GOOD PRACTICES AND INSTRUCTIONS

BIO TREE LTD
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Introduction

World petrol and gas reserves are decreasing and their yield, deliveries and high interest are making the final product too expensive. Bulgaria and central Europe generally are having limited stocks of similar energy sources and they are importing the bulk of their needs. When it is about petrol this is near 100%, in the cases about gas it is the same. If we make a conclusion this is going to be an almost full dependence from external sources that could not be influenced. Europe is facing the challenge of the climate change, the increasing dependence of importing resources and energy and the rising energy costs. In this condition the European aims for sustainable development are becoming more difficult for achieving. The new European energy policy, in particular – and the national, aim to overcome these challenges for the benefit of all European citizens. The starting point of the European energy policy is at the tree priority directions:

- Mastering the negative climate changes;
- limiting the external dependence of EU of imported energy resources;
- encouragement of the economical growth and employment and this way it will assuring secure and affordable energy for the users;

Achieving these goals is impossible without the development and the use of a wide range of renewable energy technologies – wind, solar, hydro, tidal and thermal. The biomass from energy cultures that have a particular application in Bulgaria are at the development stage where they are ready for commercial application.

Renewable energy

The renewable energy sources are providing sustainable and carbon neutral natural source of heat or energy, as well as improving the security and the diversity of the deliveries of energy sources.
Some types of renewable energy are having the potential to create and sustain significant employment in the economical regions. The main limitations with the renewable energy sources are linked to the consumers confidence and with the reliability and delivery (due to the nature of some of the sources for example wind), as well as the costs for the construction that are reflecting at the energy supply prices. The increasing interest into the renewable energy and the forecasted potential is a result of multiple factors:

- The world conviction that the levels of the carbon emissions needs immediate decrease for reducing their effect over the global warming;
- This has led to the entry of many international binding instruments under the Kyoto Protocol limiting the levels of carbon emissions to certain levels up to 2012. In the European Union the binding norms will continue to be valid even after Kyoto;
- The decreasing reserves and the increasing prices of the fossil energy sources, particularly gas, petrol and their sensibility to political influences.
- The need to reduce according to the energy import needs by reliable supplies that the local sources can provide;
- The extremely vulnerable position where the conventional agricultural production is in at the overall economy of the country and the press on her by multiple countries are urging to alternative and sustainable possibilities for the use of the land such as the growth of energy crops.

Big part of the potential that the biomass from energy cultures have in the reduction of carbon emissions is coming from:

- Displacement of the fossil fuel sources for heating as a beginning and subsequently with the development of the technologies for small and medium-sized power plants for electricity production.
- The neutral status of the biomass from energy cultures regarding to The CO₂ emissions, when the growing culture consumes as much as atmosphere carbon dioxide that subsequently is being released in the conversion and into the renewable energy as heat or electricity.
- The total carbon cost has been calculated for the production of energy from biomass, gas and coals and shows the emissions of CO₂ from 60g, 400g и 1,000g for kW electricity respectively.
Biomass

All the sustainable energy sources are entirely obtaining its energy from the sun except the tidal and geothermal ones. In the case of energy cultures from biomass the solar energy is transformed by the plant into a chemical energy stored in the biomass through the natural process photosynthesis. This could be oils or oilseed crops, the grass Miscanthus (elephant grass) or under the shape of wooden biomass for the species with short rotation period such as Paulownia, poplar or willow whose stems are going to be cutted. The wooden species represents 60% of the total yield of biomass and Paulownia turns out to be the most effective culture for our latitudes comparing its year yield from with the one from poplar, willow or Miscanthus.

The main advantage of Paulownia as an energy crops is the rapid growth in the first 1-2 years of its development and the ability of its root system to maintain the formation of new plants at the place of the trunk.

The material will be planted in the spring as at the end of the first vegetative period it shall be cutted at ground level in order to provoke the next year formation of multiple new stems. The growth in the next year is rapidly reaching 3-4 metres untill the end of the year and more than 6-7 metres in the second year when it will be cutted for processing of the produced biomass. A similar plantation can live 20-25 years and suggests 10-12 harvests, after that the land could be reused for another application.

The expected quantity of the yield per acre is different according to few factors. At first comes choosing the kind, place, climate factors, additional irrigation and all the others factors affecting the traditional crops. The expected yields of Paulownia could vary within the range of 30-40 tdm/ha/y or in two years rotational cycle up to 80 tdm/ha.

Measured in units of energy the dry mass from Paulownia has energy content about 18MJ energy for a kilogram 42% from the energy in equivalent volume of light fuel. This way we can recalculate the yield per hectare per year equivalent to 12 000-17 000 litres fuel from hectar and from here we can easily evaluate the yield from Paulownia in financial equivalent.

At this background there is an expectation on the prices of the fuels that they will gradually continue to grow and an investment in an energy crop like Paulownia is really reasonable.
1. PRODUCTION OF PAULOWNIA FOR BIOMASS

1.1 Choosing the site

The downmentioned climatic, geographical and biological requirements of Paulownia are intended to guide investors to the appropriate growing energy crops on his choice for the plantation site.

Paulownia grows up to 2000m altitude and latitude 40°N и 40°S. For husbandry with investment purposes is recommended the latitude do be less than 750m – 800m.

The growth of the trees starts in the spring, when the temperature of the soil is reaching 15°C -16°C. Optimal temperatures for Paulownia’s growth are in the range of 24°C -33°C.

Paulownia is highly adaptive to diverse soils and grows at a wide range, but the best development could be seen with deep and well drained soils. The best and preferred for raising Paulownia are the light aerated and sandy soils without slope.

**Unappropriate** for raising Paulownia are the clay, rocky, podzolic and soaked (swamped) soils. Soils that contain clay more than 25% and porosity under 50% are not appropriate for growing Paulownia.

Good growth of Paulownia is observed with soils having a pH from 5.0 to 8.9. Paulownia can not tolerate soil salinity more than 1%.

1.2 Requirements of Paulownia for the climatic and agronomic conditions.

Paulownia is highly adaptive tree species, but in order to ensure the economical effect of the plantation and a hight yield if quality timber you have to provide the following: appropriate soil, climate and agrotechnical conditions.
1.3 Instructions for soil sampling for soil analysis from areas intended for Paulownia cultivation.

Basic requirement

The soil sample should be representative for the area where it was taken. For this purpose it is necessary to take an average sample of each area, regardless its size. If the size is more than 10 ha, an average soil sample has to be taken on every 10 ha – so called elementary section. At slopes there are formations of elementary sections in the upper, middle and down part of the field. Collecting the first average samples has to be performed during normal meteorological conditions.
Method for soil sampling

The soil samples are taken by hand or by mechanical probes mandatory from three depths 0 – 30 cm, 30 – 60 cm and 60 – 90 cm. From every elementary section an average probe must be taken, that has been formed by 15-20 stitches. The stitches will be made in diagonals or zigzag (in the attached diagrams) in the elementary section, escaping the indistinctive for the field zones. Soil from all stitches will be collected /each depth in a different bag/ into an appropriate container and will be mixed in order to become homogene. From there an average probe will be taken with the weight of 400-500gr for the normal soils and 600-800gr for the skeletal(stony soils). The average sample has to be placed into an appropriate resistant wrapping bag, having the following details on it:
Region..............................................................
City.................................................................
Holding farm).....................................................
Identificational № of the roperty......................
Depth of taking.............................................. ......cm
Date of akina.....................................................
Numeration of the probes starts from № 1 for each field. For analysis the soil samples shall be sent with an inscription on them.

Analysis required for evaluation of the lands from the agricultural and forestry fund for building Paulownia plantations:

- pH
- Humus
- Mechanical structure
- Total carbonates
- Mineral nitrogen
- Assimilable phosphorus
- Assimilable potassium
- Content of calcium and magnesium
- Microelements – Fe, Zn, Cu, Mn
- Conductance
Choosing the planting material has a key role for ensuring the economic impact of a plantation for biomass. The main criteria are the temperature regime and the rainfalls. These are the two main requirements for the choice of planting material. BIO Tree company suggests the hybrid kinds expressly selected for biomass yield. The hybrid varieties selected in Bio
Tree company are appropriate for: yield of high quality timber – kind **Belli**s**i**s**s**a and for biomass production – kind **Oxi**.

**1.5. Planting and growing – general conditions**

**1.5.1. Site preparation**

Usually Paulownia is planted during spring and mid-summer in dependence of the development stage of the planting material /one year old saplings or young planting material/ and prefers horizontal or south orientated slopes. As all young trees, Paulownia plants should be well protected from herbivorous animals.

**1.5.2. Sun**

Paulownia requires a lot of sunlight for its best growth.

**1.5.3 Rain**

Irrigation is necessary if during the first vegetative period the rain is less than 150 mm per month. In comparison 10mm of rain delivers 10 liters of water. Watering is needed in the following years if the monthly rainfall is under 50mm. Insufficient watering slows the growth but does not kill the plant.

**1.5.4 Wind**

Plantation is good to be placed in areas without strong winds reaching over 28km/h. When there are powerful winds at the place of planting stabilizing post has to be put during the first year of development until they form strong wooden stem. The speed of the wind is dangerous for the young plants over 45km/h and such areas have to be avoided.

**1.6.1. Pastures and lands covered with bushes**

When selecting a pastures and meadows for plantation with Paulownia, the terrain has to be pre-treated with herbicide at least 4-5 weeks before planting. The adherence of this period is required by the necessity of the full degradation of the traces from the herbicide in the soil and not to harm the young and fragile plants. The Herbicide must be chosen to be able for removal after and to provide long – lasting control for at least 9 months.

The terrain shall be cleaned before the planting and any re-growth of the
weeds must be strictly controlled.

1.6.2. Control on the weeds after planting
Control over the weeds is helping the growth and the virality of the plant. A circle with diameter 1.5 m around every single tree shall be maintained without any weeds at least for the next 2 years. Springtime you have to spray just before the beginning of the growth (waking up), but you should escape a contact with the stem of the tree. If young rooting cuttings appears around the tree they must be removed by hand and not by herbicide.

1.6.3. Trench
Before planting it is recommended plowing the land /minimum at 40 – 60 cm/ aiming to crush the soil and to remove the roots of the perennial weeds and bushes. If the soil is heavy and clay the trenching shall be at the depth of 70cm - 80 cm.

1.6.4. Disking /leveling/
After trenching it is necessary to level the land two times. After that it could be considered that the land is prepared for furrowing, marking, planting.

1.6.5. Furrowing and marking
The furrowing is performed at the depth of 20 cm. After that you have to mark the planting spots. In every single planting spot you have to put additional fertilizer or manure that is mixed with soil in advance. The tree is planted in a way that the connection between the stem and the root to be of moisture saturation of the soil during the winter it is recommended to build a mound (pile), so the level of the soil will increase at the planting spot. It is appropriate the mound to be 25cm -30 cm higher than its surrounding soil.

1.6.6. Determining the planting scheme

- **Paulownia for timber production** — When creating a plantation for timber we recommend the planting scheme with 4x4, 5x5 meters or 5x4 meters between the trees which means 500 or 600 trees per hectare.
Larger density leads to competition for area between the trees and slower their growth after the first 3-4 years. Lower density leads to faster initial growth which lowers the timber quality. Higher density does not lead to commercial effect, the necessity of elimination of plants is connected with expenses for eradication and herbicide treatment to stop the regeneration from the roots and in the end the 3-4 years old stems does not possess enough volume to be used for timber.

- **Paulownia for biomass** – For effective yields we recommend the trees to be planted with higher density than the one used for timber production. The density should be between 3500 and 10 000 plants per hectare which depends on the rotation cycles of for the biomass collection strongly linked with the purposes of the biomass (pellets, chips, bioethanol, fodder) and the harvest machines.

**1.6.7. Irrigation**

It is recommended before planting to irrigate well the terrain. The saplings shall be irrigated at the day of their planting and after that, until they develop a strong root system (about 2 years). The second irrigation shall be 2-4 days after their planting. Irrigation after planting shall be regular and amply, especially in a dry season. Irrigation is necessary if the rain during the first vegetative season is not less than 150 mm per month. It is also necessary in the following years if the monthly precipitations are less than 50 mm.

The regular development of Paulownia requires:

- or rains with with relatively equal alignment - minimum 120 - 150 mm per month irrigation /drip /and/or subsoil moisture at
- the depth of 11.5 m.

The main requirement for maximum growth is the regular and amply irrigation at a time of the vegetational period.

**1.6.8. Fertilising**

Paulownia is tolerant to poor soils and could reach acceptable dimentions for the stem diameter. Paulownia thought, grows much better in fertile soils. The experiments shows that the best is to apply the fertiliser under the form of nitrogen, phosphorus and potassium at the time of planting. Nitrogen is more effective, when it is applied as an independent element.
Sometimes it is necessary to fertilise the soil at the time of planting, but it is strictly in accordance with the results of the soil analysis. If preliminary soil analysis has not been performed you can do feeding up by the following materials and start up nutrients:

- soil: organic fertiliser - 1 : 1
- triple superphosphate /TSP/ - 200gr
- potassium phosphate - 120gr
- ammonium nitrate - 150gr

During the exploitation of the plantation the soil is getting poorer and you have to keep that in mind. Because of that it is necessary to use an additional fertilisers during certain periods. The duration of the periods depends on the basic position of the soil and also on the growth rate and the rotation cycles of the plantations. It is recommended after the first rotation cycles to monitor the amount of nitrogen, potassium and phosphorus in the soil, after a scheme for alternate loading has been issued.

1.6.9. Pruning

The goal of raising Paulownia is to produce a good crop of trees possessing a good shape and in a good condition. This could be achieved by for stimulation of the development of maximal quantity timber without wooden knots on the tree trunk. This could be achieved by removing the branches, that are not having big importance in the maintenance of and optimal leaves number needed for the photosynthetic activity.

1.6.10. Planting without complete treatment of the soil

/it is allowed only in the cases when the complete treatment of the soil, forestation in a forestry fund, decoration of parcs and gardens are not possible/

If for any reason you have to plant Paulownia without any treatment in advance it is necessary to plant the plants into holes, previously excavated. Firstly the planting spots shall be marked, after the holes shall be excavated. If the land is not loose, the holes shall be as wider as they can be /for heavy soils it is obligatory/- at least 60x60x60 cm. The top soil shall be separated from the bottom soil in the process of digging. After that the hole shall be half filled with topsoil (it is
recommended to mix with organic fertiliser).
The plant shall be planted in a way that the connection between the stem and the root will be about 1 cm below the ground level. The left soil is superimposed and rammed. At a flat land, especially if there is a risk of saturation of the soil during the winter is recommended to build a mound (hillock), so the soil at the hole will be 30 cm above the ground level. According to the depth of the holes and theirs dimensions an excavation technic will be choosen. The size of the hole will be choosen depending to the pre-treatment of the soil starting from 30X30X30 cm and reaching up to 60X60X60cm.

**Key Factors:**
- Soil analysis for determining the content clay and microelements and for estimate how much the soil is suitable for Paulownia growth;
- Soil preparation is fundamental for the satisfactory growth;
- The weeds control is the most important aspect in the preparation of the place and the tree growth during the first and the second year;

- Irrigation is necessary if the summer rain is insufficient;

**1.7 Diseases and enemies**
Paulownia plantations do not suffer the typical diseases for the region. A problem could be the sensitivity of the stem of stem and root decay in a young age. Preparations against the grey decay and others is used for avoiding it. The fight is not hard, but the disease depends on the irrigation manner of the planting material during the first months and the drainage of the soil. The presence of competitive vegetation in 50 cm zone around the root system deteriorates significantly the growth in height and diameter. The constant cleaning around the stems is really important because it can affect considerably the yield.

**1.8 Yields**
According the conditions, the choosen genotype /hybride kind/, the keeping and the rest of the factors normally affecting the traditional crops, the yields of Paulownia could vary into serious limits from 30-40 tdm/ha/y (tons dry matter per hectar per year) or at biennial rotation cycle to 70-80 tdm/ha.
1.9 Harvest the production

The harvest of Paulownia production happens from late autumn until early spring. At normal conditions this gives a period of 3 months from December to the beginning of March. This time troubles the machines entry and must be considered. If the conditions suggest earlier development the buds cutting shall be withdrawed back in time. In general this means harvest of the production before the juices of the plant begins their movement in the stem and that way the stored in the roots reserves to assure the development of new ones.

There are three manners for harvesting the crops. Direct harvest like wooden chips, harvest of entire stems and harvest of cutted sticks with certain length and each of them possess its advantages and disadvantages. In most of the cases the harvest of the production is a process of cooperation between different owners due to the specific of the process and the price of the engines used. The separately purchase and the use of such machine is a right choice only in few cases. Here the necessity of drying places shall be added as well as the requirements of the chain with providers and the final users of the production. All of that aggregate determines the choice for harvesting and the following activities with the production.

1.9.1 Direct collection of chips

In that case the culture will be harvested and processed in chips at the cutting of the stems. In that case the material might need artificial drying in order to escape decay. Most of the machines for this type harvesting are constructed to gather double rows by one turn possessing significantly changes picking heads, that will be installed into the standart machines for foraging. The machine cuts the stem and turns it after into chips and throw it in a trailer. In this case the already used trailers for collecting a silage could be applied. If the production is harvested while it is fresh, the quality of the chips is much better and the fuel costs and amortization of the machine will minimize. This is the most effective operation to harvest the production but also requires special drying places. The chips starts to rot as like composting, that leads to energy loss. Dryiers with ventilated floors used for the cereals are successfully applied in this operation. In addition the chips is collected and dryied after the cereal harvest has been already dryied and by this way the expensive equipment is used additionaly. This type harvesting machines have the capacity of 5-6 hectares per day. In the case for Bulgaria where the lands are more compact...
and scattered the capacity could be esteemed as 3-4 hectares per day.

1.9.2 Harvest of whole stems

In this case the culture will be harvested on whole stems. Multiple conditions must be considered while choosing the harvest method.

The machines mostly chop and release the stems, that are important for harvesting, removing and storage like a separate operations. There are still no effective machines that could tie the chopped stems and it might be difficult to work with 6-10m rods. The collected stems shall be transferred for second time for slicing before they turn into use. The collected stems are being grouped straight in a formation similar like haystack. Thus they are going to have good enough natural air ventilation for the necessary period of about 2 months for wood drying without decompose. In this case it means that the special needful dryers in the direct chips collecting are necessary. The quality of the chips obtained by this method is lower than in a case of direct collecting. Slicing the chips is more energy intensive operation because the chopped wood has been dried. The machines used for cutting the stems have the capacity of 4-6 hectares per day, thought they remains at the places of cutting and needs to be collected and transported. Even that this is more expensive harvest method in terms of operating costs in Bulgaria in the presence of small plantations, scattered plantations and the lack of expensive dryers and picker machines, this method might turn out more applicable and practiced.

1.9.3 Harvest rods

This method takes an average place between the direct collecting of chips and the cutting of whole stems. This type picker machines has been developed for sugar cane and forms small pieces from the whole stem of length about 5-10 cm in a way similar of the chips collecting. The machine throws the pieces in a trailer for removal from the plantation. In this case the bigger size of the pieces and the ameliorated air circulation between them the natural drying is possible in a way similar to the collecting of whole stems. This pieces also needs additional cutting before use in order to maximize the combustion efficiency, but unlike the whole stems they could be easily manipulated. Here again the quality of the chips is worse than the one obtained directly, because the material that has been cutted is relatively dry.
1.10. Drying and storage

Regarding the fact that the need of fuel supplement is almost constantly throughout the whole year and depends on the final user it will requires a specific type drying and storage. The part of the providers chain is not enough clarified and requires work on the problems and theirs addressees. The fresh harvested crops are having moisture around 21.3% (for comparison another energy crop is having natural moisture around 50%) and the need of drying is determined by the chosen harvest method. Generally this is only the directly collected chips that might need artificial drying. The whole cutted stems are not able to reheat by themselves and to provoke decay and because of that will get dry naturally. The artificial drying is an expensive operation and requires a precise quantity of energy for decreasing the humidity to 20% so the chips could stay stable for a longterm and for that reason the cutting shall be pursuant in order to escape the necessity of artificial drying.

The drying is necessary because when the humidity is increased the cellulose is easier digested by the fungi and bacteria and the tree starts to decay. This causes loss of calorific value and generally loss of its fuel quality. The percent of chips drying depends on the combustion chambers. The big furnaces are accepting 30% moisture chips when the smaller ones are working more effectively with dry material. Completely dry material is having the energy value of 19 MJ/kg and the one with 22% humidity is having 17MJ/kg for a reason that part of its energy is used for the drying process.

1.11. Recovery at a place

When the Paulownia plantations reaches the end of their living cycle, the area shall be transformed into a grass land or infield. The root system of Paulownia is significant and its mechanical removal could cause a substantially damage of the soil.

After the last harvest gives new sprouts, when they are at the height of 30-50 cm), Paulownia is exclusively sensitive to herbicides, so the one time use of herbicide (5l/ha glyphosate) is enough for destructing the actively growing culture. The culture shall be left at least two weeks after the spraying in order to ensure the full absorption and penetration of the herbicide.

By using a cultivator from the sprouts and the soil surface layer a shallow tillable layer appears, where a cereal will be planted.

Furthermore the bigger part of the root system is in the soil without harming its structure. A recovery like that of the lands for growing cereals could last whole
season. The conversion of the land into a complete tillable land could last longer time so the roots can decay. Otherwise there is going to be a need of a much complicated and expensive mechanical removal of the sprouts and the roots.

2.0. ECONOMIC APPLICATION

The final bruto energy consumption in Bulgaria could be summarized into three general groups; for heating and cooling needs (44,1%), electroenergy consumption (30,3%) and transport energy (25,6 %). Therefor it is difficult to understand why most of the initiatives for energy production from renewable sources is directed to production of electricity. In addition, the technologies for heat generating are the most developed than all the others. For that reason there is a great interest in them and into their development as a renewable sources for energy, that are most applicable for the agriculture in Bulgaria. The logistics for supply of very large megawatt plant composite by multiple small producers will represent a serious logistic problem. The supply of relatively small central (less than 1 MW) from small cooperative is the most sustainable development way.

In this way the possibilities for delivery of heating to the final user are increasing, threw one company for energy deliveries, having this way the for selling product with additional costs and not a raw material (wooden chips).

2.1. Burning, Gazification and Pyrolysis

There are three thermodynamical processes that could be used for converting the energy from the wooden chips into a usable energy – heat or electrical; Burning, gasification and pyrolysis. In small dimensions, as it would be practical for the conditions in Bulgaria the technologies for direct burning already exists and they are applied, the technologies for gasification in small dimensions are still developing and their commercialization is just about to happen, the pyrolysis is still in the stadium of research and development.

2.1.1. Burning

Generally this is the most effective way to obtain heat from the wooden chips. The process includes burning of the wooden chips with a sufficient amount of
oxygen to be carried out by turning the bigger part of the fuel into a carbon dioxide and water. This is an established technology with multiple systems at the market.

Inevitably there are losses in all combustion systems, but the contemporain well maintained boilers for chips are having an efficiency coefficient for energy conversion of over 80%. The wooden chips is with low density and the energy balance is maximized if the fuel is used as close as it is possible for its place of manufacture. It is considered that the maximum distance for transportation of the fuel shall not surpass 20 km. In this situation the energy balance will be more than 30:1. There is a wide range of equipment starting from few kilowatts up to a lot of megawatts. The generated heat could be used directly for the production of hot water or air or be used to produce steam that will drive the turbines for electricity production.

The capital costs for the last application are expected to be limited in their distribution in Bulgarian conditions. The most appropriate systems are having storage for chips and boilers with fuel cameras, charged with thermostatic controlled probes with the necessaire security systems preventing back burning. If the burning system is powered by chips with humidity of 20%-10% the energetic value is going to be in the range of 17-19 MJ/kg.

The wooden chips could also be used for pellets and for specially made for them furnaces. This process requires the wood to be dried up to under 10% moisture, subsequently inside metal moulds and at the end smashed in the shape of pellets as all the processes are energy-taking. This is having a negative impact over the energy balance of the production of chips and decreases its advantages according to the others fuels. The production of pellet from specially raised for that wooden crops is with small economic effect. Their production from waste products in the processing of wood is understandable since there is not a big investment there for getting raw material.

Another important issue at the construction of installations is the necessity of space for storage for the raw wood material, that requires up to nine times bigger volume per unit energy compared to the liquid fuels (1m³ fuel requires about 8m³ of wood with humidity of 20% capable of providing equivalent amounts of energy).
2.1.2. Gazification

This is a shape of partial combustion where the included in the chips energy is being released under the shape of flammable gases, water vapors and carbon monoxide. This will be achieved by heating up the fuel up to high temperatures (over 700 °C) at controlled deficiency of oxygen interfering the full combustion up to water and carbon dioxide. This is relatively simple chemical process and could be implemented in multiple systems (updraft, downdraft, fluidised bed) depending on the place where the oxygen is being saled or its direction of transit in the gazificated container.

The obtained gazes are being cooled and purified and the combustion ends in a standard internal combustion engine. Mostly used is the compression ignition engine (diesel) as the most tolerant to the gas with a different nature. The small amount diesel fuel (10%) is being used for improving the gas combustion. This is having the additional advantage, in the absence of gas from wood the engine could run entirely on diesel fuel.

By the use of gas obtained of wood for fuel in the engine it produces 75-80% by the power than if it works entirely on diesel fuel. Small systems from the range of 100-250KW generated electricity are being developed but not commercialized. The adaptation of wood to gas is relatively seamless but its purification from particles and soots in order to allow the seamless combustion in the engine is a serious problem.

The efficacy evidences for the energy conversion by the use of engine and generator shows that it is in the range of 25-30%. But if the generated extra heat is being used for electricity generation the efficacy could be increased up to 75-80%. The gas obtained in the process is with low calorific value between 4 and 5 MJ/m³ and it is not economically viable for storage, so it is used at the time of its formation.
This is the technology that is still in a process of research and development. It is including heating up of the chips to temperatures from $430^\circ\text{C}$ - $700^\circ\text{C}$ with a full lack of air, whereat an energy is being released as a pyrolytic fuel, dense carbon and inflammable gases. The relative parts of these products depends on the used temperatures and from the residence time of the chips in the reactor. The main advantage in this process is that it can produce liquid fuel that can be stored and transported relatively easy. It has calorific equivalent of $16\text{MJ/kg}$, but it is acid and has a significant water content, i.e. it is corrosive and appears unstable.

2.2 Bioremediation

Using Paulownia as a renewable energy culture with short rotation cycles is an economically justified investment not just because of the high energy cost at the moment. In this context we also should add the ability to extract compounds from the contaminated soil and water, that further increases the stability of the investment. This process called bioremediation is especially applicable in the contemporains climate changes, where shall be taken actions for the management of the waste from farms and sewage. For many reasons Paulownia is very good kind for recycling (bioremediation) of wastes. Paulownia uses significant quantities of water compared to other wooden species. The huge root system of Paulownia and its descending into depth of about $2\text{ metres}$, contributes extraction of compounds not just from the topsoil but also from deeper horizons. This characteristic of the type represents excellent skills for amelioration of highly contaminated soils, but also the application of waste waters for its irrigation. The huge leaves, the fast growth, the tolerance to pollution and the significant evapotranspiration contributes the extraction of destructive compounds from the soil and water.

Precisely these characteristics are making Paulownia and engine for sustainable bioremediation. Guiding principle for all the systems for bioremediation is that the substances included in the system through the contaminated soil and
water are being extracted after the harvest and thus the system is stable.

In a personal research (Zhu, 1991) finds out that 8 years old Paulownia are able to take away N with a speed of 930 kg/ha per year estimated according to the average nitrogen content in the leaves of 2.6%. World Institute for Paulownia describes the type as owner of the exceptional ability to take away nitrates, heavy metals, pollutants and other elements from the shallow and the deep part of the soil. With the loss of the leaves the plant enriches the soil after once it has recycled many destructive ingredients.
3.0 ENVIRONMENTAL IMPACT OF THE USE OF PAULOWNIA

2.3 Costs and economic evaluation

Expenditures and income from growing Paulownia for timber per 1 ha

Expenditures and income from growing Paulownia for biomass per 10 ha
3.0 ENVIRONMENTAL IMPACT OF THE USE OF PAULOWNIA

The use of Paulownia at short rotation cycles as regards to the environment and the biodiversity differs in several general characteristics from the crops grown for food.

- With the crops commonly most used is a small part from the whole plant even when there are minimal cosmetic damages of the crop yields are significantly reduced.

With Paulownia when the whole plant is in use similar cosmetic damages are having minimal impact and the step, where significant economical losses starts is considerably high, that leads to savings from pests combat and diseases control.

- Paulownia forms relatively stable habitat comparing to the annual crops, although the harvesting invades it in a way. However, if Paulownia’s blocks are at different ages (one and two years) the natural enemies of the pests can settle and survive in neighborhood by naturally controlling the pests. Similar cases are observed with serious pests as leaf beetles and rust. Any change in the use of the land from one with annual plowing and cereals in Paulownia plantations inevitably leads towards changes in the ecology/biodiversity.

Plantations of Paulownia could also be buffers in terms of limiting the diseases transfer between the different agricultural. A full assessment could be made only after long use of Paulownia plantations operated at the same location combined with the relevant scientific assessments. These changes will be affected by the use of herbicides, pesticides, inorganic and organic fertilisers, wastewaters and cyclicality of cutting. In general the overall effect at the places where Paulownia is replacing the intensive agricultural crops cultivation will be positive, but where it replaces improved pastures it will have minimal effect.
3.1. Flora

The change in land use from one for pastures and annual crops to another for multiple year tree type with regular harvest will change the ground flora. The species diversity in the plants community under Paulownia will firstly grow very fast and subsequently slow as the species are changing until reaching and establishing a poorer species community. Starting point of these changes and the rate of change depends on the soil type and the factors: treatment with herbicides, the use of fertilisers and the crop collecting periods.

- The density of the plants in the Paulownia plantations is high. With other similar crops it has been found that initially there are many germinating seeds and subsequently shortly living many years (often aggressive trees and bushes) and at the end with perennial types with conservational values.

- Plantations established at pastures are developing richer multi flora plantations than plantations build up on pastures with annual plowing and treated with herbicides.

- Harvesting the production prevents the creation of completely stable ground vegetation. Instant harvesting of the biomass has a dramatical impact over the microclimate, sunlight, use of the water resulting as instant increase in the species composition. During the next year it will be less again.

- Herbicides — Paulownia requires the use of herbicides for its stable establishment in the place and the cultivation at least during the first two exploitation seasons. Subsequently the tolerance to weeds is much higher and this increases the level for uptaking pre care for control over the weeds. In time gradually the invasive weed species are reduced and it is only observed less competitive multi year shadow resistant vegetation.
3.2. Invertebrates

The richness of insects with Paulownia is considerably less than with other fast growing species. There are also some leaves flies and aphids. This causes a decrease in the necessity for insecticides use.

- Species with conservational importance are not observed with Paulownia.
- Research on the condition of the earth worms under Paulownia plantations has not been made. During research on other fast growing cultures has been observed their decrease. In multi year established willow plantations in Germany they are showing an increase.
- The diversity of invertebrates at the ground floor is mostly according to the nature of the ground vegetation. Intensively cultivated plantations are unlikely to provide rich habitats.
- After cutting the biomass a short term peaks could be expected in the number and the diversity of the invertebrates.
- The invertebrate fauna is considerably poorer than the fauna found at the annual crops despite the significantly greater diversity of the conditions for existence.