



## **ANALYSIS OF ADDITIONAL SOURCES OF WOOD FUEL IN UKRAINE**

UABio Position Paper N 15

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## Introduction

Wood biomass traditionally has been widely used in Ukraine for energy production. Before, it was fuelwood used in ovens and domestic boilers. Recently, a great deal of foreign and domestic equipment for the combustion of wood chips, wood pellets and briquettes has been introduced in the country. Demand for wood fuel is growing, while the potential of wood biomass is rather limited, about 2 Mtce/yr (felling residues, wood processing waste, and fuelwood). *Position Paper 15* of the Bioenergy Association of Ukraine analyzes possibility of obtaining wood fuel from such additional sources as shelterbelt forests, shelter forests along motor roads and railways, and also dead wood.

## General description of selected types of protection forests in Ukraine

According to the existing legislation of Ukraine, forests are divided into the following *types* depending on their main role<sup>1</sup>: 1) forests of nature protection, scientific, historical and cultural purposes; 2) recreation and sanitation forests; 3) protection forests; 4) production forests.

*Protection forests* are forest plots that protect natural environment and objects from the negative influence of natural and anthropogenic factors, including:

*forest belts of linear type: shelterbelt forests*, state forest shelter-belts, forest belts along settlements;

*forest plots (forest belts)* situated along canals, *railways* and *motor roads*;

*forest plots (forest belts)* situated along both sides of highways; the area of **250 m** width is excluded from the production forests.



**Fig. 1.** Shelterbelt forests

Main felling is allowed in the protection forests along highways and in the protection forests of up to 100 ha area<sup>2</sup>. Within these forests, there may be *special protection* forest plots, for which only restricted forest exploitation is allowed.

<sup>1</sup> CMU Resolution «On approval of the Order for diving forests into types and identifying special protection forest plots» (№ 733 of 16.05.2007, amended) <http://zakon2.rada.gov.ua/laws/show/733-2007-%D0%BF>

<sup>2</sup> CMU Resolution «On settling matters regarding special use of forest resources»

According to the Law of Ukraine «On natural environmental protection»<sup>3</sup> (Article 60), shelterbelt forests are under *special protection* as natural complexes of high ecology value for keeping favorable environment, preventing and stabilizing negative natural phenomena.

According to the Forest Code of Ukraine<sup>4</sup> (Article 4), *forest resources* include forest plots and *forest shelter-belts of linear type* provided that their area is over **0.1 ha**. Forest belt of less than 0.1 ha may be considered as a group of trees and shrubs on agricultural land and classified as a separate specific object on the land of agricultural purpose.

According to the Land Code of Ukraine<sup>5</sup> (Article 22), shelterbelt forests and other protection plantation (except for those referred to lands of forestry purpose) belong to lands of *agricultural purpose* but are **not agricultural lands**. Shelterbelt forests and other protection plantations may be handed over to the *ownership* of citizens, agricultural enterprises, companies and organizations created by former employees of state communal agricultural enterprises, companies and organizations (Article 25).

It should be noted that *draft law* № 4296<sup>6</sup> of 23.03.2016 suggests the following additions:

to the Land Code of Ukraine:

Land of forest management purposes do not include land under *the linear protection plantations except for those passed forestry sector for the use*.

to the Forest Code of Ukraine:

*Determining the land type for the linear protection plantations based on their end use can be done according to the land related legislation by local authorities which pass the land to ownership or use and create objects of nature protection and historical-cultural purpose.*

It is important taking into account an uncertain legal status of shelterbelt forests that will be described below.

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(№ 761 of 23.05.2007, amended) <http://zakon2.rada.gov.ua/laws/show/761-2007-%D0%BF>

<sup>3</sup> Law of Ukraine "On Natural Environmental Protection" (№ 1264-XII of 25.06.1991, amended) <http://zakon0.rada.gov.ua/laws/show/1264-12/page>

<sup>4</sup> Forest Code of Ukraine (Law № 3852-XII of 21.01.1994, amended) <http://zakon2.rada.gov.ua/laws/show/3852-12>

<sup>5</sup> Land Code of Ukraine (Law № 2768-III of 25.10.2001, amended) <http://zakon2.rada.gov.ua/laws/show/2768-14>

<sup>6</sup> Draft Law of Ukraine «On amending some laws of Ukraine as for determining the target use of land plots under shelterbelt forests» [http://w1.c1.rada.gov.ua/pls/zweb2/webproc4\\_1?pf3511=58501](http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?pf3511=58501)

## Current state of the shelterbelt forests in Ukraine. Existing problems and possible ways to tackle them

Shelterbelt forests (SBF) are artificial plantations that delimit fields and contribute to climate regulation, soil protection and water protection (**Table 1**). Once, they were created in Ukraine as an element of agro-technical measures provide industrial production of agricultural crops<sup>7</sup>. Now these plantations have different wood species, age and structure. Main wood species are red oak (>41%), American ash (15%), bastard acacia (14%)<sup>8</sup>.

Growing shelter-belts for fields is a part of protection forestation that is the basis of *agricultural afforestation*. Taking into account current global warming, specialists of agricultural afforestation consider afforestation as a possible way to mitigate greenhouse effect and negative influence of hot winds<sup>9</sup>.

**Table 1.** Ecology efficiency of forest shelter-belts<sup>10</sup>

| Main indexes   | Open area | Agro-forest landscape |
|--|-----------|-----------------------|
| Water reserve in snow, mm                                    | 70-80     | 110-120               |
| Absorption of water into soil, mm                            | 58-63     | 100-108               |
| Surface flow, mm   | 19-20     | 6-7                   |
| Soil washout, m <sup>3</sup> /ha                             | 3.0-4.0   | 0.5-0.7               |
| Summary evaporation of moisture during vegetation period, mm | 750-760   | 625-640               |
| Relative air humidity at 13-00 in July, %                    | 25-28     | 30-34                 |
| Relative air humidity in dry years, %                        | 14-15     | 20-22                 |
| General number of animal species                             | 35-60     | 83-149                |
| Zoological mass per 100 ha, kg                               | 180-186   | 356-880               |

Without forest belts, air mass may move intensively in winter and spring-winter period that is the main cause of soil erosion (weathering and uneven distribution of fertile layer). In addition, winter

<sup>7</sup> Analytical report on the legal status of shelterbelt forests <http://www.aau.org.ua/pres-sluzba/novini-1/novini-asu/analitichniycentrasuanalitichnanotatkasodopravovogostatusupolezahisnihlisosmug>

<sup>8</sup> Lesnik V.V., Shum I.V. Shelterbelt forests: agrosilvicultural resources, current state, ways for improvement. Presentation by scientists of the Institute of agro-ecology and nature management (Kyiv).

<sup>9</sup> S.V. Rogovskyi, I.D. Vasilenko, V.M. Cherniak, V.M. Khryk. Agricultural afforestation: practical work. Textbook. Kyiv, 2011.

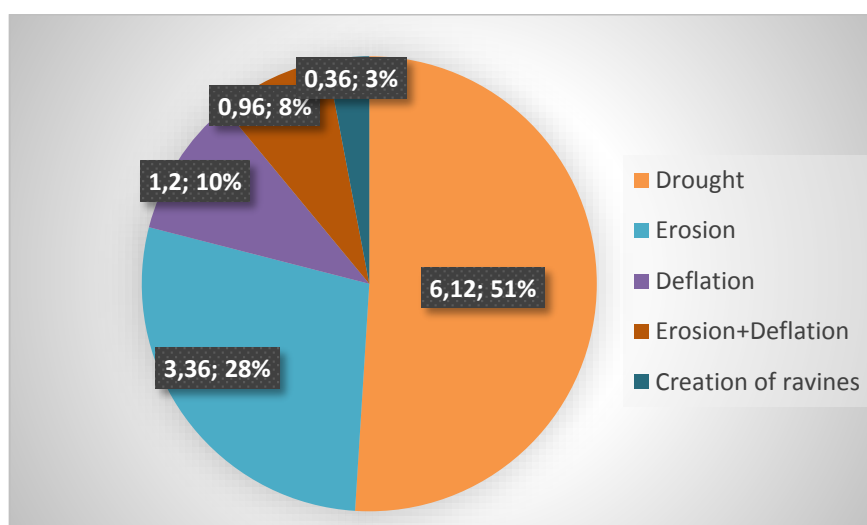
<http://elibrary.nubip.edu.ua/11414/1/%D0%90%D0%B3%D1%80%D0%BE%D0%BB%D1%96%D1%81%D0%BE%D0%BC%D0%B5%D0%BB%D1%96%D0%BE%D1%80%D0%B0%D1%86%D1%96%D1%8F-%D0%BF%D1%80%D0%B0%D0%BA%D1%82%D0%B8%D0%BA%D1%83%D0%BC.pdf>

<sup>10</sup> Source: materials of Ukrainian company AltBioT Ltd that specializes in reconstructing and planting forest shelter-belts.

crops are severely damaged due to uneven distribution of snow layer and freezing-out central parts of a field in winter.

In Ukraine, average yearly loss of agricultural product due to the combined influence of natural and anthropogenic factors is about **10-12 Mt** of grain equivalent<sup>11, 12</sup> (**Fig. 2**). At that, specialists point to the following lines of *the positive influence* of SBF upon agriculture<sup>11, 13, 14</sup>:

- yield of crops increases by 15-20% as compared with unprotected fields;
- agro-chemical properties of soil improve;
- negative influence of wind and water erosion upon the fertile layer is weaker: wind velocity decrease by 20-30% at the fields protected by forest belts;
- microclimate conditions improve: on the lands protected by forest shelter-belts, 80% of moisture penetrate into soil; nonproductive evaporation of moisture decreases by 2 times; temperature of the air surface layer increases by 1-3 °C, and relative humidity grows by 3-5%;
- agricultural land are better protected from motor transport emissions;
- favorable conditions are created for ecological and stable crop farming, for ecological and efficient land use.



**Fig. 2.** Assessment of impact of different factors upon the loss of agricultural product (calculation for **12 Mt** of grain equivalent)<sup>10, 15</sup>

<sup>11</sup> <http://latifundist.com/blog/read/1294-10-insajtov-dlya-agrarijev-ot-profilnyh-i-neprofilnyh-spetsialistov>

<sup>12</sup> Godovaniuk A.Y. Shelterbelt forests have required protection themselves for over twenty years. Legal aspects of the problem // Topical policy problems, 2013, issue 49, p. 228-237.

<sup>13</sup> Openko I.A., Yevsiukov T.O. Land under protection forest plantations for fields: present state, problems, ways for solution // Balanced nature management, № 1, 2014, p.125-131.

[http://natureus.org.ua/repec/archive/1\\_2014/22.pdf](http://natureus.org.ua/repec/archive/1_2014/22.pdf)

<sup>14</sup> Lukisha V.V. Ecology roles of protection forest plantations for fields // Ecology sciences, 2013, № 2, p.56-64.

<http://ecoj.dea.gov.ua/wp-content/uploads/2013/02/shelter.pdf>

<sup>15</sup> Eolian erosion, also called deflation, is the removal of loose, fine-grained particles by the turbulent action of the wind [https://en.wikipedia.org/wiki/Aeolian\\_processes#Eolian\\_erosion](https://en.wikipedia.org/wiki/Aeolian_processes#Eolian_erosion)

Average percentage of protection forests in Ukraine is **1.3-1.5%** while the optimal one should be **3-4.5%** depending on a natural-climatic zone<sup>14, 16, 17</sup>. Thus, to ensure reliable protection of fields, the area of forest shelter-belts must be increased by 2-3 times.

The State program for the formation of the national ecology network of Ukraine for 2000-2015<sup>18</sup> envisaged creation (planting) of 174,000 ha of shelterbelt forests. Activity to increase the area of SBF was also planned by the State target program «Forests of Ukraine» for 2010-2015<sup>19</sup> In reality, the area of SBF does not increase and, moreover, decreases almost every year (**Table 2**) that gives concern to specialists. During past 10 years, there have been planted the same amount of SBF as during one year in 1980s. The dramatic decrease in the forest planting areas directly affected the amount of SBF put into use – their amount was reduced by 90% as compared with 1990<sup>20</sup>.

**Table 2.** Area of the shelterbelt forests in Ukraine<sup>21</sup>

| Data as of: | Area, 1000 ha       |                                    |
|-------------|---------------------|------------------------------------|
|             | Shelterbelt forests | Other protection forest plantation |
| 01.01.2011  | 449.0               | 989.5                              |
| 01.01.2012  | 446.5               | 1000.2                             |
| 01.01.2013  | 446.6               | 1035.6                             |
| 01.01.2014  | 446.1               | 1032.9                             |
| 01.01.2015  | 446.1               | 1034.8                             |

According to official statistical data, at present there are **446,000** ha of the shelterbelt forests in Ukraine. The biggest areas are located in Zaporizhzhia oblast (51,900 ha), Odesa oblast (50,000 ha) and Dnipropetrovsk oblast (42,500 ha), while Ivano-Frankivsk, Rivne and Chernivtsi oblasts do not have SBF at all (**Table 3**).

A number of specialists consider the official statistic data unreliable taking into account that the shelterbelt forests undergo illegal felling, and state inventory of SBF has not been conducted since

<sup>16</sup> Pylypenko O.I., Justification of parameters of the protection forest percentage / O.I. Pylypenko, V.Yu. Yukhnovsky // Scientific bulletin of NAU. – K.: NAU, 1998. – Issue 10. – p. 326-342.

<sup>17</sup> Stadnyk A.P. Problems of the protection afforestation and agricultural afforestation in Ukraine and ways to solve them // Agrobiology. – 2012. - № 8. – p.153-157. [http://www.irbis-nbuv.gov.ua/cgi-bin/irbis\\_nbuv/cgiirbis\\_64.exe?I21DBN=LINK&P21DBN=UJRN&Z21ID=&S21REF=10&S21CNR=20&S21STN=1&S21FMT=ASP\\_meta&C21COM=S&2\\_S21P03=FILA=&2\\_S21STR=agr\\_2012\\_8\\_40](http://www.irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?I21DBN=LINK&P21DBN=UJRN&Z21ID=&S21REF=10&S21CNR=20&S21STN=1&S21FMT=ASP_meta&C21COM=S&2_S21P03=FILA=&2_S21STR=agr_2012_8_40)

<sup>18</sup> Approved by the Law of Ukraine № 1989-III of 21.09.2000 (amended) <http://zakon3.rada.gov.ua/laws/show/1989-14>

<sup>19</sup> Resolution of CMU № 977 of 16.09.2009 (amended) <http://zakon5.rada.gov.ua/laws/show/977-2009-%D0%BF/page>

<sup>20</sup> I. Lytsur. How to prevent disappearance of shelterbelt forests after the end of land reform? <http://ua-ekonomist.com/11548-yak-ne-dopustiti-zniknennya-polezahisnih-Isovich-smug-z-zaknchennyam-zemelnoyi-reformi.html>

<sup>21</sup> Data obtained from the State Statistics Service of Ukraine by request. Letter № 15.2-20/112 of 29.01.2016.



1976<sup>22,23</sup>. Actual area of SBF is assessed by the specialists at **350,000** ha, and to achieve normative indexes it is necessary to plant **700,000** ha more.

**Table 3.** Area of protection forest plantations in Ukraine as of 01.01.2015<sup>21</sup>

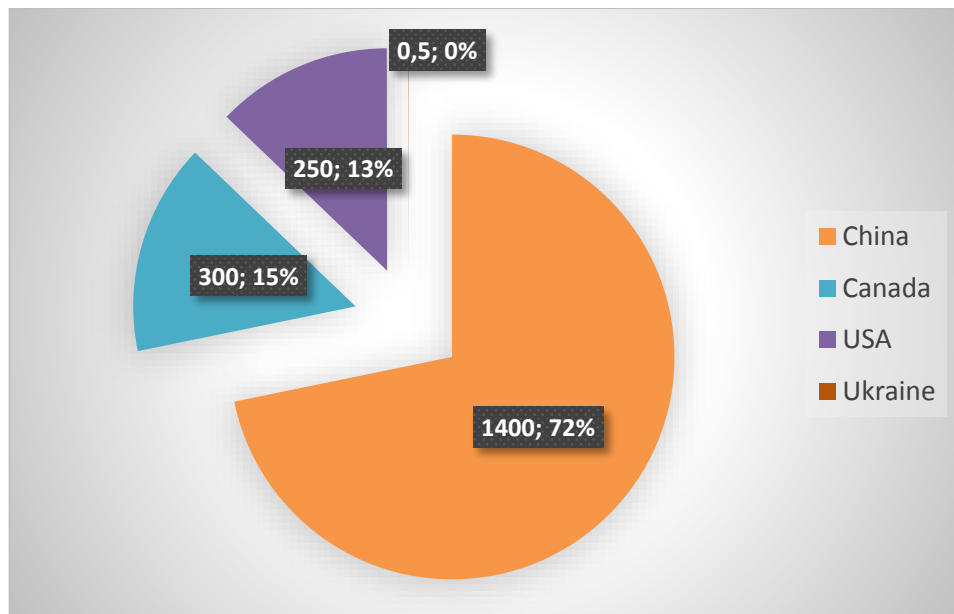
| Oblasts         | Area, 1000 ha       |                                    |
|-----------------|---------------------|------------------------------------|
|                 | Shelterbelt forests | Other protection forest plantation |
| <b>Ukraine</b>  | <b>446.1</b>        | <b>1034.8</b>                      |
| AR Crimea       | 23.9                | 8.6                                |
| Vinnitsia       | 17.6                | 16.0                               |
| Volyn           | 0.2                 | 18.4                               |
| Dnipropetrovsk  | 42.5                | 44.1                               |
| Donetsk         | 31.9                | 21.1                               |
| Zhytomyr        | 5.0                 | 43.1                               |
| Zakarpatska     | 0.1                 | 30.9                               |
| Zaporizhzhia    | 51.9                | 58.2                               |
| Ivano-Frankivsk | -                   | 18.9                               |
| Kyiv            | 12.3                | 53.4                               |
| Kirovograd      | 28.1                | 17.3                               |
| Lugansk         | 30.3                | 115.6                              |
| Lviv            | 0.1                 | 36.8                               |
| Mykolaiv        | 33.8                | 18.9                               |
| Odesa           | 50.0                | 30.3                               |
| Poltava         | 20.0                | 53.5                               |
| Rivne           | -                   | 63.6                               |
| Sumy            | 13.0                | 58.9                               |
| Ternopil        | 0.9                 | 61.1                               |
| Kharkiv         | 26.5                | 123.0                              |
| Kherson         | 29.0                | 56.6                               |
| Khmelnitsky     | 4.2                 | 45.4                               |
| Cherkasy        | 14.1                | 14.6                               |
| Chernivtsi      | -                   | 2.3                                |
| Chernihiv       | 10.3                | 22.9                               |
| Kyiv city       | -                   | 0.2                                |
| Sevastopol city | 0.4                 | 1.1                                |

Shelterbelt forests protect millions hectares of cropland in Ukraine (*1 ha of the forest belt protect 20-30 ha of arable land*). That contributes to more effective use of the land and reduced prime cost of crop growing products<sup>20</sup>. It is obvious that the shelterbelt forests play an important role for the national economy.

<sup>22</sup> V. Nazarenko. Why no one need shelterbelt forests?

<http://www.gorod.cn.ua/news/gorod-i-region/37379-chomu-polezahisni-lisosmugi-nikomu-ne-potribni.html>

<sup>23</sup> V.Yu. Yukhnovsky, V.M. Maliuga, M.O. Shtofel, C.M. Dudarets. Ways to solve the problem of agricultural afforestation <http://nubip.edu.ua/sites/default/files/u39/CNFNNZ.pdf>



**Fig. 3.** Structure of the creation of protection forest plantations in the world, *1000 ha*, 2012<sup>10</sup>

Unfortunately, the shelterbelt forests are now neglected in the country. As a result, they *cannot* play their protection role. In addition, due to the improper state of SBF, up to **3** m of the field bordering the forest plantations come out of agricultural management. After the reconstruction (cleaning cutting) of SBF these parts of the field can be used again. According to data of the Institute of agro-ecology and nature management (Kyiv), as of beginning of 2011 only 5% of the total area of SBF went through the forest amelioration care<sup>8</sup>.

In fact, now the forest shelter-belts belong to nobody as *their owners are unknown*. As a result of the implemented land reform, land shares became private ownership of the farmers, while SBF located on the shares remained in the state ownership. Due to the undivided object of ownership and uncertainty of the state ownership (SBF remained no one's property), the private ownership almost completely "took up" the state ownership. Legal collision also lies in the fact that potentially, shelterbelt forests are the lands for agricultural use but are not agricultural land<sup>20, 22</sup>.

Main part of the shelterbelt forests was created in 1950-70s. They belonged to collective farms and obtained depreciation deductions. The funds were used for the salary of agrosilviculture specialists. Now a private owner is not interested in caring of SBF or paying someone for this. That is why the amount of the shelterbelt forests decreases considerably. And it is connected not only with illegal felling but also with less amount of forest plantations created and put into use. To stabilize the amount of SBF and prevent their decrease and disappearance, it is necessary to put into use about 4,000 ha each year. That requires planting 6,000-7,000 ha of SBF per year. A similar result can be obtained from another calculation, namely, to divide the area of SBF by their lifetime of 60-70 years<sup>20</sup>.

Shelterbelt forests, which are not passed into ownership and are not put into permanent use (about 318,000 ha<sup>23</sup>), are not subject of protection, care and recovery (**Fig. 4**). Absence of improvement felling led to getting up roots and young growth; the number of rodents increased sharply. Illegal felling results in soil sodding and packing, appearance of young growth and shrubs. Very often, forest plantations become the source of weeds, are used as pasture and landfill, and are damaged by fire during burning stubble remains on the fields.



**Fig. 4.** Current state of shelterbelt forests in Ukraine as a result of absence of care of them

Furthermore, forest plantations without proper care *lose* their wind breaking and water regulation properties due to the damage of their *construction*<sup>24</sup>. Air flows do not pass through them, and round the tree and shrub plantations, and the wind blows out the fertile soil from some areas of the field and carries it in excessive quantities on the border of shelterbelts. In addition, some parts of the field have excessive moisture, while the others lack for it<sup>11</sup>.

Thus, the current problems related to the proper management, control and protection of land under SBF that urgently require settlement are<sup>13</sup>:

- identification of the owner of land under SBF and their legal regime;

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<sup>24</sup> Information on shelter forest constructions and wind breaking action is presented in **Annex 1**.

- inventory and registration of land under SBF (quantitative and qualitative) and also their state and land-improvement efficiency;
- improvement of economic condition of SBF and land under them.

Legal basis for the creation of linear shelterbelt forests (including SBF) and shelter forest management is *Conception for the development of agricultural afforestation* (2013)<sup>25</sup>. Implementation of the Conception is planned during 2014-2025 according to the following approved *Action Plan*<sup>26</sup>:

1. To suggest amendments to existing laws and other legal documents regarding reforestation, the use and management of linear shelter forests (hereafter shelter forests) (2015-2016).
2. To develop a state support system for the creation of shelter forests (2016-2017).
3. To carry out inventory of lands under shelter forests (2015-2017).
4. To provide management of the shelter forests (2017-2020).
5. To introduce monitoring of the shelter forests as a part of forest monitoring (2016-2025).
6. To determine norms for the creation of shelter forests taking into account types of soil and natural zones (2015-2018).
7. To develop a qualification description for the position of agrosilviculture specialist (2014-2015).

It should be noted that the above actions are quite well in line with recommendations of Ukrainian specialists as for solving problems of SBF<sup>13, 23</sup>. One of alternative opinions is that inventory of shelterbelt forests at the expense of state budget is not feasible. That is why it is suggested to determine and register the area of existing SBF in the course of their reconstruction (cleaning cutting) and renewal (planting). Specialists also think that SBF must be protected from illegal felling to the extent of criminalizing it.

### **Recommendations for the renewal and reconstruction of shelterbelt forests in Ukraine**

We consider it necessary to perform deep reconstruction and renewal of the shelterbelt forests. The activity must be carried out according to science-based recommendations within a target *State Program* that should be elaborated based on the *Conception for the development of agricultural afforestation*<sup>25, 26</sup>. The activity should be supervised by the Research Institute of Forestry and Agricultural Afforestation (Kharkiv city)<sup>27</sup> that is the leading Ukrainian scientific institution in this area.

Implementation of the suggested State program will result in the *recovery* of protection properties of forest plantations and creation of the additional *resource of wood fuel*. At that, priority should

<sup>25</sup> Resolution by CMU № 725-p of 18.09.2013 <http://zakon5.rada.gov.ua/laws/show/725-2013-%D1%80>

<sup>26</sup> Resolution of CMU № 582-p of 18.06.2014 <http://zakon3.rada.gov.ua/laws/show/582-2014-%D1%80>

<sup>27</sup> <http://uriffm.org.ua/>

be given to *southern-eastern* oblasts of the country as they are agrarian regions with lack natural forest. For these regions, we suggest to plant walnut in the *end rows* of SBF (both, reconstructed and renewed) so that people will be able to collect walnuts and sell to procurement companies. This will allow to launch an additional economic activity.

Thus, the reconstruction of shelterbelt forests in Ukraine will give an opportunity to restore ecosystem balance and increase the yield of agricultural crops by **0.3-0.6 t/ha**<sup>11</sup>. Additional outcome of the state program implementation will be development of local economies and creation of new jobs in rural areas, in amount of about **10,000**.

We suggest the following *basic conception* for the practical implementation of reconstruction and renewal of shelterbelt forests in Ukraine:

- To have right to perform reconstruction and planting of SBF, a specialized company must go through a *tender*. Such companies should possess their *own* (not leased) machinery for felling trees, processing tops and roots and producing wood chips.
- The right to hold tenders should be given to local authorities *at least at the level* of regional state administration. That will allow to avoid possible disputes between districts of an oblasts where the activity on SBF is planned.
- *Private* companies ought to have right to take part in the tender as it is stated in the *Conception for the development of agricultural afforestation*<sup>25</sup> that activity on the optimization of area of linear shelter belts may be financed by investors.
- The company that wins the tender should have *right* for a long-term (20-25 years) leasing or concession of the shelter forests to perform the planned activity. Legal basis for this must be *included* in the current legislation of Ukraine.
- Reconstruction and planting of SBF is carried out mainly at the expense of *investors*.
- Wood obtained in the course of reconstruction and renewal of shelterbelt forests (a) is the *property* of the investor and “*payment*” for his work; (b) *obligatory* must be used for energy (*except for trees that can be used as merchantable wood*).

Wood of SBF in Ukraine is mainly of *low quality* (**Fig. 5**). That is why almost all the residues of the cleaning cutting can be sustainably used for energy. According to expert estimation, in the course of SBF reconstruction one can obtain **100-200** solid m<sup>3</sup> of low-quality wood per hectare<sup>10</sup>. For the country as a whole it is:

$$175 \text{ s.m}^3/\text{ha} \times 446,000 \text{ ha} = \mathbf{78 \text{ mln.s.m}^3}, \text{ or } \mathbf{54.6 \text{ mln.t}}$$

Taking into account that implementation of the State Program will take 15-25 years, annual amount of wood residues available for energy is:

$$78 \text{ mln.s.m}^3/20 \text{ years} = \mathbf{3.9 \text{ mln.s.m}^3/\text{yr}}, \text{ or } \mathbf{2.73 \text{ mln.t/yr (0.93 Mtce/yr)}}^{28}.$$

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<sup>28</sup> Based on 700 kg/m<sup>3</sup> wood density and its heating value of 10 MJ/kg.



**Fig. 5.** Examples of low-quality wood from Ukraine's SBF<sup>10</sup>

### ***Ideas for the implementation of a pilot project in Mykolaiv oblast***

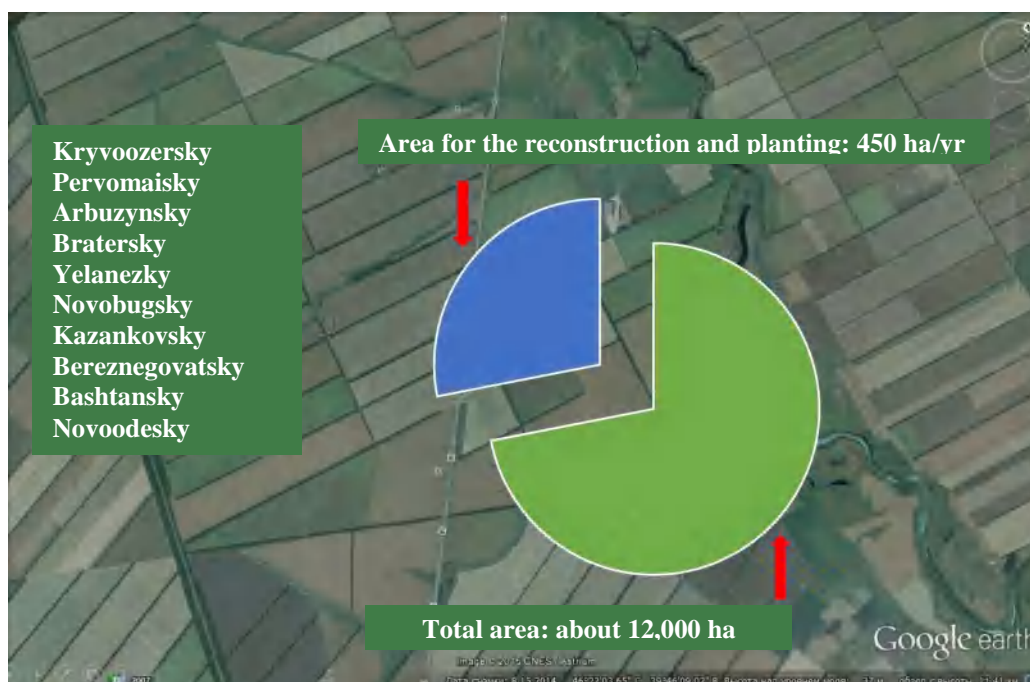
This section presents general description of a *potential pilot project* on the reconstruction and renewal of SBF in Mykolaiv oblast as an example for the replication in other Ukraine's regions. The information is based on a techno-economic assessment developed by a specialized Ukrainian company that has successful experience in this area<sup>10</sup>. It is also envisaged that another specialized organization, the Research Institute of Forestry and Agricultural Afforestation (Kharkiv city)<sup>27</sup>, will participate in the project.

About 12,000 ha of SBF in Mykolaiv oblast are planned to be involved in the project (the total area of SBF in the oblast is over 30,000 ha). It is supposed that annually 450 ha will be reconstructed and renewed (**Fig. 6**).

The project includes the following *stages*:

- Development of legal normative documents that are legal basis for the reconstruction and renewal of shelterbelt forests in Mykolaiv oblast.
- Development of construction documents, assessment of the project cost.
- Execution of reconstruction and renewal of shelterbelt forests.
- Collection of wood residues and production of wood chips.
- Sale of the wood chips to consumers.

It is planned that the work will be done by special certified multiple-skill teams (Fig. 7, 8). The project profit is based on selling wood chips to consumers. Payback period of the project is 2-3 years.



**Fig. 6.** Districts of Mykolaiv oblast involved in the planned pilot project on the reconstruction and renewal of SBF<sup>10</sup>



**Рис. 7.** Certified working teams at work



**Рис. 8.** Machinery used by the working teams

### **Forest plantations alongside of motor roads and railways**

On motor roads, the main source of air pollutants is vehicles. To reduce the level of air contamination, among other technical and sanitary measures, they apply *afforestation alongside of motor roads* (Fig. 9). In addition, the vehicles are also the source of other negative impacts, such as noise and vibration. Forest plantations play an important part in reducing their levels to the established standards (Table 4).



**Fig. 9.** Forest plantations along motor roads



According to State Standard of Ukraine # 3587<sup>29</sup>, shelter forests outside settlements should be located at the distance of at least 8.25-14 from the road edge depending on a road type (**Table 5**). The document also prohibits planting trees and bushes on road borders and shoulders of road. Such plants must be removed during 10 days from the moment of their discovery.

**Table 4.** Reduction of noise level by shelter forests, dB<sup>30</sup>.

| Type of plantation  | Plantation width, m | Reduction of noise level behind the plantation strip, dB |     |     |       |
|---|---------------------|--|-----|-----|-------|
|   |                     | Traffic intensity, cars/hour                             |     |     |       |
|   |                     | <60  | 200 | 600 | >1200 |
| 1. One row with chess trees planting in a strip   | 10                  | 4  | 5   | 5   | 6     |
| 2. Two rows with the distance between rows of 3-5 m; rows are similar to the one row planting | 10                  | 8  | 9   | 9   | 10    |
| 3. Three rows of hardwood species with shrubs in the form of hedges                           | 10                  | 6  | 7   | 8   | 8     |
| 4. Four rows of hardwood species with shrubs in the form two-level fence                      | 15                  | 7  | 8   | 9   | 9     |
| 5. Four rows of coniferous species with chess planting and two-level shrub                    | 15                  | 13   | 15  | 17  | 18    |
| 6. Five rows of hardwood species (similar to item 4)  | 20                  | 8  | 9   | 10  | 11    |
| 7. Five rows of coniferous species (similar to item 5)  | 20                  | 14   | 16  | 18  | 19    |
| 6. Six rows of hardwood species (similar to item 4)   | 25                  | 9  | 10  | 11  | 12    |

**Table 5.** Requirements on the green spaces allocation on public roads<sup>29</sup>.

| Road category | The distance from the roadway edge to the nearest edge of the tree trunk (edge of the shrub), <i>not less than</i> , m |
|---------------|--|
| I             | 14.00  |
| II            | 11.25  |
| III           | 9.50   |
| IV            | 9.00   |
| V             | 8.25   |

An organization responsible for the management of road within a settlement should also supervise observance of the norms as for location of green plantations along the road (**Table 6**). The distance

<sup>29</sup> State Standard of Ukraine (ДСТУ) # 3587. Motor roads, streets and railway crossings. Requirements to operation state // State Standard of Ukraine, 1997. <http://ukryama.com/files/DSTU3587-97UA.pdf>

<sup>30</sup> Environmental requirements for roads. Designing // Sectorial building standards ГБН В.2.3-218-007:2012. State Agency of automobile roads of Ukraine (Ukravtodor) <http://www.ukravtodor.gov.ua/uploads/files/201401/2014-01-09-01-02-05-v-2-3-218-007-2012.pdf>

between the road edge and crown must be at least 0.5 m. If the norm is not observed, cutting (felling) of the green plantation should be performed during a month from the moment of discovery of the violation.

**Table 6.** Requirements on the distance between green spaces and roads in the inhabited locality<sup>29</sup>.

| Distance from the edge of the street roadway to the nearest edge of: |                              |
|--|------------------------------|
| a tree trunk: not less than 4 m                                      | a shrub: not less than 1.5 m |

*Note.* The shrubs height in case of their placement at a distance from 1.5 m to 5 m from the roadway edge should not exceed 0.5 m

It should be noted that together with the positive role (reduction of air pollution and noise level) forest plantations along motor roads play a **negative role**. If in an emergency vehicle is heading off to the roadside, the probability of fatal outcome is much higher in case of a collision with a tree trunk than with the bushes. In the world practice it is more often to consider **gradually changing of forest plantations along the motor roads with a shrub plantations**. Woody biomass obtained in the course of this activity can be used for *energy purposes*.

There is an absence of statistical data on the area of shelter forest along roads. The collection of this data is not provided by the forms the State Statistics Service of Ukraine.<sup>31</sup> So only expert evaluation can be done based on length of public roads of national importance (49117.4 km<sup>32</sup>) and the possible width of forest belts (10 m, see. **Tab. 4**). Accepting that the reconstruction will be carried out on quarter of the road length during 10 years, the total amount of wood fuel will be:

*in total:* 49117.4 km × 10 m × 0.25 × 175 s.m<sup>3</sup>/ha = **2.15** mln. s.m<sup>3</sup>, or about **1.5** mln. t.

*per year:* 2.15 mln. s.m<sup>3</sup>/10 years = **215** th. s.m<sup>3</sup>/year, or **150** kt/year (**51.4** ktce/year)<sup>28</sup>.

According to the State Building Standards<sup>33</sup>, **shelter forest along the railways (Fig. 10)** is used to protect them from snow, sand and earth drifts and the harmful effects of adverse natural phenomena. They are also used to protect against noise during trains passing and against dust during mass transportation of bulk cargo. It should be noted that when the technical measures for the protection of the railway are chosen, preference is given to the creation of shelter forest.

*Special windproof forests*<sup>34</sup> are designed for railways sections undergoing the annual impact of strong winds (with a speed of 15 m/s and above), in places of ice formation and drift of track by a fine soil on non-agricultural land or lands unsuitable for growing crops. The arrangement of windproof forests are permitted on agricultural land with the consent of their owners when gusts

<sup>31</sup> Letter from the State Service of Ukraine for surveying, mapping and cadaster № Г-857/0-593/6-16 of 10.03.2016.

<sup>32</sup> Resolution by CMU № 712 of 16.09.2015 «On approval of the list of public roads of national importance» <http://zakon0.rada.gov.ua/laws/show/712-2015-%D0%BF/page>

<sup>33</sup> State Building Standards B.2.3-19-2008. Transport facilities. Railway track 1520 mm. Design standards. // Ministry of Regional Development of Ukraine, Kyiv, 2008. <http://dbn.at.ua/load/normativy/dbn/1-1-0-126>

<sup>34</sup> Wind decreasing forests are the forests in areas of railways, preventing the annual action of strong winds (with a speed of 15 m/s and above).

of strong wind could endanger the safety of trains. In blizzard areas the width of windproof forests, the design of forest belts and the composition of plantations are developed in general per sample of snow proof forests. It is allowed to take the width of these belts at the level of 12-15 m in areas where the snowstorm is not observed.

The distance from the axis of the last track, located on the embankment and zero locations<sup>35</sup>, to forest is taken 30 m in perpendicular directions of blizzard winds and 20 meters in oblique directions.

In the steppe and forest-steppe zones, on areas that covered with snow, shelter forest is created at the distance of at least 20 m from the axis of the last track, but no closer than 5 m from the excavation edge at the point its biggest depth.



**Fig. 10.** Shelter forest along the railways.

The width of the belts is determined in the process of railway design or implementation of measures to enhance the protection of existing railways and is agreed with the railway service. Shelter forest can have one or many belts, their characteristics and placement depend on soil and climatic conditions and the amount of snow that is fallen during the winter. Approximate characteristics of shelter forest are presented at the **Table 7**.

Oak, pine, larch, ash, spruce, black walnut, Ailant, white acacia, poplar, alder and others can be used as basic species for railways shelter forest in Ukraine. Railway divisions of shelter forest (separated structural divisions of the railway) are created for the care and maintenance of shelter forest.

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<sup>35</sup> Zero location is the section of railway track, where the bottom of track's top is arranged in the marks of natural earth surface (including transition of excavation in the mound).

**Table 7.** Approximate characteristics of shelter forest along railway track <sup>33</sup>.

| Structure of the plantation | Snow gathering, m <sup>3</sup> /linear meter of width | Width of belts, m | The width of the gaps between the belts, m |
|-----------------------------|---|-------------------|--|
| One-belt                    | Up to 100   | 15-35(50)*        | -  |
| 2-3-belts                   | 101-300   | 35-65             | 10-20                                      |
| 3-belts                     | More than 301   | 15-35             | 35-40                                      |

\* *the maximum width of belt for one-belt plantations.*

If the railway track crosses forests, then the adjacent woods belong to a *special protection zone* with width not less than 500 meters from each side. Continuous felling of trees is prohibited in this zone.

We believe that the width of shelter forest along railways is overly broad in many cases. It seems appropriate *to reduce* them to a (maximum) 10 rows of trees. Biomass obtained in the course of this activity could be used for the *production of biofuels*.

Since there is an *absence*<sup>31</sup> of statistical data on the area of shelter forest along railways, only expert evaluation can be done based on length of public railway tracks (20948.1 km<sup>36</sup>), the possible width of forest belts (15 m, see Table 7) and the same assumptions as for shelter forest along motor roads. Then the amount of wood fuel derived from the reconstruction of shelter forests along the Ukrainian railroad will be:

*in total:* 20948.1 km × 15 m × 0.25 × 175 s.m<sup>3</sup>/ha = **1.37** mln. s.m<sup>3</sup>, or about **0.96** mln. t.  
*per year:* 1,37 mln. s.m<sup>3</sup>/10 years = **137** th. s.m<sup>3</sup>/year, or **95.9** kt/year (**32.7** ktce/year)<sup>28</sup>.

## **Dead-wood**

Dead-wood is standing dead trees and bushes. The cause of the formation of dead-wood is sharp climatic fluctuations of temperature and moisture, “lower fire” (burning of dry grass during which trees are not burnt, but much damaged), thermal, chemical, mechanical, or other significant damage of the root system, bark or foliage of trees, as well as their aging and drying<sup>37</sup>.

Experts do not object that the dead wood from natural forests may be almost completely utilized for energy production. Yet it is necessary to leave in place several large trees per hectare for biodiversity<sup>38</sup>.

<sup>36</sup> Data od State Statistical Service of Ukraine

[http://www.ukrstat.gov.ua/operativ/operativ2005/tz/tz\\_rik/tz\\_u/ts\\_u.htm](http://www.ukrstat.gov.ua/operativ/operativ2005/tz/tz_rik/tz_u/ts_u.htm)

<sup>37</sup> <https://uk.wikipedia.org/wiki/%D0%A1%D1%83%D1%85%D0%BE%D1%81%D1%82%D1%96%D0%B9> (Wikipedia).

<sup>38</sup> Legislative and regulatory support for Conservation of Nature in the forest sector of Ukraine. Analytical Report, 2012.

[http://fleg1.fleg.org.ua/fileadmin/user\\_upload/ufs/04.%20Program%20Information/4.02%20Program%20Components/4.02.05%20Public%20Awareness/Final\\_Report\\_June\\_29.pdf](http://fleg1.fleg.org.ua/fileadmin/user_upload/ufs/04.%20Program%20Information/4.02%20Program%20Components/4.02.05%20Public%20Awareness/Final_Report_June_29.pdf)

Dead-wood exists in all woods and along with other types of waste of growing forest plays an important role in the cycle of the organic substances. Under normal conditions, the amount of dead wood is up to 10-11 m<sup>3</sup>/ha. A separate dangerous case for the environment is mass drying of trees, when the amount of dead wood per hectare is increased by the order.

In the Ukrainian Carpathians, the area of diseased firs is growing annually. *Fir forests dry* and fall. The first forestry experts drew attention to the phenomenon about 30 years ago, but lately drying firs become widespread<sup>39</sup>. Forests of Lviv and Ivano-Frankivsk regions have the largest impact. According to the Institute of Ecology of the Carpathians, the main reason for the disease of firs is mottled butt rot and some other factors<sup>40, 41</sup>. Now, the area of drying firs is estimated at 30-35 th. ha, and the volume of dead wood – 7.4 mln. m<sup>3</sup> (**Table 8**). If this area was cleared of dead-wood within 5-10 years<sup>42</sup>, then every year we could get about **0.5-1** mln. m<sup>3</sup> of wood fuel (**0.2-0.4** Mtce).

**Table 8.** Estimation of dead-wood stock in the Ukrainian Carpathians and Polissia

| Region  | Dead-wood area,<br>th. ha | Dead-wood volume,<br>th. m <sup>3</sup> |
|---|---------------------------|---|
| <i>Ukrainian Carpathians (drying of firs)</i>   |                           |   |
| Ivano-Frankivsk   | 30-35 <sup>43,44</sup>    | 4000-7000 <sup>39, 40</sup>             |
| Lviv  |                           |   |
| <i>Ukrainian Polissia*</i><br><i>(dead-wood of soft-leaved forests)</i> <sup>45</sup> |                           |   |
| Volyn   | 5.3                       | 50.1                                    |
| Zhytomyr  | 14.5                      | 165.2                                   |
| Kyiv  | 3.7                       | 52.7                                    |
| Rivne   | 6.8                       | 78.7                                    |
| Sumy  | 6.1                       | 60.0                                    |
| Chernihiv   | 4.0                       | 38.8                                    |
| <i>Total, Ukrainian Polissia</i>  | <i>40.4</i>               | <i>445.5</i>                            |

\*only oblasts which belong to Ukrainian Polissia region were taken into account

<sup>39</sup> Bohdan Skavron. Why the Carpathians are turning reddish? <http://gk-press.if.ua/x4665/>

<sup>40</sup> Bohdan Kushnir. Mass drying of firs in the Carpathians. [http://www.lvivlis.com.ua/uk/Media\\_about\\_us/337.html](http://www.lvivlis.com.ua/uk/Media_about_us/337.html)

<sup>41</sup> The area of diseased firs in the Carpathians has increased.

[http://vidido.ua/index.php/pogliad/article/ploa\\_hvorih\\_smerek\\_u\\_karpatah\\_zbil\\_shilasja\\_-\\_ekologi/](http://vidido.ua/index.php/pogliad/article/ploa_hvorih_smerek_u_karpatah_zbil_shilasja_-_ekologi/)

<sup>42</sup> Academician Myhailo Holubets, honorary director of the Institute of Ecology of the Carpathians, estimates dead-wood fir trees in the Carpathians in 4-5 Mm<sup>3</sup>, and believes that the area must be cleared of fallen trees within 5 years.

[http://www.lvivlis.com.ua/uk/Media\\_about\\_us/337.html](http://www.lvivlis.com.ua/uk/Media_about_us/337.html)

<sup>43</sup> Nadiia Sapyga. Environmental disaster: In the Carpathians fir trees dry by hectares.

[http://zik.ua/news/2015/07/16/ekologichna\\_katastrofa\\_u\\_karpatah\\_smereky\\_vsyhayut\\_gektaramy\\_607957](http://zik.ua/news/2015/07/16/ekologichna_katastrofa_u_karpatah_smereky_vsyhayut_gektaramy_607957)

<sup>44</sup> Svitlana Isachenko. The Carpathians lost firs. <http://www.fleg.org.ua/konkurs-2014/292>

<sup>45</sup> A. Bilous. The stock of dead-wood and debris-strewn soft-leaved forests of Ukrainian Polissia // Scientific reports of NULES, No. 4, 2013.

In soft-leaved forests of Ukrainian Polissia, the total volume of dead wood is estimated at more than 445 th. m<sup>3</sup> over the area of 40 th. ha<sup>45</sup>, including about 165 th. m<sup>3</sup> in the Zhytomyr oblast (14.5 th. ha, and this area has increased over the past 2 years for more than 2 th. ha because of drying pines<sup>46</sup>) (see **Table 8**). More than half of the dead-wood amount of the Ukrainian Polissia is concentrated in birch forests (54%), alder forests (31%), aspen forests (9.3%) and other types of plantations (5.7%). The average amount of dead-wood is 11 m<sup>3</sup>/ha.



**Fig. 11.** Pines drying in forests of Zhytomyr oblast.

Experts believe that in Ukraine the system of forest accounting does not provide reliable information on volumes of dead wood and its development in forests of the country. When forest management, the volumes of dead-wood and fallen trees are evaluated by eye, but only in taxation forest plots<sup>47</sup> with the presence of these categories of wood above a certain limit (usually 5 or 10 m<sup>3</sup>/ha)<sup>48</sup>. Using a specific methodological approach, experts from NULES have estimated the amount of dead-wood in Ukraine at 92.6 mln. m<sup>3</sup> (with a mean square error of 10-15%) (**Table 9**).

Assuming that only *a half* of the total volume of dead-wood is technically achievable and economically viable for utilization over 10 years, this amount will be:

$$92.56 / 2 / 10 = \mathbf{4.63} \text{ mln. m}^3/\text{yr} \text{ or } \mathbf{3.24} \text{ mln. t/yr (1.44 mln. tce/yr)}^{49}.$$

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<sup>46</sup> Pines dry in Zhytomyr forests because of the global warming.

<http://zhzh.info/news/2015-09-10-25010>

<sup>47</sup> Forest plot is one of types of forest areas.

<sup>48</sup> Carbon, climate and land management in Ukraine: the forest sector: Monograph / [A. Shvydenko, P. Lakyda, D. Shchepashchenko, R. Vasylyshyn, Yu. Marchuk]. – Korsun-Shevchenkivskiy: Individual entrepreneur V. Gavryshenko, 2014. – 283 p.

<sup>49</sup> Based on 700 kg/m<sup>3</sup> wood density and its calorific value of 13 MJ/kg.

**Table 9.** Amount of standing dead-wood and fallen dead-wood in forests of Ukraine<sup>48</sup>.

| Region          | The area of forest divisions covered with forest vegetation, th. ha | Volume of wood, mln. m <sup>3</sup> | Volume, mln. m <sup>3</sup> |                  |
|-----------------|---|-------------------------------------|-----------------------------|------------------|
|                 |   |                                     | standing dead-wood          | fallen dead-wood |
| AR Crimea       | 311.5   | 44.59                               | 1.99                        | 1.61             |
| Vinnitsia       | 346.5   | 71.80                               | 3.16                        | 2.55             |
| Volyn           | 624.6   | 127.64                              | 5.23                        | 4.22             |
| Dnipropetrovsk  | 179.2   | 19.78                               | 1.19                        | 0.46             |
| Donetsk         | 184.1   | 25.52                               | 1.42                        | 0.55             |
| Zhytomyr        | 1001.6  | 220.99                              | 9.30                        | 7.51             |
| Zakarpatska     | 656.7   | 211.31                              | 7.91                        | 8.57             |
| Zaporizhzhia    | 101.0   | 6.38                                | 0.61                        | 0.24             |
| Ivano-Frankivsk | 571.0   | 156.26                              | 6.29                        | 6.81             |
| Kyiv            | 655.4   | 164.32                              | 9.65                        | 7.79             |
| Kirovograd      | 164.5   | 24.78                               | 1.29                        | 0.50             |
| Lugansk         | 292.4   | 44.63                               | 2.25                        | 0.88             |
| Lviv            | 621.2   | 158.57                              | 6.65                        | 7.20             |
| Mykolaiv        | 98.2  | 7.37                                | 0.59                        | 0.23             |
| Odesa           | <b>203.9</b>  | 18.54                               | 1.79                        | 0.70             |
| Poltava         | <b>247.4</b>  | 53.69                               | 2.25                        | <b>1.63</b>      |
| Rivne           | <b>729.3</b>  | 137.47                              | 6.04                        | 4.37             |
| Sumy            | <b>425.0</b>  | 109.25                              | 4.76                        | 3.45             |
| Ternopil        | 183.2   | 36.29                               | 1.46                        | 1.06             |
| Kharkiv         | 378.3   | 81.12                               | 3.71                        | 2.69             |
| Kherson         | 116.3   | 11.55                               | 0.83                        | <b>0.32</b>      |
| Khmelnitsky     | 265.1   | 57.03                               | 2.40                        | 1.74             |
| Cherkasy        | <b>315.1</b>  | 72.24                               | 2.76                        | <b>2.00</b>      |
| Chernivtsi      | <b>236.7</b>  | 65.49                               | 2.39                        | 2.59             |
| Chernihiv       | 665.7   | 175.36                              | 6.66                        | 4.82             |
| <b>Total</b>    | <b>9573.9</b>   | <b>2101.97</b>                      | <b>92.56</b>                | <b>74.49</b>     |

## Conclusions

Wood biomass traditionally has been widely used in Ukraine for energy production. Demand for wood fuel is growing, while the potential of wood biomass is rather limited. To increase the energy potential of wood biomass along with the traditional sources (felling residues, wood processing waste, and fuelwood) additional sources should be obtained. They can be shelterbelt forests, shelter forests along motor roads and railways, and also dead wood.

Shelterbelt forests are artificial plantations that delimit fields and contribute to climate regulation, soil protection and water protection. Due to the uncertain legal situation that has created in Ukraine with the owner of SBF, the shelterbelt forests for many years have not received proper care and

gradually have lost their protective properties. Shelterbelt forests need urgent reconstruction and renewal. Through the implementation of these works, it is real to obtain additionally about **1 mln. t/yr** of wood fuel.

Caring of forest belts along motor roads and railways can provide another **84 ktce/yr** of biomass. Dead wood is also a powerful potential source of wood for energy production in the amount of more than **1.4 mln. tce/yr**.

Thus, the total amount of wood fuel from additional sources in Ukraine is estimated at **2.5 mln. tce/yr (Table 10)**. This amount is very significant, because it increases the existing energy potential of wood (**2 mln. tce/yr** from conventional sources) in **2.3** times up to **4.5 mln. tce/yr (Fig. 12)**.

**Table 10.** Estimation of fuel wood resources from additional sources in Ukraine.

| Source of wood fuel  | Total,<br>mln. t* | Number of years<br>of use ** | Annual potential of wood fuel<br>(technically achievable, economically<br>feasible) |             |
|----------------------|-------------------|------------------------------|---|-------------|
|                      |                   |                              | kt/yr   | ktce/yr     |
| SBF                  | 54.6              | 20                           | 2730  | 932         |
| SF along motor roads | 1.5               | 10                           | 150   | 51.4        |
| SF along railways    | 0.96              | 10                           | 96  | 32.7        |
| Dead wood            | 32.4              | 10                           | 3240  | 1440        |
| <b>Total</b>         | <b>89.46</b>      |                              | <b>6216</b>   | <b>2456</b> |

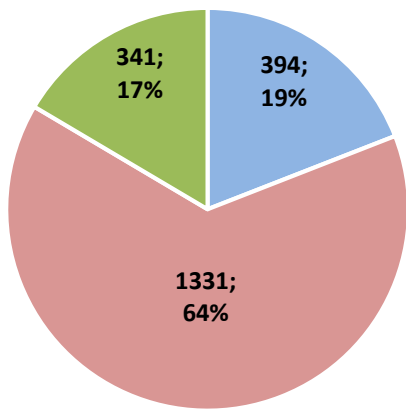
\* For the evaluation of the technical/economic potential of wood fuel

\*\* As a guide.

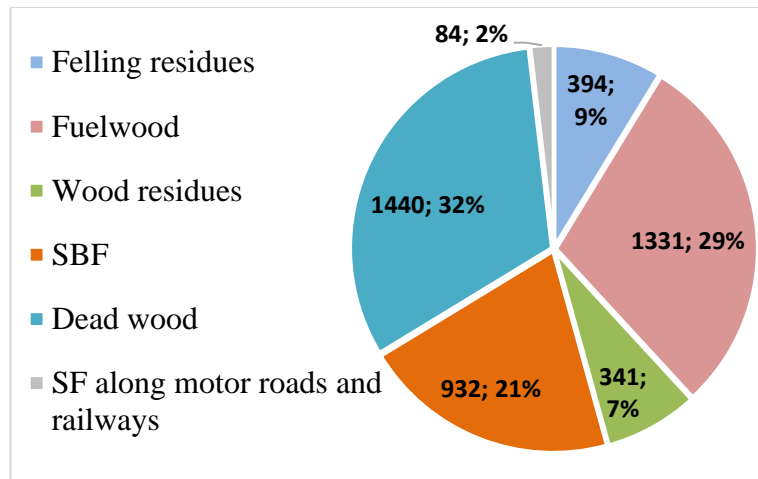
Participation of **private companies**, which will be able to **raise funding and provide appropriate material resources**, is vital for the implementation of projects for the reconstruction and renewal of SBF, obtaining of wood fuel by ordering other protection plantation, and harvesting of dead wood. To do this, *some amendments and additions* should be introduced in the current legislation of Ukraine. These changes should *resolve a number of important questions*, including:

- identifying of an owner of shelterbelt forests;
- granting the right to hold a tender for reconstruction and renewal of SBF to local authorities at the level not lower than the oblast state administrations;
- providing the possibility of long-term lease of SBF and other protective plantations for private companies;
- providing the possibility for private business to have an access to dead wood and logging waste.





Wood biomass from traditional sources:  
total 2067 ktce/yr



Wood biomass from traditional  
and additional sources: total 4523 ktce/yr

**Fig. 12.** Energy potential of wood biomass in Ukraine (2014).

## Annex 1. Constructions of shelter forests

**Construction** is a geometrical arrangement of trees and shrubs in the area, which provides in longitudinal and vertical section of a shelter forest the presence of gaps, changes the aerodynamic properties of the surface wind flow throughout the entire life cycle and determines the ameliorative effect on the surrounding areas. Dimensions of clear spaces and their area determine wind penetration (openness) of linear plantations. There are thickly planted (windproof), open planted and thinly planted constructions<sup>9</sup>.

**Thickly planted (windproof) shelter forest** is complex mixed plantings with shrubs (bushes), in which the last mentioned make up about a third. They are characterized by the presence of small gaps in the longitudinal profile of a shelter forest. Most of the air flows flow over such shelter forests, and about 10% of the wind passes through them.

**Open planted shelter forest** is characterized by more equal distribution of gaps in the longitudinal profile of a shelter forest (15-35%), and its wind penetration reaches 50-75%. The main amount of the air flows passes through the gaps, the rest flow over the shelter forest. Openness of the shelter forest depends on the wood species (here high bushes is 10-20%) and the width. Its density can be adjusted by cleaning cuttings.

**Thinly planted shelter forests** are characterized by more equal distribution of gaps between tree stems, tree crowns and near the ground area of the longitudinal profile of the shelter forest. There are no bushes, but there are low-growing shrubs (up to 1 m) in such shelter forest. Sometimes there are tall bushes in the lower storey, but they periodically (3-5 years) are polled, that is cut down. There are very few gaps in the crowns, but they amount to 30-70% in the middle and lower parts of the longitudinal profile of the shelter forest. Wind penetration of such shelter forest is 70-75%.

**The effectiveness** of wind-regulating shelter forests is determined by their influence on the surrounding area and the degree of reduction of the wind speed. The greater the height of the shelter forest, the larger area it protects. **The distance of the protective effect** of shelter forests (wind shade) is determined by the distance multiplied on the average height of trees in the shelter forest. It is higher in thinly planted shelter forests than in thickly planted ones.

**The distance of wind braking effect** of shelter forests is expressed by the distance multiplied on their height. Maximum impact of the thickly planted shelter forest on reducing of wind speed at ground level is 40H (height), open planted – 60 H, thinly planted – 80 H. However, the most effective affected area (average) of thickly planted construction is 15H, open planted – 20 H, thinly planted – 20-30 H. This figure depends on wind penetration of the shelter forests and wind speed.

**By types of construction**, SBF in Ukraine are divided into thinly planted (16.8%), open planted (31.6%), and thickly planted (16.8%)<sup>8</sup>.

## **Abbreviations**

CMU – Cabinet of Ministers of Ukraine

ha – hectare

ktce – thousand tons of coal equivalent

mln. – million

Mtce – million tons of coal equivalent

NULES – National University of Life and Environmental Sciences of Ukraine

mln.s.m<sup>3</sup> – million tons of solid m<sup>3</sup>

SBF – shelterbelt forests

SF – shelter forests

s.m<sup>3</sup> – solid m<sup>3</sup>

th. – thousand

## **Previous publications by UABio**

<http://www.uabio.org/activity/uabio-analytics>

1. *Position Paper N 1* (2012) “Position of bioenergy in the draft updated energy strategy of Ukraine till 2030”.
2. *Position Paper N 2* (2013) “Analysis of the Law of Ukraine “On amending the Law of Ukraine «On Electricity” No5485-VI of 20.11.2012”.
3. *Position Paper N 3* (2013) “Barriers to the development of bioenergy in Ukraine”.
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Civic union "Bioenergy Association of Ukraine" (UABio) was established to create a common platform for cooperation on bioenergy market in Ukraine, as well as to provide the most favorable business environment, accelerated and sustainable development of bioenergy. General constituent assembly of UABio was held on September, 25, 2012 in Kyiv. The Association was officially registered on 8 April 2013. Among UABio members there are over 10 leading companies and over 20 recognized experts working in the field of bioenergy.

<http://uabio.org>

