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Study cut-off date: 12 May 2023

Acknowledgements

Viacheslav Antonenko is the main author of this report. Oleg Dzioubinski and Gianluca Sambucini of the UNECE Sustainable Energy Division, Kostiantyn Gura, Chair of the Group of Experts on Renewable Energy (GERE), and Bohdan Radchenko of the State Agency of Infrastructure Projects of Ukraine contributed to the report through their review and comments.
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Acronyms and Abbreviations

CAPEX – capital expenditures
CMU – Cabinet of Ministers of Ukraine
CO2 - Carbon Dioxide
CZK - Czech koruna
EU – European Union
EUR - euro
IRR – internal rate of return
OPEX – operational expenditures
UNEC – United Nations Economic Commission for Europe
UNFCCC – United Nations Framework Convention on Climate Change
UNIDO - United Nations Industrial Development Organization
VAT – value added tax
Introduction

Energy crops are plants that are specifically grown for use directly as fuel or for biomass production. The plants produce large yield and easy in growing.

A buffer strip is an area of land maintained in permanent vegetation that helps to control air quality, soil quality, and water quality, along with other environmental problems, dealing primarily on land that is used in agriculture of croplands. The root systems of the planted vegetation in these buffers hold soil particles together which alleviate the soil of wind erosion and stabilize stream banks providing protection against substantial erosion and landslides. In Ukraine the most common type is a wind buffer. It is often called a windbreak, shelterbelt or a forest strip. Its purpose is to protect areas from wind causing erosion on the bare soil\(^1\). The forest strips are usually presented by trees and shrubs grown on arable land, gardens, pastures, along roads and railways, along irrigation and shipping canals.

According to the State Program for 2000-2015\(^2\) it was planned to plant 174,000 ha of forest strips or 11,600 ha yearly\(^3\). The results of the last forest census conducted in 2016 by the State Statistic Office, the total area of forests in Ukraine was 10.1 million hectares, while the total area of forest belts was 940,000 hectares (9.3%)\(^4\). Assuming the average width of a forest belt in the field is around 30 m, its total length is approximately 300,000 km.

In Ukraine there are requirements regarding the presence of forest strips along highways and railways. In accordance with the Law of Ukraine "On Forests and Forestry" and the Rules for the Improvement of the Territories of Settlements, approved by the Resolution of the Cabinet of Ministers of Ukraine dated July 2, 1996 No. 777, forest strips must be preserved at a certain distance from the roads.

According to these requirements, the width of the forest strip along highways should be at least 30 meters, and along railways - at least 15 meters. Such forest strips should perform a number of functions, in particular, preserve the natural landscape, ensure the restoration of soil fertility, and protect roads from landslides and other negative phenomena. Also, in the forest strips, economic work related to the preservation and management of forest resources can be carried out.

According to the State Highway Service of Ukraine (as of January 1, 2021), the total length of highways in Ukraine is about 168,000 km, of which:
- state roads - 24,939 km;
- of regional significance - 47,271 km;
- of local importance - 95,790 km.

\(^1\) https://en.wikipedia.org/wiki/Buffer_strip#WindBuffers
According to the State Statistics Service of Ukraine, as of the end of 2020, the total length of railway tracks in Ukraine was 21,736 km. In many countries, including Ukraine, legislation does not establish strict requirements for the mandatory presence of forest strips along roads. However, many states recommend the use of forest strips as an effective means of reducing noise and dust reflection from road traffic, as well as to preserve biodiversity and protect water resources. Different countries may have different requirements for forest strips along roads. For example, in Sweden, according to the Road Transport Code, forest strips must be preserved along all new highways. Unfortunately, there is no reliable data on forest strips number along the highways in Ukraine. But it is obvious that it amounts to tens of thousands km converted into some hundred thousand hectares.

1. Study Goal

The study’s goal is to analyze potential development of energy crops along highways, taking into account the use of crop plantations as highway protection as well as for economic and environmental benefits. The analysis is based on economic evaluation, assessment of the legislative framework with the view of proposing a pilot project and possible modifications to the legislation and therefore creating a suitable environment for investments in energy crops along roads and highways at a larger scale in Ukraine.

2. General Knowledge

Cultivation of fast-growing tree species (willow, poplar, and acacia) within the forest strips can ensure several important tasks:
- sustainable source of biomass
- road traffic safety: snowdrifts, ice, side wind
- improve the yield of grain crops
- enrich of biodiversity
- fire safety (poplar and willow are extremely fire-resistant)
- capturing CO₂
- environmental protection functions

Forest strips regulate the speed and direction of air flows thus form a specific microclimate of the ground zone. As a result, it contributes to animal husbandry and crop production. Low wind speed prevents erosion, slow air movement improves water regime and contributes dew formation.

The structure of the forest strip is determined by the structure of the longitudinal profile and is characterized by openwork (ratio of openings to the total area).

According to their construction, forest strips are divided into: blowing; openwork; dense.
Forest strips with a dense structure are those in which the through openings do not exceed 10% of the total area of the longitudinal profile. These are mostly multi-row plantations, created from dense tree species and high dense undergrowth, capable of forming a dense forest edge. The wind practically does not penetrate through such strips, and on the leeward side it is calm.

Forest strips with an openwork structure are those in which through openings of the longitudinal profile occupy 15–45% of its entire area and are uniformly blown by the wind without changing its direction. On the windward side, the feeling of calm disappears, but the wind speed still drops sharply.

Forest strips with a blowing structure are characterized by a rather dense tent, in which up to 10% of through openings and openwork (more than 60%) of the under-tent space are created by tree trunks and low bushes.

3. Forest Strips Along Roads

Forest strips along railroads and highways have their own specifics and are designed to protect roads from snow drifts. They are planted in the form of 2-3 rows with the calculation of snow deposition between them. Field roads are lined with alleys or blown forest strips, placing them on the windward side.

It has been established that 1 ha of forest strip along the road reduces overall air pollution by 10–35%, and also provides a 10–15% decrease in air temperature and humidity in the area adjacent to the road surface; a strip of tree and shrub plantations with a width of 25–30 m reduces the level of carbon dioxide concentration by 70%; absorbs 75–80 kg of fluorine, 200 kg of sulfur gas, 30–70 tons of dust.

Unauthorized felling has become a typical problem for forest strips along roads. Excessive liquefaction leads to the fact that grassy vegetation penetrates into the space under the tent and

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5 Pictures sources: 1) https://de.khnu.km.ua/labrun.aspx?a=738&b=1&c=2; 2) https://www.shevchenkove.org.ua/person_syte/Goch/Dosvid/%D0%9E%D1%81%D0%BD%20%D0%BC%D0%B5%D0%BB%D1%96%D0%BE%D1%80%D0%B0%D1%86%20%D0%B5%D0%BB%D0%B5%D0%BA%D1%82%20%D0%BF%D0%BE%D1%81%D0%B1%202020/6/6.htm

solid turfing occurs. In addition, the forest belts are periodically affected by fire. Young plantations are damaged by agricultural machinery. Natural and climatic conditions, in particular, long dry periods and their frequent periodicity, have a negative impact on the vitality of artificial plantations. Today, a significant proportion of such plantations are strongly weakened and drying plantations. And such criteria apply to all categories of protected areas, which leads to a partial loss of their functional capacity, as well as to the reduction of forest improvement areas.

Some researchers consider it appropriate to use poplars and willows to form protective forest strips along highways.

Willow (Salix L.) is a genus of plants that includes trees and shrubs of various sizes. For the creation of energy plantations, the rod-like willow (Salix viminalis) is most often used - a tall bush, the plantations of which are capable of producing up to 18-20 t/ha of dry biomass per year. An important feature of willow, which contributes to its significant spread, is the ability to easily reproduce by stems.

Poplar (Populus L.) is a genus close to willow, the plants of which also easily reproduce vegetatively, but unlike willow, their plantations are also successfully renewed by root sprouts. The poplar is not inferior to the willow in terms of productivity. Black poplar and delta-shaped poplar hybrids, commonly known as Populus euramericana, are used for biomass production.

As the main species, it is recommended to plant poplar in conditions of sufficient moisture in clean rows, alternating it with clean rows of accompanying (linden, maple, Tatar maple, common elm, pear, etc.) or shrub species (yellow acacia, hazel, Tatar honeysuckle, etc.). For the maximum accumulation of energy mass in such forest strips, instead of rows of companion plants and shrubs, paired rows of energy willow can be introduced (Fig. 2). Energy raw materials can be harvested starting from the age of 3 by alternately selecting paired rows every 2-4 years in the following sequence: 1-2nd, 7-8th, 4-5th, 10-11th.

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4. Legislative Basis

In Ukraine, managers (owners) of field protection forest strips can be:

1. Bodies of local self-government, state power.
2. Private landowners (farmers, agricultural enterprises, etc.)
3. State enterprises.

These entities are eligible to rent out the forest strips. A private farmer, as well as a state-owned forestry could rent the forest strips and provide the Maintenance Services. However, to cut the trees you need to get a special logging ticket. It is issued by the Regional Department of a State Forest Agency in accordance with Article 69 of the Forest Code of Ukraine for maintenance and reconstructive felling. There are Rules for Maintenance and Preservation of forest strips located on agricultural lands (Decree #650 from 22.07.2020, CMU10).

4.1. Main legislative obstacles

There are some substantial legislative obstacles related to state-owned and other public land. In the private sector all is clear. However, the main potential of the energy crops is within marginal (unproductive) lands of worse quality, which is mostly state or public property.

Obstacles:

- state and communal owned land renting is overcomplicated;
- rent price of state land is volatile and could be changed during years due to change in normative monetary valuation;
- short terms of land lease contracts;
- absence of a transparent and stable biomass market;
- significant capital investment and long payback;
- lack of state support11;
- lack of transparent heat tariffs.

On the other hand, the heating sector has a great impact on the energy crops sector. The end product of plantation = a feedstock for heating sector - wood chips.

Thus, the main customer for plantation is a heating station. Therefore, it is very important to have transparent and stable heat tariffs for years to come. To implement this, it is necessary to:

- limit political interference in tariff formation (especially for the population);
- reject the direct subsidies for natural gas;

10 https://zakon.rada.gov.ua/laws/show/650-2020-%D0%BF#Text
11 https://uabio.org/energy-crops/
- transition to households subsidizing.

In addition, a transparent and understandable product sales market is important, which can be solved by creating a biofuel exchange (for example, Baltpool).

Thus, solving the above problems will create predictable and understandable conditions for long-term planning, which will facilitate bank financing.

4.2. **Changes in legislation for investments attraction**

Current legislation does not create any favorable conditions for growing energy plants. However, there is a certain vision how to overcome these problems. Draft Law No. 5227, No. 5228 (12 March 2021) provide:
- definition of the term "energy crops".
- increasing the land lease term to 20 years.
- simplification of the lease of unproductive lands - without conducting land auctions. Since such land is not suitable for growing traditional crops, there is usually no competition for it, so bidding is ineffective.
- changes to the Tax Code of Ukraine regarding rent. The maximum rent for unproductive and degraded land is 5% of the normative monetary value.
- the possibility of state support.

By October 2021, the draft law received some comments from the Parliament Offices: Budgetary Committee, EU Integration Committee, Scientific Committee12. The main provisions need to provide the following:
- justification of state support and the sources of such expenses;
- make sure there is no contradiction with the law of the European Union and the Association Agreement. However, it is necessary to postpone consideration of the draft law until the relevant opinion of the European Commission is received;
- provide stability criteria and guarantees of origin.

The draft law is being worked on. Included in the agenda: 2911-IX dated 7 February 2023. Still not voted.

In addition, with the aim of creating a biomass market, the State Agency for Energy Efficiency and Energy Saving has developed a draft of the Law "On Amendments to Certain Legislative Acts of Ukraine Regarding the Development of Trade in Solid Biological Fuels"13, which provides for the creation of an electronic biofuel trading system. This could among other effects help to get bank funding.

12 http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=71384
13 https://saee.gov.ua/uk/documents/3599
5. Fuel Properties

Harvesting of energy crops is carried out during the period of winter dormancy (November - February). The lower calorific value of wood biofuels is mainly determined by the moisture content. Approximately nine cubic meters of wood chips in calorific value is equivalent to 1000 cubic meters of natural gas. The ash content usually does not exceed 1%, and the highest ash content is observed in the bark of 2-10%.

Table 1. Fuel properties

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Willow</th>
<th>Poplar</th>
<th>Pine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity as received, %</td>
<td>50-53</td>
<td>50-55</td>
<td>40</td>
</tr>
<tr>
<td>( Q_r ), MJ/kg (dry)</td>
<td>18.5</td>
<td>18.7</td>
<td>~19</td>
</tr>
<tr>
<td>Volatile matter, %</td>
<td>79</td>
<td>83</td>
<td>&gt;70</td>
</tr>
<tr>
<td>Ash, %</td>
<td>1.5-2</td>
<td>0.5-1.9</td>
<td>0.6-1.5</td>
</tr>
</tbody>
</table>
| Elemental composition, %:
  C                                | 50.28    | 47.95    | 50      |
  H                                | 5.98     | 5.92     | 6       |
  O                                | 42.65    | 45.29    | 43      |
  Cl                               | 0.02-0.03| 0.03 – 0.04| 0.02 |
  N                                | 0.5-1.0  | 0.77 – 0.9| 0.3    |
  S                                | 0.03 – 0.34| 0.03 – 0.2| 0.05  |
| Ash melting point, °C             | >1,500   | 1,160-1,500| 1,000-1,400|

Table 2. Comparative characteristics of energy plants for the production of solid biofuel\(^4\)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield of dry mass, (t/ha)/year</th>
<th>LCV, MJ/kg dry m</th>
<th>Energy yield, GJ/ha</th>
<th>Humidity at harvest, %</th>
<th>Ash, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willow</td>
<td>8-15</td>
<td>18.5</td>
<td>280-315</td>
<td>53</td>
<td>2,0</td>
</tr>
<tr>
<td>Poplar</td>
<td>9-16</td>
<td>18.7</td>
<td>170-300</td>
<td>49</td>
<td>1,5</td>
</tr>
</tbody>
</table>

The average characteristics of wood chips from willow and poplar in terms of moisture (50%) and ash content (up to 2%) do not differ much from similar values of wood chips from forest wood (moisture 45%, ash content 1.5%).

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\(^4\) UDC: 633:582.4:573.4:574
KHIVRYCH O.B., candidate s.-g. sciences; KVAK V.M., KASKIV V.V., MAMAYSUR V.V., MAKARENKO A.S.
ENERGY PLANTS AS AN ALTERNATIVE TO TRADITIONAL TYPES OF FUELS
6. Production program for cultivation

The yield directly depends on climatic, soil and other conditions. Crops have different needs in the water, frost and drought resistance.

Table 3. Climatic conditions of energy crops cultivation

<table>
<thead>
<tr>
<th>Crop</th>
<th>Water need</th>
<th>Frost resistance</th>
<th>Drought resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willow</td>
<td>High (from 650 mm/year)</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Poplar</td>
<td>Average (from 500 mm/year)</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Willow is a tree-like crop, which is a bush or shrub-like tree up to 6-8 m high. Usually, energy willow is densely growing, has a large number of shoots, which reproduces quite easily. The average yield of willow is 10-12 tons of dry weight per hectare per year. The largest harvest is obtained in the 4-5th year of cultivation - 16-20 dry t/ha/year.

Poplar, like willow, belongs to perennial woody energy crops. It is grown in conditions similar to willow and using similar technologies. Poplar is resistant to pests and can grow on poor soils and polluted lands, but it is less frost-resistant than willow, so it is not usually grown in northern European countries. Culture practically does not require the use of pesticides and fertilizers. From the plantation of energy poplar, you can get biomass in the amount of 8-15 dry t/ha per year, and on good soils, new clones can yield up to 16 - 20 dry t/ha per year.

Cultivation of all energy crops can be conventionally divided into 3 stages: 1) soil preparation; 2) direct cultivation (planting, plantation care); 3) harvesting (the final operation is the liquidation of the plantation after the end of its existence). Depending on the type of energy crop, the cultivation process has its own characteristics.

The area of the plantation and the productivity of the crop also affect the choice of equipment for planting seedlings, caring for the plantation, harvesting and transporting it to the intermediate warehouse. The type and power of the equipment is chosen in such a way as to load it as much as possible during the year.

Our task is to compare the plantation area of 50, 100 and 1000 hectares. For each option we choose the optimal ratio between rented and purchased machinery.
7. Technical Card

The technology of soil preparation is similar to the preparation of soil for the vegetable group of crops and depends on the condition of the land plot. The introduction into circulation of land that has long been occupied by forest strips requires a greater number of operations and is more costly.

Therefore, soil preparation will include:
- uprooting of old plantations
- clearing of bushes and various debris
- fight against perennial weeds by chemical means (glyphosate);
- disk for grinding the rest of the rhizomes (at least 2 times);
- deep autumn plowing to a depth of 20-25 cm;
- introduction of complex mineral fertilizer, depending on the results of soil samples;
- pre-planting leveling and soil compaction.

The soil must be free from plant residues, plowed, crushed and compacted.

Table 4. Schedule of agrotechnical operations of growing willow/poplar in a two-year cycle

<table>
<thead>
<tr>
<th>Year</th>
<th>Season</th>
<th>Operation</th>
</tr>
</thead>
</table>
| 0    | Fall   | Soil preparation:  
- mowing, grubbing of existing plants (if necessary);  
- application of a contact herbicide to control perennial weeds;  
- soil treatment with a disc cultivator;  
- plowing;  
- cultivation;  
- cover crop sowing\(^{15}\) (used if it is possible to prepare the soil within 1 year);  
- soil treatment with a cultipacker \(^{16}\). |
| 1    | Spring | Planting:  
- soil treatment with a disk cultivator;  
- soil treatment with cultipacker;  
- planting seedlings;  
- introduction of preemergence herbicides;  
- mechanical and/or herbicide control of weeds |
| 1    | Winter | Technological cut (if necessary) |
| 2    | Spring | Application of fertilizers (if necessary); Weed control (as needed) |
| 3    | All year | The first growth of the plantation is 3 years |
| 4    | Winter | Harvesting the 1st harvest (the yield will be 60-70% of the potential of a mature plantation) |
| 5    | Spring | Application of fertilizers (if necessary); Cultivation between rows |
| 6    | All year | Plantation growth - 2 years |
| 6    | Winter | Harvesting the 2nd harvest |
| 7-22 |        | Repeating the 2-year cycle with harvesting. |
| 25   | Spring/Summer | Liquidation of the plantation |

\(^{15}\) Cover (fragrant) crop (c.c.) is a crop that is sown to improve the quality of the soil. When plowing a cover crop, the soil is enriched with organic substances and nitrogen (legumes, etc.).

8. Planting Material

The seedlings harvesting takes place in January-February. For manual planting we use short cuttings (length 20 cm, diameter 0.7-2.8 cm). For mechanized method of planting we use longer seedlings of 1.5-2 m long. They are cut by machine into 18-20 cm cuttings during the planting process. This is true both for willow and for poplar.

(a - short cuttings for manual planting, b - long seedlings for machine)

Figure 3. Life cycle of a willow plantation

Figure 4. Willow seedlings

18 Picture source: [https://www.crops4energy.co.uk/src-cuttings-rods/](https://www.crops4energy.co.uk/src-cuttings-rods/)
19 Picture source: [https://www.crops4energy.co.uk/src-poplar-cuttings-and-rods/](https://www.crops4energy.co.uk/src-poplar-cuttings-and-rods/)
There are different plantation layouts. The planting scheme (layout) is chosen according to the end product you want to have – bushes (higher density) or separate trees (low density) - and due to applied harvesting machines. For example, a willow can be planted in paired rows at a distance of 0.75 m, the distance between pairs of rows is 1.5 m. Productivity of manual planting is approximately – 1ha/8h (6 workers).

With a plantation area of 10 hectares or more, mechanized planting of seedlings is carried out with the help of machinery.

Productivity of work with machine planting is 10-15 ha/day. Features of mechanized planting compared to manual planting are as follows:

- higher quality planting material is used (long rods that do not dry out);
- there is no need to cut the planting material into pieces manually;
- less human factor;
- parallel driving system during care and harvesting;
- less damage to rooted seedlings during care.

The main principle of care is a timely weed control. Harvesting is carried out in accordance with the development of the plant or the chosen method of cultivation (for poplar).

For willow it is usually need to use fertilizer. With a 2-year willow growing cycle, biomass is collected once every two years, after which fertilization (nitrogen, potassium) is applied, depending on the results of soil samples. In case of poplar plantation the fertilizer is not used. The total yield during plantation lifetime is approximately 400 tons (1400 m3) of wood chips per hectare.

Figure 5. Planting scheme of willow

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9. Evaluation of Economic Component

The model is based on a practical experience of planting the poplar plantations in Ukraine. However, it is also true for willow as the planting technology is pretty much the same. Thus, we are not going to distinguish between the two crops.

The study describes planting the short cuttings 20 cm long using the special automated planting machine. The first yield comes in 3 years. Then the harvesting occurs every other year. Planting density: 12,000 pcs/ha

The task is to compare business models of planting the crops on each side of the road in 6-8 rows (the width approx. 16 m per side) with separate analysis of the areas of 50 ha, 100 ha, and 1000 ha. This layout means that to plant 1 ha you need to travel 310 m along the road. This leads to extension of all supply chain. For example, transportation of seedlings during the planting, delivery the equipment to the location and back to a depo, wood chips transport to the storage etc.

In addition, some sections of protective strips along the road could be inclined. Forest strips are usually used for terrain slopes of no more than 2°. However, the energy crops could be cultivated at even bigger slopes. The limitation factor here is the agriculture machinery which can operate at the slopes up to 8°.

Table 5. Initial data for financial modeling

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>1000 ha</th>
<th>100/50 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedlings price incl. transport</td>
<td>EUR/pcs</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Harvesting cycle</td>
<td>years</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Yield (after 3 years)</td>
<td>t/ha</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Planting density</td>
<td>pcs/ha</td>
<td>12,000</td>
<td></td>
</tr>
<tr>
<td>Land recultivation (unrooting, cleaning etc)</td>
<td>EUR/ha</td>
<td>2,150</td>
<td></td>
</tr>
<tr>
<td>Rent of land</td>
<td>UAH/ha</td>
<td>1,200</td>
<td></td>
</tr>
<tr>
<td>OPEX for harvesting (fuel, repairs etc)</td>
<td>UAH/ha</td>
<td>7,200</td>
<td></td>
</tr>
<tr>
<td>Director</td>
<td>EUR/m</td>
<td>1,000</td>
<td>500</td>
</tr>
<tr>
<td>Agronomist salary</td>
<td>EUR/m</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Other admin. expenses (fuel, car, materials etc)</td>
<td>EUR/year</td>
<td>6,000</td>
<td>3000</td>
</tr>
<tr>
<td>Reserve</td>
<td>EUR/ha/yr</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Price of wood chips (at plantation, on-truck stream)</td>
<td>UAH/t</td>
<td>1,200</td>
<td></td>
</tr>
<tr>
<td>Windstrips’ service fee</td>
<td>UAH/ha/yr</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Income TAX</td>
<td>%</td>
<td>18.00%</td>
<td></td>
</tr>
</tbody>
</table>

The current circumstances exclude any bank funding in Ukraine. However, the bank funding (if such happens) shall improve the project feasibility.
The planting process requires a high level of coherence of actions. Also you need to organize many processes: machinery, people, papers, fuel, land etc. Therefore, it is smart to plan some steps. Each following year we are going to plant more hectares.

**Table 6. Planting steps schedule**

<table>
<thead>
<tr>
<th>Year</th>
<th>new area</th>
<th>Total area</th>
<th>new area</th>
<th>Total area</th>
<th>new area</th>
<th>Total area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000 ha Scenario</td>
<td>100 ha Scenario</td>
<td>50 ha Scenario</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>2025</td>
<td>100</td>
<td>150</td>
<td>50</td>
<td>100</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>2026</td>
<td>425</td>
<td>575</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>2027</td>
<td>425</td>
<td>1,000</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>2028</td>
<td>0</td>
<td>1,000</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>next years</td>
<td>0</td>
<td>1,000</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>50</td>
</tr>
</tbody>
</table>

![Figure 6. Needed land bank and planting steps](image)

Machinery (either rent or purchase) need to be prepared for the following operations:
- land Recultivation (bulldozers, unrooting machines, forest harvester, wood chipper, tractors with heavy disks, dump trucks etc.)
- field preparation works (>200 hp tractor, plough, disks, cultivator etc.)
- planting (special machines, tractor to drag the machine, disks and mulcher for weeding, sprinkler for chemicals)
- harvesting (harvester with a special SRC head)

The rent/purchase solution is based on the financial feasibility which in turn depends on the size of plantation.
Table 7. Machinery need and prices

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Purchase price, EUR</th>
<th>Rent, EUR/ha</th>
<th>speed (ha/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic planter</td>
<td>50,000</td>
<td>200</td>
<td>12</td>
</tr>
<tr>
<td>Tractor 80 hp (T-80)</td>
<td>15,000</td>
<td>70</td>
<td>vary</td>
</tr>
<tr>
<td>Tractor 200 hp</td>
<td>100,000</td>
<td>140</td>
<td>vary</td>
</tr>
<tr>
<td>Sprinkler</td>
<td>1,500</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Discs / harrows</td>
<td>2,000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Claas Jaguar + HSAB chipping head</td>
<td>400,000</td>
<td>350</td>
<td>6</td>
</tr>
</tbody>
</table>

Figure 7. Planting machines examples

Table 8. Chemical need and prices

<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Consumption, l/ha</th>
<th>Price, EUR/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>0, 1</td>
<td>Roundup Max</td>
<td>2.4</td>
<td>9.0</td>
</tr>
<tr>
<td>1, 2</td>
<td>Insecticide</td>
<td>0.5</td>
<td>20.0</td>
</tr>
<tr>
<td>1</td>
<td>Stomp</td>
<td>3.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

10. Results of the Modeling

The capital expenditures (CAPEX) include land preparation works, seedlings, machinery, chemicals and labor for planting and the care costs for the first vegetation year.

Table 9. Capital expenditures

<table>
<thead>
<tr>
<th>OPERATION NAME</th>
<th>Unit</th>
<th>1,000</th>
<th>100</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land recultivation (unrooting, cleaning etc)</td>
<td>EUR/ha</td>
<td>2,150</td>
<td>2,150</td>
<td>2,150</td>
</tr>
<tr>
<td>Seedlings</td>
<td>EUR/ha</td>
<td>888</td>
<td>888</td>
<td>888</td>
</tr>
<tr>
<td>Planting services</td>
<td>EUR/ha</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Ploughing (buy as a service)</td>
<td>EUR/ha</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Discing, cultivation (buy as a service)</td>
<td>EUR/ha</td>
<td>0(^{23})</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Rent of planting machine</td>
<td>EUR/ha</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Longer Supply Chain cost</td>
<td>EUR/ha</td>
<td>51</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>Planting costs (incl. tractor rent, salaries, fuel, materials)</td>
<td>EUR/ha</td>
<td>247</td>
<td>267</td>
<td>267</td>
</tr>
<tr>
<td>Subtotal 1</td>
<td>EUR/ha</td>
<td>3,546</td>
<td>3,766</td>
<td>3,766</td>
</tr>
<tr>
<td>CAPEX on Machinery</td>
<td>EUR/ha</td>
<td>59</td>
<td>35</td>
<td>70</td>
</tr>
<tr>
<td>Planting Machinery</td>
<td>EUR/ha</td>
<td>400</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Harvesting Machinery</td>
<td>EUR/ha</td>
<td>459</td>
<td>35</td>
<td>70</td>
</tr>
<tr>
<td>Subtotal 2</td>
<td>EUR/ha</td>
<td>405</td>
<td>380</td>
<td>3,836</td>
</tr>
<tr>
<td>Grand Total</td>
<td>EUR/ha</td>
<td>4,005</td>
<td>3,801</td>
<td>3,836</td>
</tr>
</tbody>
</table>

Table 10. Capital expenditures by planting steps

<table>
<thead>
<tr>
<th></th>
<th>1000 ha</th>
<th></th>
<th>100 ha</th>
<th></th>
<th>50 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planting services</td>
<td>Machines</td>
<td>Total</td>
<td>Planting services</td>
<td>Machines</td>
</tr>
<tr>
<td>2024</td>
<td>177,300</td>
<td>53,500</td>
<td>230,800</td>
<td>188,300</td>
<td>3,500</td>
</tr>
<tr>
<td>2025</td>
<td>354,601</td>
<td>53,500</td>
<td>354,601</td>
<td>188,300</td>
<td>188,300</td>
</tr>
<tr>
<td>2026</td>
<td>1,507,053</td>
<td>5,700</td>
<td>1,512,753</td>
<td>1,507,053</td>
<td>400,000</td>
</tr>
<tr>
<td>2027</td>
<td>1,507,053</td>
<td>400,000</td>
<td>380,101</td>
<td>188,300</td>
<td>3,500</td>
</tr>
<tr>
<td><strong>SUM</strong></td>
<td><strong>3,546,008</strong></td>
<td><strong>459,200</strong></td>
<td><strong>4,005,208</strong></td>
<td><strong>380,101</strong></td>
<td><strong>188,300</strong></td>
</tr>
</tbody>
</table>

The operational expenditures (OPEX) consist on administrative costs, M&O, land rent, O&M of harvesting machine and rent of the harvesting machine.

\(^{23}\) Here the rent = “0” because of the planting machine purchase (50,000 EUR)
Table 11. Operational expenditures at harvesting

<table>
<thead>
<tr>
<th></th>
<th>EUR/ha</th>
<th>1,000</th>
<th>100</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting (as a service)</td>
<td></td>
<td>0</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Harvesting O&amp;M</td>
<td>EUR/ha</td>
<td>171</td>
<td>Incl.</td>
<td>Incl.</td>
</tr>
</tbody>
</table>

Table 12. Operational expenditures by years

<table>
<thead>
<tr>
<th></th>
<th>1000 ha</th>
<th>100 ha</th>
<th>50 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>Admin, rent</td>
<td>Total</td>
<td>Harvest</td>
</tr>
<tr>
<td>2024</td>
<td>0</td>
<td>34,943</td>
<td>34,943</td>
</tr>
<tr>
<td>2025</td>
<td>0</td>
<td>38,300</td>
<td>38,300</td>
</tr>
<tr>
<td>2026</td>
<td>0</td>
<td>52,568</td>
<td>52,568</td>
</tr>
<tr>
<td>2027</td>
<td>8,571</td>
<td>66,835</td>
<td>75,407</td>
</tr>
<tr>
<td>2028</td>
<td>17,143</td>
<td>66,835</td>
<td>83,978</td>
</tr>
<tr>
<td>2029</td>
<td>81,429</td>
<td>66,835</td>
<td>148,264</td>
</tr>
<tr>
<td>2030</td>
<td>90,000</td>
<td>66,835</td>
<td>156,835</td>
</tr>
<tr>
<td>next</td>
<td>changing</td>
<td>66,835</td>
<td>changing</td>
</tr>
</tbody>
</table>

Table 13. Internal rate of return (IRR) for the poplar plantations along the roads

<table>
<thead>
<tr>
<th></th>
<th>1000 ha</th>
<th>100 ha</th>
<th>50 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.29%</td>
<td>0.7%</td>
<td>-10.2%</td>
</tr>
</tbody>
</table>

The cash flow for Scenario 1 is presented below. The project lifespan is 20 years.
### Table 14. Cash flow of 1000-ha plantation

<table>
<thead>
<tr>
<th>Year</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
<th>2027</th>
<th>2028</th>
<th>2029</th>
<th>2030</th>
<th>2031</th>
<th>2032</th>
<th>2033</th>
<th>2034</th>
<th>2035</th>
<th>2036</th>
<th>2037</th>
<th>2038</th>
<th>2039</th>
<th>2040</th>
<th>2041</th>
<th>2042</th>
<th>2043</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenues</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>71,429</td>
<td>142,857</td>
<td>678,571</td>
<td>750,000</td>
<td>678,571</td>
<td>750,000</td>
<td>678,571</td>
<td>750,000</td>
<td>678,571</td>
<td>750,000</td>
<td>678,571</td>
<td>750,000</td>
<td>678,571</td>
<td>750,000</td>
<td>678,571</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest OPEX</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-8,571</td>
<td>-17,143</td>
<td>-81,429</td>
<td>-90,000</td>
<td>-81,429</td>
<td>-90,000</td>
<td>-81,429</td>
<td>-90,000</td>
<td>-81,429</td>
<td>-90,000</td>
<td>-81,429</td>
<td>-90,000</td>
<td>-81,429</td>
<td>-90,000</td>
<td>-81,429</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other admin</td>
<td>-6,250</td>
<td>-6,750</td>
<td>-8,875</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td>-11,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-10,598</td>
<td>-9,455</td>
<td>-106,770</td>
<td>-95,455</td>
<td>-106,770</td>
<td>-95,455</td>
<td>-106,770</td>
<td>-95,455</td>
<td>-106,770</td>
<td>-95,455</td>
<td>-106,770</td>
<td>-95,455</td>
<td>-106,770</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAPEX</td>
<td>-230,800</td>
<td>-354,601</td>
<td>-1,512,753</td>
<td>-1,907,053</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cumulative</td>
<td>-265,743</td>
<td>-658,643</td>
<td>-2,223,964</td>
<td>-4,086,715</td>
<td>-3,651,863</td>
<td>-3,165,498</td>
<td>-2,730,616</td>
<td>-2,244,221</td>
<td>-1,809,369</td>
<td>-1,322,974</td>
<td>-888,122</td>
<td>-401,727</td>
<td>33,125</td>
<td>519,520</td>
<td>954,372</td>
<td>1,440,767</td>
<td>1,875,619</td>
<td>2,862,014</td>
<td>2,796,866</td>
<td></td>
</tr>
<tr>
<td>IRR</td>
<td>7.29%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11. Compare the business model of growing energy crops along highways and in agricultural fields.

From the economical perspective, there are two main differences between the energy crops along the highways and agricultural fields:

- much lower cost of land preparation works for the agricultural fields. It is usually no need to make an expensive unrooting, cleaning etc. In the most cases we use meadow or pasture covered with grass and small bushes. Thus, the costs are within 100-300 EUR/ha
- the layout of a common field (it is usually wide unlike forest strips) leads to a shorter supply chain and less planting cost.

Using the same modeling approach the result for arable lands is following:

Table 15. Internal rate of return (IRR) for the poplar plantations at the arable agricultural field

<table>
<thead>
<tr>
<th></th>
<th>1000 ha</th>
<th>100 ha</th>
<th>50 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR</td>
<td>16.06%</td>
<td>6.35%</td>
<td>-8.3%</td>
</tr>
</tbody>
</table>

12. Summarize the investment attractiveness of growing energy crops along highways for potential investors.

The present conditions are not very attractive for business. The cost of land recultivation is far too high. And the future revenues hardly compensate for the high CAPEX. The IRR of 7% is quite low for Ukrainian conditions and the risks are very high (not only due to the war). For example, the Ukraine 10Y Government Bond has an estimated 23.363% yield\(^{24}\).

In order to increase the attractiveness, it is offered to consider the following measures:

1) Pay for land recultivation services. In theory, the road service company should care for the forest strips and provide appropriate maintenance.
2) Cancel or lower the land rent price.
3) Introduce forest strip service fee. The land along the roads belongs to the road company. They are obviously in charge of maintaining the good condition of the plants.

Below we model the situation: 100% subsidy for recultivation; land rent price = 0; forest strips service fee = 30 EUR/ha.

Table 16. Internal rate of return for the poplar plantations along the roads applying state support measures

<table>
<thead>
<tr>
<th></th>
<th>1000 ha</th>
<th>100 ha</th>
<th>50 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR</td>
<td>19.87%</td>
<td>9.8%</td>
<td>-2.9%</td>
</tr>
</tbody>
</table>

We can see that this situation could be attractive for an investor as the IRR is approaching 20% (period - 20 years).

12.1. Sensitivity

The Sensitivity analysis is applied abovementioned scenario 1000 ha with subsidies, with a basic IRR rate of 19.87%.

1. Best Case scenario
   a) Seedling price: -15% discount; price =0.063 EUR/pc
      IRR= 21.1%
   b) Price of biomass: 15% increase; 1380 UAH/t
      IRR= 22.7%
   c) Yield: 15% increase; 57.5 t/ha per harvest
      IRR= 22.7%

Combination: a+b+c
IRR = 27.3%

Table 17. Sensitivity analysis for the best case scenarios

<table>
<thead>
<tr>
<th></th>
<th>Basic Scenario</th>
<th>a) Seedlings price discount -15%</th>
<th>b) Chips price increase +15%</th>
<th>c) Yield increase +15%</th>
<th>Best Case Combination a+b+c</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR</td>
<td>19.87%</td>
<td>21.1%</td>
<td>22.7%</td>
<td>22.7%</td>
<td>27.3%</td>
</tr>
</tbody>
</table>

2. Perfect Storm scenario:
   - seedlings=+15%, wood chips price=-15%; yield = -15%
IRR = 12.9%

Table 18. Sensitivity analysis for the perfect storm scenario

<table>
<thead>
<tr>
<th></th>
<th>Basic Scenario</th>
<th>Perfect Storm seedlings=+15%, wood chips price=-15%; yield = -15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR</td>
<td>19.87%</td>
<td>21.1%</td>
</tr>
</tbody>
</table>
13. Assess the expediency of directing state funding to the specified projects

According to the presented business model, energy crops along the roads have relatively high capital investment due to huge land preparation works. The calculations show that the profitability increases together with the scale of the project (planted area). But anyway, even in a case of 1000 hectares the IRR is only 7.3%, which is absolutely low for a potential investor. Therefore, some State support (cheap loan or subsidies) could make the project more attractive for private investments.

In the present study we tried to model such a subsidy. For example, the Land recultivation costs play a significant role in the profitability of the energy crops project. As a Road Service company should provide a service and maintenance of the forest strips it is easy to imagine some cooperation in this regard. For example, a Road Service company could prepare the land along the roads (and obviously they have an appropriate machinery and experience) and the Energy Crop company will establish plantation and provide the service of the forest strip for the next 20 years. Some additional subsidies could be some forest strip service fee (e.g. 30 EUR/ha) and decrease or cancel the land rent. In this case the 1000-ha project will show almost 20% of the IRR.

14. Planting of energy crops and carrying out research work on a pilot site along the highway

The current study foresees renovation of old or creating new forest strips along the road using the fast-growing trees. The forest strips should meet the road safety rules according to Rules for Maintenance and Preservation of Forest Strips. Also the renovated forest strips should provide following road safety functions: manage snow dispersal and ice formation, reduce sideward, increase fire safety.

Pilot project should be established in Kyiv Oblast. The Ministry of Infrastructure will provide a site along the regional road (will be determined later). The energy crops will be planted on both sides of the road 1,000 m. The width of one forest belt is 16 m, thus the total area will be 32,000 m².

In case of production plantations (>50 ha) it is feasible to use small cuttings (±25 cm). The cuttings are relatively cheap, moreover, the planting process could be automatized with special planting machines. However, there are some drawbacks such as higher requirements for the land quality, weeding and bug control.

However, for the pilot (study) project we suggest to use the rods of 1.0 m and 1.5 m long. The long rods have better survival rate and could be harvested a year earlier, which is a big

25 [https://zakon.rada.gov.ua/laws/show/650-2020-%D0%BF#Text](https://zakon.rada.gov.ua/laws/show/650-2020-%D0%BF#Text)
advantage for the study purposes. For example, planting in spring 2024, the first cut will be by the end of 2026.

The study program should include a comparison of the different growing cycles and planting layouts. Therefore, the planting scheme will be complex: from 3,200 to 12,000 pcs per ha. The total amount of needed planting material roughly amounts to 20,000 pcs (preliminarily). The average retail price is 20 CZK/pc (or 0.8 EUR/pc)\(^\text{26}\).

**Planting material**
- seedlings = 20,000 EUR;
- VAT on seedlings 20% = 4,000 EUR;
- customs duties 5% = 1,000 EUR;
- delivery from the EU to Kyiv (assume 1,500 km) = 3,000 EUR.

Total: **28,000 EUR**

**Land preparation**
The soil should be properly prepared. The nature of works and its cost depend on the concrete land plot and the condition of the forest belt (bushes, trees, stumps, etc). Therefore, on this stage we cannot estimate the costs accurately. However, in our model (see Section 9) we assume the land recultivation costs of 2,150 EUR per ha. We can use this cost as a basis. Thus, the field preparation costs could be up to **7,000 EUR**.

It is important to emphasize that the land preparation works should be started 9 – 6 months before the planting date (summer-autumn in case of spring planting).

**Planting and 1\textsuperscript{st} year care**
An experimental plantation of 3.2 ha will use more resources and specific costs than a standard production plantation (effect of scale). For example, here we need to use a manual labour as it is not feasible to buy or even rent the planting machine for such a small plantation. Also, we need to hire outsource companies to perform agricultural services. The estimated costs are presented in the table below.

<table>
<thead>
<tr>
<th>Service</th>
<th>EUR/ha</th>
<th>EUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing (buy as a service)</td>
<td>100</td>
<td>320</td>
</tr>
<tr>
<td>Discing, cultivation (buy as a service)</td>
<td>100</td>
<td>320</td>
</tr>
<tr>
<td>Manual planting costs (incl. salaries, materials)</td>
<td>800</td>
<td>2,560</td>
</tr>
<tr>
<td>Chemicals and weeding (buy as a service)</td>
<td>250</td>
<td>800</td>
</tr>
</tbody>
</table>

**Sum: 4,000 EUR**

Overall, the estimated costs to establish a pilot plantation along 1,000 m of the road in Kyiv oblast is approximately **39,000 EUR**.

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\(^{26}\) [https://www.vypestujsiles.cz/cenik/](https://www.vypestujsiles.cz/cenik/)
The research work on the pilot plantation will study the impact of energy crops on road safety, road quality, CO\textsubscript{2} absorption, fire safety, snowstorms, soil erosion etc. At this stage the cost of such a study is hard to estimate. It depends on the Terms of References and the study program. However, it is more or less accurate to judge the overall timing of the study. At least, it should cover the period from land preparation to the first cut – 3 years or more.

**Conclusions and Recommendations**

Forest strips are effective means of improving road safety, reducing noise and dust reflection, preserving biodiversity, protecting water resources, etc. However, it is important to ensure proper care and conservation of forest strips to ensure their functionality and maximum ecological effect. Ukraine has an extensive network of roads and railways with a total length of 190,000 km. Not all roads are equipped with protective forest strips. In addition, as a result of illegal logging, fires, natural disasters and lack of care, a large part of the forest strips are in a neglected state (or completely destroyed) and have lost their protective properties. However, the work to restore forest strips requires significant capital investments, which can be a burden for state-owned companies that operate highways.

The use of fast-growing trees in forest strips can help to restore the forest strips, as an additional product appears here - fuel feedstock, the income from which can compensate for the costs of reclamation of forest strips. Under certain conditions, the cultivation of fast-growing energy trees on roadside strips can be attractive to a private investor.

The energy crops along the roads require relatively high capital investment. Substantial part of the initial investment is related to the land preparation costs. In contrast to agricultural fields, the land along the highways usually requires additional works e.g., cutting of old plants and bushes, unrooting, deep plowing, leveling etc. In addition, the longer supply chain increases the costs for highways even more.

The modeling shows that a financial result is significantly affected by the scale of the project. For example, a basic plantation of 1,000 ha along the highways results in IRR of 7%, while a 100-ha plantation has IRR of 1% only. Today, this level of profitability is unlikely to be sufficient to attract private investment and not enough to compensate for the risks. Even before the war the investors used to seek projects with IRR more than 20%.

Some financial tools such as available bank loans, private-public partnerships, or a state subsidy could be a gamechanger.

There are some recommendations for the government that could help to open the sector of energy crops along the roads:

- compensate for or purchase the land recultivation services. In theory, a road service company should care for the forest strips and provide appropriate maintenance;
- waive or substantially reduce the land rent price for energy crops projects;
- introduce forest strips service fee.

The abovementioned measures lead the project IRR to approach 20% value.

The roadside strips renovation needs yet to be assessed, but it is already obvious that we can talk about tens of thousands of hectares. Such renovation plans could be a part of a
bigger strategy of postwar reconstruction of Ukraine, for example, as a part of road reconstruction component.

The energy crops along the highways play an important role for the country:

- Protection from pollution and noise: forest strips can reduce the level of air pollution and noise from highways, which helps to preserve the health of the population.
- Ecological role: forest strips are important for ecology, as they preserve and increase the biodiversity of the region, create conditions for the life of animals and plants, reduce soil erosion and influence the microclimate in the region.
- Resource saving: forest strips are economically beneficial because they can reduce road maintenance costs, reduce the number of accidents and improve traffic conditions.
- Renewable resources: woodlands are a source of renewable resources such as wood which can be used to produce electricity or heat. This type of energy production is environmentally friendly and helps reduce fossil fuels dependence contributing to the Paris Agreement.
- Reducing CO2 emissions: growing energy crops reduces CO2 emissions into the atmosphere.
- Job creation: Growing and caring for energy crops requires labor, which can create new jobs in the regions.
- Beauty and aesthetics: forest strips create a beautiful spectacular landscape, which contributes to improving the aesthetics of the region and attracting tourists.