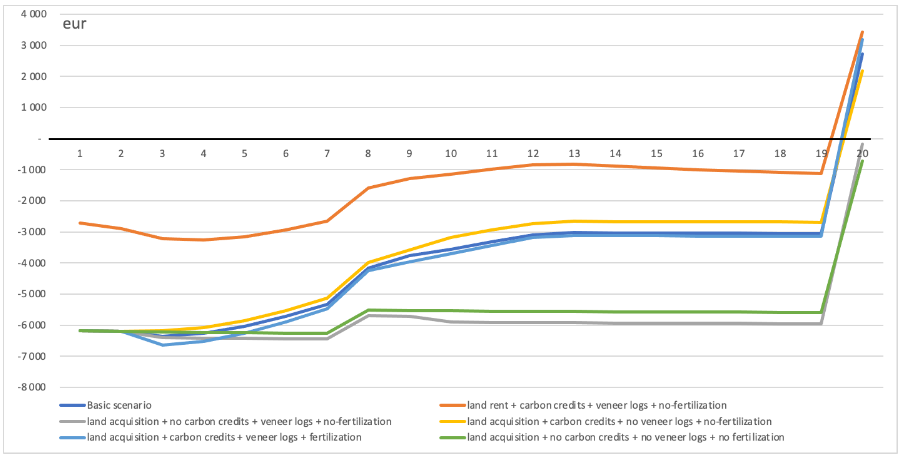
Simple pay back is ensured for all business scenarios. For all scenarios simple payback is ensured in 8-13 years if carbon removal revenues are considered. This shows the importance of carbon revenues for profitability on any business case.

**Picture 6-2. Simple payback (accumulated cashflows) of different scenarios**




Discounted (9,5%) pay back can be achieved only in 20 years, after revenues are generated from final harvesting.

**Picture 6-3. Discounted (9,5%) payback of different scenarios**




Analysis shows that the highest return is expected in case of **land rent** + carbon credits + veneer logs + fertilization scenario implementation, while the lowest return is expected in case of **land acquisition** + no carbon credits + no veneer logs + no fertilization scenario implementation. The highest profitability increase can be achieved by switching from land acquisition to land rent and engaging carbon removal revenues.

**Table 6-1. Scenario ranking**

| ranking | Scenario | IRR | NPV (@9,5%), eur/ha |
|---|---|---|---|
| 1 | land rent + carbon credits + veneer logs + fertilization | 15,6% | 3897 |
| 2 | land rent + carbon credits + veneer logs + no-fertilization | 15,4% | 3433 |
| 3 | land acquisition + carbon credits + veneer logs + fertilization | 12,6% | 3182 |
| **4** | **Basic scenario (land acquisition + carbon credits + veneer logs + no-fertilization )** | **12,3%** | **2719** |
| 5 | land acquisition + carbon credits + no veneer logs + no-fertilization | 11,9% | 2170 |
| 6 | land acquisition + no carbon credits + veneer logs + no-fertilization | 9,3% | -183 |
| 7 | land acquisition + no carbon credits + no veneer logs + no fertilization | 8,7% | -731 |

# 7 Comparison of investments into other geographic markets

Investment scenarios of different Baltic region countries (Lithuania, Latvia and Sweden) in terms of cost and revenue assumptions are very similar with the most variation in land prices. Grassland prices are compared while evaluating investment scenarios in different countries.

Considering returns of basic scenario in different geographic markets, Latvia is ranked in the first place, followed by Lithuania and Sweden. In different Swedish regions there are substantial differences in grassland prices, e.g. in such Swedish regions, which may be suitable for Snowtiger poplar establishment, grassland prices (2022) are the lowest in the whole EU: Mellersta Norrland (997 eur/ha) and Övre Norrland (611 eur/ha). Therefore, investment into Swedish market may be financially beneficial, taking into account that differently form Lithuanian and Latvian markets banking financing for investment into land and plantation establishment may be available.

**Table 7-1. Geographic market rankings**

| ranking | Basic scenario (land acquisition + carbon credits + veneer logs + no-fertilization ) | IRR | NPV (@9,5%), eur/ha |
|---|---|---|---|
| 1 | Latvia (grassland price 3000 eur/ha) | 13,3% | 3338 |
| **2** | Lithuania (land price 4000 eur/ha) | **12,3%** | **2719** |
| 3 | Sweden (grassland price 4400 eur/ha) | 11,9% | 2471 |

## Conclusions

The key lessons we learned from business planning (B4) during NutriBiomass4LIFE project implementation:

- Business of woody biomass growing on agricultural land is not an easy choice for landowners and farmers, despite expected financial return, lucrative contribution to climate change mitigation and other environmental goals – the key constraint, very long-term investment horizon, where significant investment have to be made at the beginning of the business cycle, while revenues from harvested biomass can be expected in very long term.
- Business case of poplar growing for longer rotation – for industrial roundwood production - has a stronger financial and environmental return comparing to energy use wood production only. Carbon removal revenues, if available, can provide incentive for planting and farming of trees on agricultural land.
- The key success factors for hybrid poplar plantation establishment are water availability, suitable soil, selection of suitable clones and good establishment and weed management in the first year.
- Overall costs for establishment of poplar plantation is about 2700 eur/ha. Much higher investment are related to the land itself, e.g. in Lithuania's case – 4000 eur/ha.
- Financial calculations show that poplar plantation establishment case can generate about 9,3% of internal rate of return (IRR) considering land investment as well. Additional revenues from $CO^2$ removal (sale of carbon credits) can improve profitability of poplar growing business case to achieve 12,3 % internal rate of return (IRR) and 2719 eur/ha net present value (NPV @ 9,5% discount rate).
- The highest financial return can be achieved by switching from land acquisition to land rent scenario and engaging carbon removal revenues. Minor improvements are expected due to producing higher grade veneer logs and fertilization with DMWTSD.
- Business of nutrient rich waste recycling/reusage in biomass plantations is under heavy pressure of unbalanced policies, which give a clear preference for nutrient rich waste (sewage sludge) incineration over reusage. Fertilization with DMWTSD scenario is not included in the basic business case scenario as in Lithuania due to unfavourable to circular economy policy all dry sewage sludge digestate switched towards incineration while in Latvia and Sweden production of DMWTSD is negligent.
- Fertilization with DMWTSD may increase biomass yield by 12%-20%. Comparing to the basic no-fertilization scenario, fertilization scenario scenario provides +0,3% increase in IRR and 416 eur/ha increase in NPV.
- The highest return from all business scenarios can be expected in case of land rent + carbon credits + veneer logs + fertilization scenario implementation, while the lowest return is

expected in case of land acquisition + no carbon credits + no veneer logs + no fertilization scenario implementation.

- Investment returns from poplar plantation establishment in the Baltic sea region are quite similar, differences primary determined by variation in land prices, which are the lowest in Latvia, followed by Lithuania and Sweden.

## Appendix – Biomass plantation establishment financial model

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **YEARS** | | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **TOTALS** |
| **INVESTMENTS AND COSTS** | | | | | | | | | | | | | | | | | | | | | | | | |
| Poplar establishment area, net | ha | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Establishment density | seedlings/ha | 1600 | | | | | | | | | | | | | | | | | | | | | | 1 600 |
| Type of seedlings | | **Long poles** | | | | | | | | | | | | | | | | | | | | | | |
| Land costs | | | | | | | | | | | | | | | | | | | | | | | | |
| Land acquisition price | eur/ha | YES | 4000 | 4000 | | | | | | | | | | | | | | | | | | | | 4 000 |
| Brokerage costs | eur/ha | | 150 | 150 | | | | | | | | | | | | | | | | | | | | 150 |
| Land tax | eur/ha | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 20 |
| Land lease | eur/ha | NO | 200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| Land preparation costs | | | | | | | | | | | | | | | | | | | | | | | | |
| Weed disking before ploughing | eur/ha | NO | 100 | 0 | | | | | | | | | | | | | | | | | | | | |
| Ploughing | eur/ha | | 200 | 200 | | | | | | | | | | | | | | | | | | | | 200 |
| Cultivation / disking | eur/ha | | 100 | 100 | | | | | | | | | | | | | | | | | | | | 100 |
| Establishment costs | | | | | | | | | | | | | | | | | | | | | | | | |
| Seedling costs | eur/seedling | | 1,1 | 1760 | | | | | | | | | | | | | | | | | | | | 1 760 |
| Planting costs | eur/ha | | 440 | 440 | | | | | | | | | | | | | | | | | | | | 440 |
| Weed control | | | | | | | | | | | | | | | | | | | | | | | | |
| First year disking | eur/ha | | 100 | 100 | | | | | | | | | | | | | | | | | | | | 100 |
| Second year disking | eur/ha | NO | 100 | | 0 | | | | | | | | | | | | | | | | | | | - |
| Pruning | | YES | | | | | | | | | | | | | | | | | | | | | | |
| First pruning (year 3-4) | eur/tree | | 240 | | | 240 | | | | | | | | | | | | | | | | | | 240 |
| Second pruning (year 10) | eur/tree | | 450 | | | | | | | | | | 450 | | | | | | | | | | | 450 |
| Fertilization with sewage sludge digestate | | NO | | | | | | | | | | | | | | | | | | | | | | |
| Increase in yield due to fertilization | | | 12% | | | | | | | | | | | | | | | | | | | | | |
| Fertilization price | eur/t | | 33 | | | | | | | | | | | | | | | | | | | | | |
| Fertilization rate | t/ha | | 11 | | | | | | | | | | | | | | | | | | | | | |
| Fertilization costs | eur/ha | | 363 | | | 0 | | | | | | 0 | | | | | | | | | | | | - |
| Management costs | eur/ha | YES | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 400 |
| **TOTAL COSTS** | | | | **6771** | **21** | **261** | **21** | **21** | **21** | **21** | **21** | **21** | **471** | **21** | **21** | **21** | **21** | **21** | **21** | **21** | **21** | **21** | **21** | **7 860** |
| **YIELD** | | | | | | | | | | | | | | | | | | | | | | | | |
| Yield of stem | cub m/ tree | | | 0,0000 | 0,0001 | 0,0009 | 0,0043 | 0,0110 | 0,0245 | 0,0415 | 0,0612 | 0,0862 | 0,1081 | 0,1441 | 0,1874 | 0,2384 | 0,2977 | 0,3632 | 0,4239 | 0,4824 | 0,5362 | 0,5804 | 0,6230 | 0,6230 |
| Yield of branches and tops | cub m/ tree | | 0,282 | 0,0000 | 0,0000 | 0,0003 | 0,0012 | 0,0031 | 0,0069 | 0,0117 | 0,0173 | 0,0243 | 0,0305 | 0,0406 | 0,0528 | 0,0672 | 0,0840 | 0,1024 | 0,1195 | 0,1360 | 0,1512 | 0,1637 | 0,1757 | 0,1757 |
| Number of trees | trees/ha | | | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 |
| Total yield adjustment | Change to basic scenario | | 0% | | | | | | | | | | | | | | | | | | | | | |
| Accumulated yield of stem | cub m/ha/year | | | 0,0 | 0,2 | 1,5 | 6,9 | 17,5 | 39,1 | 66,4 | 45,9 | 64,6 | 81,1 | 108,1 | 140,5 | 178,8 | 223,3 | 272,4 | 317,9 | 361,8 | 402,2 | 435,3 | 467,3 | 467,3 |
| MAI, stem | cub m/ha/year | | | 0,0 | 0,1 | 0,5 | 1,7 | 3,5 | 6,5 | 9,5 | 5,7 | 7,2 | 8,1 | 9,8 | 11,7 | 13,8 | 16,0 | 18,2 | 19,9 | 21,3 | 22,3 | 22,9 | 23,4 | 23,4 |
| Accumulated yield of tops and branches | cub m/ha/year | | | 0,0 | 0,1 | 0,4 | 1,9 | 4,9 | 11,0 | 18,7 | 12,9 | 18,2 | 22,9 | 30,5 | 39,6 | 50,4 | 63,0 | 76,8 | 89,7 | 102,0 | 113,4 | 122,7 | 131,8 | 131,8 |
| Accumulated total yield | cub m/ha/year | | | 0,0 | 0,3 | 1,9 | 8,9 | 22,5 | 50,2 | 85,2 | 58,8 | 82,9 | 104,0 | 138,6 | 180,1 | 229,2 | 286,3 | 349,2 | 407,6 | 463,8 | 515,6 | 558,0 | 599,0 | 599,0 |
| MAI, total | cub m/ha/year | | | 0,0 | 0,2 | 0,6 | 2,2 | 4,5 | 8,4 | 12,2 | 7,4 | 9,2 | 10,4 | 12,6 | 15,0 | 17,6 | 20,4 | 23,3 | 25,5 | 27,3 | 28,6 | 29,4 | 30,0 | 30,0 |

| YEARS | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SALES REVENUES** | | | | | | | | | | | | | | | | | | | | | | | | |
| Thinning | eur/cub m | | 30 | | - | - | - | - | - | - | 1 560 | - | - | - | - | - | - | - | - | - | - | - | - | 1 560 |
| Final harvesting, sawlogs | eur/cub m | 40% | 40 | | | | | | | | | | | | | | | | | | | | 7 476 | 7 476 |
| Final harvesting, veneer logs | eur/cub m | 60% | 60 | | | | | | | | | | | | | | | | | | | | 16 822 | 16 822 |
| Final harvesting, energy biomass | eur/cub m | | 30 | | | | | | | | | | | | | | | | | | | | 3 953 | 3 953 |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| **Land value appreciation** | % | | 3% | 4 120 | 4 244 | 4 371 | 4 502 | 4 637 | 4 776 | 4 919 | 5 067 | 5 219 | 5 376 | 5 537 | 5 703 | 5 874 | 6 050 | 6 232 | 6 419 | 6 611 | 6 810 | 7 014 | 7 224 | 7 224 |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| **CARBON CREDITS** | | YES | | | | | | | | | | | | | | | | | | | | | | |
| BGM and ABG ratio | | | 0,20 | | | | | | | | | | | | | | | | | | | | | |
| Wood density | | | 0,35 | | | | | | | | | | | | | | | | | | | | | |
| dmt/C ratio | | | 0,47 | | | | | | | | | | | | | | | | | | | | | |
| C/co2 ratio | | | 3,67 | | | | | | | | | | | | | | | | | | | | | |
| CO2 sequestrated in poplar plantation | tCO2/ha | | | 0 | 0 | 1 | 6 | 16 | 36 | 62 | 43 | 60 | 75 | 100 | 130 | 166 | 207 | 253 | 295 | 336 | 373 | 404 | 434 | 434 |
| Number of carbon credits sold after buffer (10%) and Ecobase comissions | number | | | | 0 | 1,3 | 5,7 | 12,6 | 19,5 | 25 | 28,9 | 31,3 | 32,5 | 22,5 | 22,4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 210 |
| Carbon credit price/revenues | eur/tCO2 | | 30 | | - | 39 | 171 | 378 | 585 | 750 | 867 | 939 | 975 | 675 | 672 | 240 | - | - | - | - | - | - | - | 6 291 |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| Simple cash flows of the period | | | | -6 771 | -21 | -222 | 150 | 357 | 564 | 729 | 2 406 | 918 | 504 | 654 | 651 | 219 | -21 | -21 | -21 | -21 | -21 | -21 | 35 455 | 35 467 |
| Accumulated simple cash flows | | | | -6 771 | -6 792 | -7 014 | -6 864 | -6 507 | -5 943 | -5 214 | -2 808 | -1 890 | -1 386 | -732 | -81 | 138 | 117 | 96 | 75 | 54 | 33 | 12 | 35 467 | 35 467 |
| **IRR** | | | **12,3%** | | | | | | | | | | | | | | | | | | | | | 12,3% |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| Discounted cash flows of the period | | | 9,5% | -6 184 | -18 | -169 | 104 | 227 | 327 | 386 | 1 164 | 406 | 203 | 241 | 219 | 67 | -6 | -5 | -5 | -4 | -4 | -4 | 5 773 | 2 719 |
| Accumulated discounted cash flows | | | | -6 184 | -6 201 | -6 370 | -6 266 | -6 039 | -5 712 | -5 326 | -4 162 | -3 756 | -3 553 | -3 312 | -3 093 | -3 025 | -3 031 | -3 037 | -3 041 | -3 046 | -3 050 | -3 054 | 2 719 | 2 719 |
| **NPV** | | | **9,5%** | **2 719** | | | | | | | | | | | | | | | | | | | | |