# ANALYSIS OF BARRIERS TO THE PRODUCTION OF ENERGY FROM AGRIBIOMASS IN UKRAINE

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**Summary**

*Position Paper No. 21* of the Bioenergy Association of Ukraine presents the analysis of existing barriers to the use of agribiomass for energy, and suggests some possible ways to overcome them. Topicality of the subject is explained by the fact that, first, Ukraine has a large potential of agricultural residues and by-products. Second, without the use of this kind of biomass for the production of fuel and energy, it is impossible to achieve the bioenergy goals set by the Energy Strategy of Ukraine until 2035. The suggested recommendations for overcoming the barriers take into account available best practices of the EU countries and the USA.

## 1. Dynamics of the production of main agricultural crops in Ukraine

Analysis of statistical data on the volumes of grain crops and sunflower production in Ukraine in the period of 2000-2018 shows a steady positive dynamics of the growth of this production (**Figure 1.1**). There have been some fluctuations in the yield of these crops during the period, but the general tendency has been increase in the yield. In 2018, the increase compared with 2000 was **2.6** times for grain corn, **1.9** times for wheat, and **1.9** times for sunflower (**Figure 1.2**).

In 2018, a record production and yield of grain corn and sunflower were obtained in Ukraine: **35.8** Mt (**78.4** centners/ha) for grain corn and **14.2** Mt (**23** centners/ha) for sunflower. In addition, for the first time the grain corn production (35.8 Mt) exceeded the total production of other cereals and legumes (34.3 Mt).

According to experts, in the coming years, Ukraine may increase the production grain and oilseed crops to **100** Mt per year[1]. Thus, we can state that the country has steadily high production volumes of main crops with the prospect of further growth, which is a big source of various types of residues and by-products.

[1] http://uga.ua/news/prezident-uza-ukrayina-2022-roku-mozhe-zbilshiti-virobnitstvo-zernovih-olijnih-100-mln-tonn-eksportuvati-blizko-70-mln-tonn/

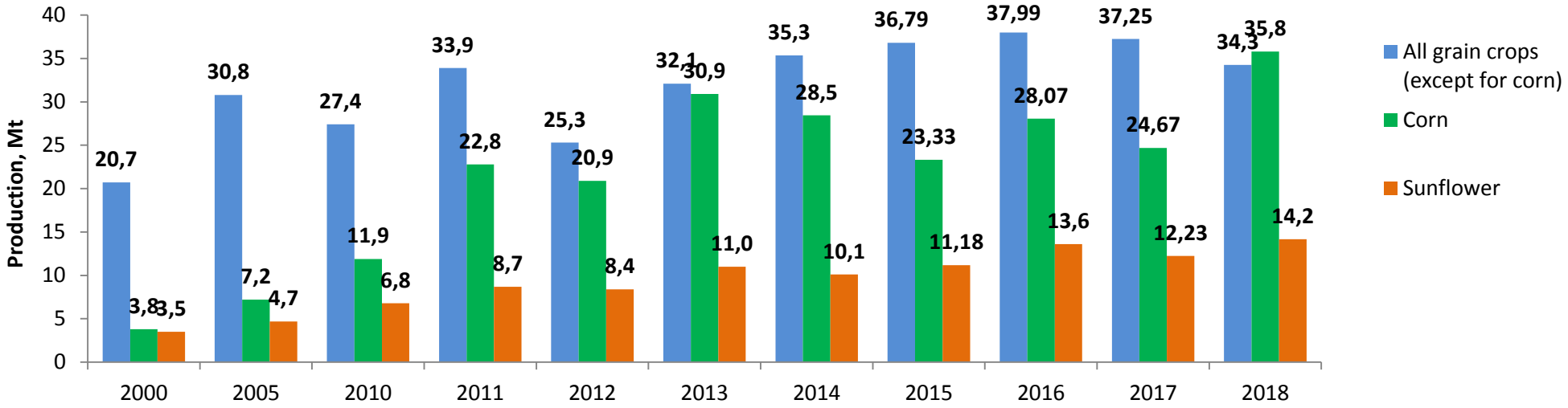


**Fig. 1.1.** Production of grain crops and sunflower in Ukraine[2] [3].

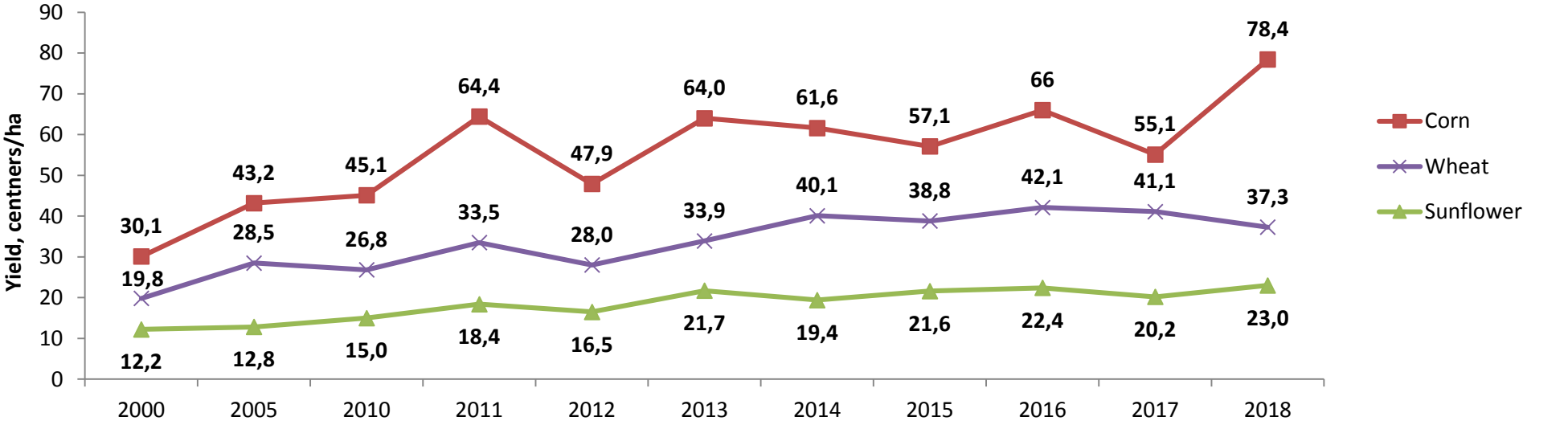


**Fig. 1.2.** Yield of wheat, grain corn and sunflower in Ukraine[2] [3].

[2] Crop production in Ukraine 2017. Statistical yearbook by SSSU, 2018 http://www.ukrstat.gov.ua/

[3] Area, gross production and yield of agricultural crops by types and by regions in 2018 (final data), SSSU.

## 2. Role of agribiomass in the bioenergy potential of Ukraine

The carried out assessments show that biomass of agrarian origin (straw of grain crops and rape, by-products of grain corn and sunflower production, sunflower husk) remains the main component of the biomass energy potential in Ukraine. According to 2017, the economic potential of these types of biomass available for energy production is almost **9** Mtoe, which is **43%** of the total biomass potential (**20.9** Mtoe). At that, these figures have been stable during recent years (**Table 2.1**). The complete utilization of the energy potential of agribiomass can cover about **18%** of the final energy consumption in Ukraine, which in 2017 amounted to 50.1 Mtoe[4].

**Table 2.1.** Biomass energy potential in Ukraine (2017).

| Type of biomass | Theoretical potential, Mt | Potential available for energy | |
|---|---|---|---|
| | | Share of the theoretical potential, % | Mtoe |
| Straw of grain crops | 35.6 | 30 | 3.65 |
| Straw of rape | 3.9 | 40 | 0.54 |
| By-products of grain corn production (stalks, cobs) | 32.1 | 40 | 2.45 |
| By-products of sunflower production (stalks, heads) | 23.2 | 40 | 1.33 |
| Secondary agri-residues (sunflower husk) | 2.4 | 100 | 0.99 |
| Wood biomass (firewood, felling residues, wood processing residues) | 6.6 | 94 | 1.54 |
| Wood biomass (dead wood, wood from reconstruction of shelter belts, APPR residues) | 8.8 | 44 | 1.01 |
| Biodiesel (from rapeseed) | - | - | 0.31 |
| Bioethanol (from corn and sugar beet) | - | - | 0.59 |
| Biogas from agri-industrial residues and by-products | 1.6 млрд. м$^3$ $CH_4$ | 50 | 0.68 |
| Landfill gas | 0.6 млрд. м$^3$ $CH_4$ | 34 | 0.18 |
| Sewage gas (from industrial and municipal wastewater) | 1.0 млрд. м$^3$ $CH_4$ | 23 | 0.19 |
| Energy crops | | | |
| - willow, poplar, miscanthus (1 million ha)* | 11.5 | 100 | 4.88 |
| - corn (for biogas) (1 million ha)* | 3.0 млрд. м$^3$ $CH_4$ | 100 | 2.57 |
| **Total** | - | - | **20.91** |
| *Total: primary and secondary agri-residues (share of the total biomass potential):*<br>*2017*<br>*2016*<br>*2015*<br>*2014*<br>*2013* | | | <br>*8.96 (43%)*<br>*9.02 (43%)*<br>*8.12 (42%)*<br>*8.56 (40%)*<br>*8.53 (44%)* |

** envisaged area of unused agricultural land for energy crops production.*

[4] Energy Balance of Ukraine for 2017. Express-issue by SSSU of 20.12.2018 http://www.ukrstat.gov.ua/

Another considerable component of the biomass energy potential of in Ukraine is energy crops that can be grown on land not used in agriculture. In case of growing energy crops intended for solid biofuels production on 1 million ha, as well as energy crops intended for the production of biogas on another 1 million ha, the total potential will be **7.5** Mtoe/yr or **36%** of the total biomass potential in Ukraine. Unfortunately, this sector still is not developing fast enough, and of the existing 3-4 million ha of unused agricultural land only about 4.8 thousand ha are currently involved in the production of energy crops (willow, miscanthus, sorghum, etc.)[5]. Thus, now the potential of energy crops is mainly virtual in nature, in contrast to crop residues and other types of agribiomass, which are real components of the potential.

The energy potential of wood biomass in Ukraine is relatively limited (about **2.6** Mtoe/yr, data of 2017, see **Table 2.1**), while its use is very high (more than **90%**). Therefore, in the near future, it is most expedient to increase the production of energy from biomass at the expense of agribiomass and energy crops, especially as the current level of utilizing potential of these types of biomass for energy production in the country is very low: **0** to **2-3%** depending on the particular type of biomass (**Table 2.2**).

For the next 10-15 years, one can predict further increase in the energy potential of agribiomass, provided the yields of agricultural crops, in particular wheat and grain corn, grow to the best European levels, are predicted (**Table 2.3**). With this approach, the potential of agribiomass can increase from the current **9** Mtoe/yr to **11.3** Mtoe/yr.

[5] Ukraine's Progress Report On The Promotion And Use Of Energy From Renewable Sources in Ukraine in the years of 2016-2017 https://www.energy-community.org/documents/reports.html

**Table 2.2.** Utilization of biomass energy potential in Ukraine (2017).

| Types of biomass and lines of utilization | Potential available for energy, kt | Amount already used for energy* | | Share of utilization of the total potential, % |
|---|---|---|---|---|
| | | kt | ktoe | |
| Straw of grain crops/rape: | 12258 | 371 | 130 | 3.0 |
| - combustion (bales) | | 200 | 68 | 1.6 |
| - production and combustion of pellets | | 155 | 55 | 1.3 |
| - production and export of pellets | | 0.97 | 0.35 | 0.01 |
| - production and combustion of briquettes | | 15 | 5.5 | 0.1 |
| Stalks and cobs of corn | 12828 | 15 | 5.0 | 0.1 |
| Stalks and heads of sunflower | 9299 | 0 | 0 | 0.0 |
| Wood biomass: | 10117 | 10037 | 2713 | 99.2 |
| - combustion (firewood) | | 7040 | 1848 | 69.6 |
| - combustion (wood chips) | | 1405 | 340 | 13.9 |
| - export of firewood/wood chips | | 850 | 223 | 8.4 |
| - production and combustion of pellets | | 240 | 97 | 2.4 |
| - production and export of pellets | | 332 | 135 | 3.3 |
| - production and combustion of briquettes | | 170 | 69 | 1.7 |
| Sunflower husk: | 2374 | 1500 | 626 | 63.2 |
| - combustion | | 650 | 271 | 27.4 |
| - production and combustion of pellets | | 300 | 125 | 12.6 |
| - production and export of pellets | | 450 | 188 | 19.0 |
| Sugar beet bagasse (W 13%) | 4410 | 200 | 10.2 | 4.5 |
| Corn silage (fresh)** | 27000 | 15 | 1.9 | 0.06 |
| Manure and litter | 30020 | 335 | 12.9 | 1.1 |
| **Total** | **108306** | **12473** | **3546** | **on average: 11.5%** |

** Authors' expert estimation. ** In case of growing on 1 Mha of unused agricultural land.*

**Table 2.3.** Comparison of yields of wheat, grain corn and sunflower in some EU countries[6] and in Ukraine[2].

| Year, crop | **Yield, centners/ha*** | | | | Predicted increase in the crop yields in Ukraine, times |
|---|---|---|---|---|---|
| | Austria | Denmark | Germany | Ukraine | |
| **2017** | | | | | wheat: **1.8** (up to 75 centners/ha)<br>corn: **1.5** (up to 90 centners/ha)<br>sunflower: *yield in Ukraine is already **on the European level** (20-22 centners/ha)* |
| - wheat | 48.7 | 82.4 | 76.4 | 41.1 | |
| - corn | 99.1 | 76.3 | 105.3 | 55.1 | |
| - sunflower | 23.3 | - | 22.0 | 20.2 | |
| **2016** | | | | | |
| - wheat | 62.5 | 72.0 | 76.4 | 42.1 | |
| - corn | 111.6 | 76.8 | 96.5 | 66.0 | |
| - sunflower | 32.9 | - | 21.4 | 22.4 | |
| **2015** | | | | | |
| - wheat | 57 | 79.5 | 80.9 | 38.8 | |
| - corn | 86.8 | 62 | 87.2 | 57.1 | |
| - sunflower | 20 | - | 19.2 | 21.6 | |

** For European countries the latest data are available for 2017. Yield in Ukraine in 2018 (centners/ha): wheat 37.3 (90.8% compared with 2017), grain corn 78.4 (142.3%), sunflower 23.0 (113.9%).*

[6] FAO statistics http://www.fao.org/faostat/en/#data/QC

## 3. Viewpoints of Ukrainian and foreign experts on the share of crop residues that can be used for energy production

It is important to note that UABio's assessment of the energy potential of crop residues[7] **takes into account other lines of their use**, in particular, for own needs of agriculture, such as organic fertilizers in crop production and litter and feed in livestock production. That is why the maximum amount of agribiomass that can be used for energy is **generally** determined as **30-40%** of the theoretical potential that is of the total amount of crop production residues. Data collected by UABio confirm that this estimation is in line with the existing world practice[8] [9].

Removal of up to **30%** of crop remains, which according to UABio's position applies to straw of cereals, means that straw is taken away from the field only ***once every three years***, and the remaining two years it is left in the field and used as organic fertilizer. Removal of up to **40%** of the by-products of grain corn and sunflower production means that, firstly, these crop residues are taken away from the field only ***once every 2-3 years***; secondly, for each crop, only a ***part*** of the crop residues is collected, for example, corn cobs or threshed sunflower heads, while everything else remains in the field.

When planning bioenergy projects, one should carefully specify the percentage of crop residues to be removed for each particular farm taking into account the full range of local conditions (crop yield, level of development of local animal husbandry, soil condition, application of mineral and organic fertilizer, etc.). As a result, the actual availability of the agribiomass potential for energy can vary from 0 to 100%.

Let us consider the views of Ukrainian and foreign experts on this issue. The official position of the National Academy of Agrarian Sciences of Ukraine remains uncertain at present. In January 2018, with the participation of UABio Head, a thematic meeting of the bureau of the Presidium of NAAS "Scientific support for the energy autonomy of agri-industrial production" was held [10]. Among other things, the meeting discussed the possibility of using up to **20%** of the non-grain part of the crops for energy. Unfortunately, the final version of the Resolution prepared based on the results of the meeting of the bureau of the Presidium of NAAS on January 24, 2018 does not include this figure (while the draft of this document did). At the same time, taking into account the goals of the Energy Strategy of Ukraine until 2035, the Resolution states that "the existing sustainable resources of wood biomass that can be used for energy production can provide no more than 30% of the biomass resources required in 2035. Other 70% should be provided at the expense of energy crops and ***by-products of agricultural production***". It is further stated that "the non-grain part of the agricultural crops is not promising for these purposes ". So, NAAN's views do not seem to be completely clear.

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[7] Definitions of terms «crop residues», «harvesting residues», «straw», «stubble remains» and some others according to DSTU 4884:2007 is presented in **Annex 1**.

[8] UABio Position Paper № 7 «Prospects for the use of agricultural residues for energy production in Ukraine», 2014 http://uabio.org/img/files/docs/Position-paper-UABIO-7-EN.pdf

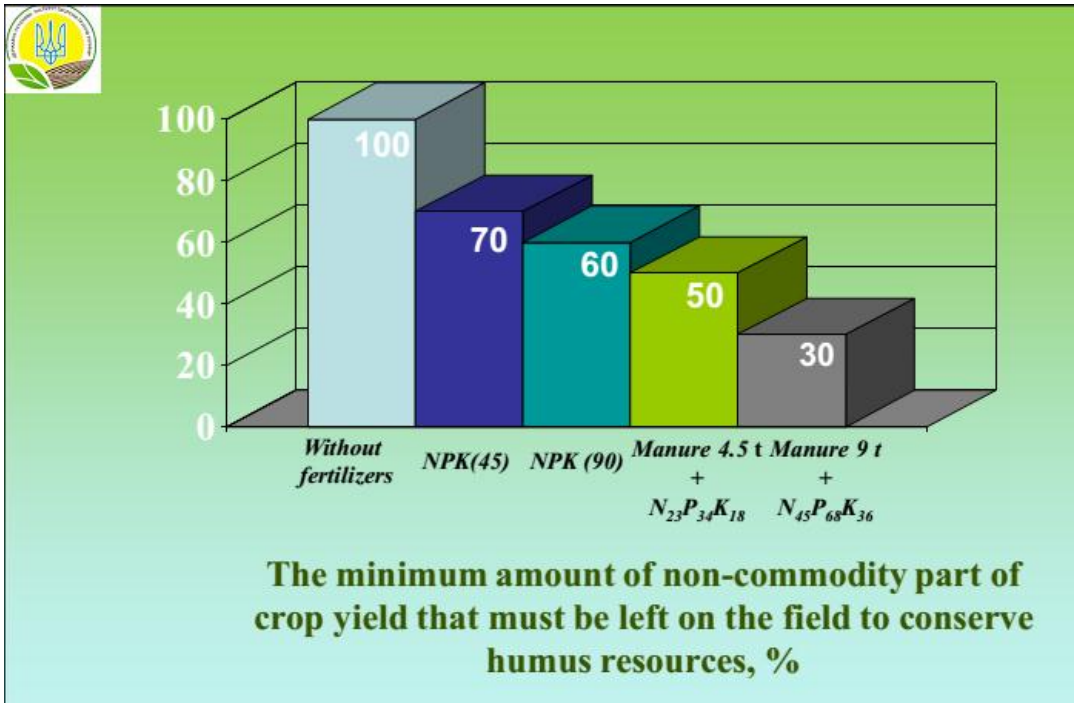
[9] Hermann Wieser, Vojislav Milijic. AVAILABILITY OF AGRO-BIOMASS IN SERBIA, 2017. http://www.bioenergy-serbia.rs/images/documents/studies/20171028_Agrobiomass_Study.pdf

[10] http://naas.gov.ua/slide/24-s-chnya-2018-r-zas-dannya-byuro-prezid-naan-/

In contrast to NAAS of Ukraine, foreign experts have a definite positive position regarding the possibility of using crop residues for energy. In this context, one can find to be very interesting materials of the International Workshop **"Agricultural Residues for Bioenergy. Problems and solutions"**[11] (27.09.2018, Kyiv). The Workshop was organized by the State Agency on Energy Efficiency and Energy Saving of Ukraine and the Embassy of the Kingdom of the Netherlands in Ukraine. The most important points of the presentations and conclusions of the Workshop are as follows[12].

***Yuri Kryvda***, *Director of Cherkasy branch of the State Institution "Soils Protection Institute of Ukraine"*[13]*:*

- Soil examination shows that on the whole the content of organic matter in the soil in Ukraine has stabilized since 2001 (at the level of 3.14-3.15%), and since 2006 has even slightly increased (to 3.17%).
- 35% of Ukraine's soils has the increased content of humus (3.1-4%), and only 1% of soils has very low content of humus (<1.1%).
- The correlation between the level of fertilization per hectare of sown area and the possible volume of removal of a non-grain part of the crops is presented in the figure below (a slide from the presentation made by Yuri Kryvda at the workshop on September 27, 2018). Thus, with the introduction of mineral fertilizers at the rate of NPK (45) one can take away from the fields up to **30%** of the non-grain part of the crops, at the rate of NPK (90) – up to **40%**, and with the introduction of 9 tons of manure per hectare and $N_{45}P_{68}K_{36}$ – up to **70%**.




[11] Materials of international Workshop «Agricultural Residues for Bioenergy. Problems and Solutions» (27.09.2018, Kyiv)
http://uabio.org/en/uabio-news/3720-nl-workshop-agroresidues-for-bioenergy-problems-and-solutions-materials
[12] Selected slides of the presentations delivered at the Workshop are given in **Annex 2**.
[13] Yuri Kryvda «State of fertility of soils in Ukraine» https://www.biobased-ukraine.nl/assets/uploads/sites/10/2018/10/2_Yuri_Kryvda_NL-UA_Workshop_27092018.pdf

***Francisco J. Arriaga**, University of Wisconsin-Madison, Department of Soil Science, USA[14]:*

- Studies **did not reveal** significant effects of corn stover removal on the corn yield.
- In order to minimize the impact of agribiomass harvesting on the soil, it is necessary to remove only **a part** of the crop residues, **to compensate** the taken away nutrients with mineral fertilizers or manure, and to use cover crops.

***Nicolae Scarlat**, Joint Research Centre (JRC), European Commission [15]:*

- Modelling the absolute change in soil organic carbon under removing various shares of crop residues from the field during 2015-2030 showed that the percentage of removed residues could be up to **50%**.

***Jan Peter Lesschen**, Wageningen University and Research (WUR), The Netherlands [16]:*

- The volume of sustainable harvesting of straw and other crop residues for energy can range from **0%** to **100%** depending on the crop yield, local soil and climatic conditions.
- It is better to take away corn stover from the field than straw of grain crops.
- It is necessary **to return** ash from the burning of crop residues **to the fields**, as well as to introduce **organic fertilizers** such as digested substratum, manure and others.

Summing up results of the Workshop, Walter Elbersen (Wageningen University and Research – WUR, The Netherlands) noted that ***the use of harvesting crop residues for energy production is a better option than the current practice of their burning in Ukraine[17]***.

It is known that the United States have experience of using large volumes of corn stover for the production of bioethanol[18,19]. USDA-Natural Resource Conservation Service published the White Paper on **"Crop Residue Removal for Biomass Energy Production: Effects on Soils and Recommendations"**[20]. In particular, the document states that "***roots appear to be the largest contributor to new soil organic matter, making residues less important for carbon accrual***".

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[14] Francisco J. Arriaga «Sustainable use of crop residues for bioenergy: USA research» https://www.biobased-ukraine.nl/assets/uploads/sites/10/2018/10/3_Francisco_Arriaga_NL-UA_Workshop_27092018.pdf

[15] Nicolae Scarlat «Spatially explicit assessments of sustainable crop residues potentials in Europe https://www.biobased-ukraine.nl/assets/uploads/sites/10/2018/10/4_Nicolae_Scarlat_NL-UA_Workshop_27092018.pdf

[16] Jan Peter Lesschen «Effect of use of agricultural residues for bioenergy on soil carbon and potential solutions» https://www.biobased-ukraine.nl/assets/uploads/sites/10/2018/10/5_Jan_Peter_Lesschen_NL-UA_Workshop_27092018.pdf

[17] Wolter Elbersen «Wrap-up: highlights and conclusions from the workshop, explanation of follow up» https://www.biobased-ukraine.nl/assets/uploads/sites/10/2018/10/Elbersen-Wrap-up-Kiev-2018-for-site.pdf

[18] In 2015 in Iowa, DuPont put into operation the largest in the USA plant for the production of bioethanol from corn stover https://www.farmprogress.com/biofuel/digging-science-cellulosic-ethanol

[19] In 2018 DuPont's plant was sold to VERBIO North America Corporation, which is planning to start there the production of biomethane from straw by 2020 https://www.verbio.de/en/investor-relations/news-publications/ad-hoc-announcements/verbio-acquires-cellulose-ethanol-plant-from-dupont-in-nevadaiowa-usa/

[20] White Paper «Crop Residue Removal for Biomass Energy Production: Effects on Soils and Recommendations» https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053255.pdf

## 4. Barriers to the use of agribiomass for energy in Ukraine and possible ways to overcome them

Different chains of energy use of agribiomass in Ukraine can be distinguished, such as the production and use of briquettes, the production and use of pellets, the production of straw bales for farmer boilers (<1 MW) and for bigger boilers and heat generators, harvesting of corn stalks for the production of fuel and/or energy, and others. Some of these chains are developing successfully now, others are developing very slowly because of specific barriers.

An example of successful chains is increasing production of straw briquettes for the population and social sphere objects. We consider the production of agribiomass briquettes more promising than the production of pellets, since the briquettes can be used in existing ovens, domestic and small solid fuel boilers with manual loading, that is, they do not require specialized equipment, in contrast to more expensive pellets[21]. In recent years, there has been a significant increase in interest in the production and consumption of agribiomass briquettes in Ukraine.

Another positive example is the introduction of grain dryers running on straw. One of the reputable producers of such equipment is Brig DLC (Pervomaysk town, Mykolaiv region). Today, about 150 grain drying complexes of Brig DLC with a productivity of 16 and 8 t/hr are used on farms with a sown area of grain crops of 1500-2000 ha and more. The largest number of Brig complexes are in operation on farms of Vinnitsa, Sumy, Chernihiv, Kirovograd regions[22].

Implementation of large-scale projects on biomass of agrarian origin is still developing very slowly, and today only two big boilers on baled straw are operating in Ukraine (the manufacturer is TTS Group[23]): 2×5 MW boilers on Dniprovsky battery farm in Dnipropetrovsk region. It is evident that the development of this sector requires additional attention and efforts, including overcoming of the existing barriers. We will analyze these barriers, grouping them by type: technological, organizational/legislative, economic and environmental barriers.

### 4.1. Technological barriers

#### *Agricultural producers do not have machinery for the harvesting of crop production by-products for energy needs*

For agricultural producers, the main goal is to obtain the maximum profit from the production of basic commodity products. In order to provide the collection of by-products, they need to partially modify the worked out agricultural technology, invest in specialized equipment and use additional resources.

For example, in order to harvest the by-products of growing corn for grain, first, the corn stover must be harvested in swaths, then pressed into bales, and after that the bales must be collected from the field and put into specially prepared warehouses for storage. It is possible that after the formation of swaths, strong and prolonged rains can begin, which will prevent the baling and

[21] This matter is considered in more detail in UABio Position Paper № 20 «ANALYSIS OF POSSIBILITIES FOR THE PRODUCTION AND USE OF AGRIBIOMASS BRIQUETTES IN UKRAINE» (2018) http://uabio.org/img/files/docs/position-paper-uabio-20-en.pdf

[22] http://www.brig-zerno.com.ua/uk/produktsiia/zernosusharne-obladnannia-na-biomasi

[23] www.ttsboilers.cz

obtaining of agribiomass with the necessary qualitative indicators. Then one will need to use additional equipment to distribute the by-products over the field. As a result, the farmer can incur significant material costs, whereas, with the usual technology of grain corn harvesting, when the combine harvester immediately spreads crop residues over the field, there is no such risk. In addition, soil, especially wet, thicken due to the movement of heavy machinery over the field. Failure to take appropriate measures may adversely affect the yield of the following year. If after the swathing of corn stover the rain does not last long, and then the weather is dry and warm, one can turn the swaths, which will create conditions for drying and further baling of the by-products.

We can also consider other variants of the partial harvesting of by-products of grain corn. In particular, a promising technology is the separation and collection of piles of cobs a combine harvester implemented in the innovation system Harcob, which was explored by the project BeCool[24] [25] [26]. The use of this system allows collecting 1.8-2.1 t/ha of cobs of 37.2 to 56.6% moisture in the extra hopper of the combine harvester. Thus, an agricultural producer and/or a specialized harvesting company must have the necessary technical means and resources to react promptly to change of the situation when harvesting the main product and by-products[27].

Possibility and optimal approaches to harvesting sunflower stalks remains an unresolved question today. Due to their natural humidity (40-50%) at the harvesting time (August-September), we can recommend siloing sunflower stalks with further production of biogas as a strategic line of use (with certain restrictions). An alternative option is to leave the stalks in the field until the late winter/early spring so that they can dry up enough, and then collect them in the form of bales or crushed mass. Biomass harvested in such a manner can be used as fuel for boilers or as raw material for the production of briquettes/pellets. The proposed option for harvesting sunflower stalks is suitable for the case of crop rotation, when spring crops[28] are planted after sunflower.

Currently, in Ukraine there are practically no examples of using sunflower production residues for energy production. Only sunflower husk is actively utilized for the production of briquettes/pellets and as fuel for boilers operating at oil extraction plants and other enterprises of the oil and fat industry.

*Suggestions for overcoming the barrier*

To make a decision on the harvesting of by-products of crop production for energy, it is important for a farmer to understand that this will not reduce the yield of the main products,

[24] Pari, L., Bergonzoli, S., Suardi, A., Alfano, V., Scarfone, A., Lazar, S. Maize Cob Harvesting: First Assessment of an Innovative System http://www.etaflorence.it/proceedings/?detail=15215
[25] https://www.becoolproject.eu/
[26] Video «BECOOL - Recovering Maize Cob: Converting Untapped Biomass Resource into Valuable Feedstock» https://www.youtube.com/watch?v=ZUGLSb8thuU&feature=youtu.be
[27] Harvesting technologies for the main product and by-products of grain corn as well as the necessary machinery are considered in detail in UABio Position Paper № 16 «Opportunities for harvesting by-products of grain corn for energy production in Ukraine» (2016) http://uabio.org/img/files/docs/position-paper-uabio-16-ua.pdf
[28] Spring crops are crops planted only in the spring (typically after the end of January in the year of harvest). See page 64 in http://www.hse.gov.uk/pesticides/resources/C/Crop-defn.pdf

especially if long-term contracts for the supply of biomass are envisaged. Therefore, it is necessary to maximally identify risks for the producer and plan measures to reduce them, in particular, to identify the necessary changes in agricultural technology and ensure the purchase of specialized equipment. On the other hand, the buyer is without fail to get the required amount of agribiomass with respective qualitative characteristics. Specific essential conditions must be described in detail in the contract for the supply of agribiomass. It is necessary to develop standard forms of such contracts for bioenergy projects.

Given the large potential of residues and crop production by-products in Ukraine, it seems expedient to implement a number of target pilot/demonstration projects. In such projects, which should be financed mainly at the expense of grant funds, it is possible to work out technologies for harvesting and supply of various types of agribiomass, to find the most optimal technical and technological solutions. We consider the following lines for the implementation of pilot/demonstration bioenergy projects to be promising:

- harvesting of corn stalks;
- harvesting of corn cobs;
- harvesting of sunflower stalks;
- introduction of boiler plants running on baled straw and corn stalks.

***Difficulties in establishing "harvesting-supply" chains***

Crops residues are biomass dispersed across the field. Its amount essentially depends on varietal features of crops, soil-climatic conditions, applied agricultural technology, etc. Existing harvesting technologies allow to partially collect only the above-ground parts of a crop (by-products), such as straw and empty glume, the collected amount of which is usually 2-5 t/ha. At that, the stubble remains and underground part of the plant remain in the field.

By-products of crop production have low bulk density (for example, loose straw has 20-50 $kg/m^3$), therefore it is expedient to press such biomass into bales (rolls), briquettes or pellets to ensure efficient logistics.

The moisture content of the by-products of crop production mainly affects its calorific value. In addition, moisture causes decomposition of biomass during storage. These and other peculiarities of crop remains must be taken into account when planning and organizing a "harvesting-supply" chain.

The need for specialized machines and equipment for harvesting, processing and logistics of by-products of crop production and solid biofuels produced from them leads to significant capital expenditures. Examples of such technology are balers to produce large rectangular bales, self-loading trailers, powerful tractors, forklifts, motor transport, crushers, briquetters, granulators, and the like. This equipment should be maximally loaded, which require careful planning due to seasonality of agricultural activity, weather dependence and agri-technological limitations. The efficiency of harvesting, processing and logistics of agribiomass significantly depends on the

professionalism of workers. In addition, special attention should be paid to the preparation of warehouses, which should ensure the proper conditions for the storage of biomass and biofuels. It is also important to establish control and monitoring of the quality and quantity of supplied raw materials and finished products.

*Suggestions for overcoming the barrier*

It is important to use existing best practices of national and foreign projects to implement projects on the energy use of by-products of crop production. Information on the results of scientific research on the relevant bioenergy technology is also valuable, especially at the initial stages of a project development and carrying out of feasibility study. Therefore, it is necessary to concentrate efforts of scientists and practical men on the development of basic technologies and approaches to establishing "harvesting-supply" chains, which are priority for domestic conditions and types of agribiomass. In addition, a significant factor is fair informing of stakeholders, which will reduce investment risks and simplify designing and implementation of projects.

***Difficulties in using biomass as fuel***

The fuel characteristics of biomass of agricultural origin are specific and differ from wood biomass (that is are worse), which requires a more thorough approach to the choice of energy equipment and the organization of the process of combustion.

For example, straw contains chlorine and alkali metals, which means that in the process of its combustion, some chemical compounds such as sodium chloride and potassium chloride are formed. These compounds cause corrosion of steel elements of energy equipment, especially at high temperatures. Another feature of straw as a fuel is the relatively low melting point of ash (900-1000° C) (**Table 4.1**), which can lead to the slugging of elements of energy equipment.

Fortunately, today in the world there already exist some constructive and other technological solutions that minimize these negative impacts and allow to use straw as a fuel successfully. Examples of such solutions are co-combustion of straw with coal, wood and other fuels or the use of "grey" straw (that is the straw kept in the open air for a long time) instead of "yellow" (fresh) straw. As a result of flushing with rains, "grey" straw contains much less chlorine and potassium compared to the "yellow" straw. It is important that the content of chlorine and alkali metals in straw of Ukrainian origin is significantly less than in straw of other countries. This is due to a significant reduction in the introduction of mineral fertilizers under crops over the past 25 years.

Corn stalks also contain chlorine and alkali metals at levels close to those of straw. But the temperature of ash melting of corn stalks is higher, almost at the level of wood, which is a positive factor in terms of their use as a fuel. In addition, the content of sulphur in corn stalks is almost 10 times lower than in straw of cereals.

**Table 4.1.** Fuel properties of different types of biomass[29].

| Parameter | Fresh straw («yellow») | Straw kept in the open air («grey») | Corn stalks* | Sunflower stalks* | Wood chips (for comparison) |
|---|---|---|---|---|---|
| Moisture content, % | 10-20 | 10-20 | 45-60**<br>15-18*** | 40-50**<br>~20*** | 40 |
| LHW, МДж/кг | 14.4 | 15 | 5-8 (W 45-60%)<br>15-17 (W 15-18%) | 16<br>(W<16%) | 10.4 |
| Volatile components, % | >70 | >70 | >60-70 | >70 | >70 |
| Ash content, % | 4 | 3 | 5-9 | 10-12 | 0.6-1.5 |
| *Ultimate composition, %:* | | | | | |
| carbon | 42 | 43 | 45.5 | 44.1 | 50 |
| hydrogen | 5 | 5.2 | 5.5 | 5.0 | 6 |
| oxygen | 37 | 38 | 41.5 | 39.4 | 43 |
| chlorine | 0.75 | 0.2 | 0.2 | 0.7-0.8 | 0.02 |
| potassium | 1.18 | 0.22 | 6.1 mg/kg d.m. | 5.0 | 0.13-0.35 |
| nitrogen | 0.35 | 0.41 | 0.3-0.7 | 0.7 | 0.3 |
| sulphur | 0.16 | 0.13 | 0.04 | 0.1 | 0.05 |
| Ash melting point, °C | 800-1000 | 950-1100 | 1100-1200 | 800-1270 | 1000-1400 |

** Data on volatile components, ash contents and ultimate composition are in % d.m.*
*** After harvesting. *** Dried in the open air.*

There is not much information on the fuel properties of sunflower stalks. It is known that their elementary composition is close to that of straw and corn stalks, but the content of ash is higher, about 11% d.m. The content of alkali metal potassium is also higher, up to 5% d.m. Nevertheless, in Ukraine there are already the first quite successful attempts to produce energy from sunflower stalks, and we consider the development of this line to be promising.

*Suggestions for overcoming the barrier*

For combustion of agribiomass it is necessary to use modern specialized equipment, hold to optimum modes of its operation and meet requirements to the quality of fuel.

## 4.2. Organizational and legal barriers

### *Underdevelopment of the biofuel market*

To date, the biofuel market in Ukraine remains poorly developed. There is no single platform for the realization of efficient purchases of different types of biomass/biofuels in required volumes and of required quality. This problem is especially acute for bioenergy projects using agribiomass. On the one hand, to attract investments, the owner of such a project must confirm availability of suppliers to provide the required type of biomass in the required quantity. On the

[29] Geletukha G.G., Zheliezna T.A., Tryboi O.V. Prospects for using agricultural residues for energy production in Ukraine. Part 2 // Industrial Heat Engineering. – 2014, V. 36, № 5, p.73-80 (in Russian)
http://uabio.org/img/files/news/pdf/agri-waste-utilization-part-2-2014.pdf

other hand, agricultural producers are ready to organize the collection, storage and supply of biomass only in case of availability of a real (not just potential) buyer (consumer) [30].

*Suggestions for overcoming the barrier*

We consider it necessary, as soon as possible, to introduce a system of e-commerce for biofuels (i.e. a biofuel exchange) in Ukraine based on the example of Lithuanian exchange Baltpool[30]. The draft law required for the establishment and operation of such an electronic trading system was developed in 2018 with the participation of UABio. Now the document is under consideration by central executive bodies.

***Difficulties in bringing to justice those responsible for burning crop residues***

The burning of crop remains in the fields is strictly **prohibited** by the legislation of Ukraine. Thus, administrative liability (in the form of a fine) and even criminal liability (in the form of custodial restraint/imprisonment) is envisaged for:

- «Destruction or impairment of forests, plantations around the settlements and along railways, as well as ***stubble remains***, dry wild grass, vegetation or its ***residues on agricultural land by fire*** or any other generally dangerous way ..." (Article 245 of the Criminal Code of Ukraine "Destruction or damage of objects of the vegetable world"[31]).
- «***Burning of stubble remains***, meadows, pastures, plots of steppe, wetland and other natural vegetation, burning of vegetation or its ***residues*** and fallen leaves ***on agricultural land***, in shelterbelts of roads and railways, in parks and other green spaces, burning of lawns in settlements without permission or with violation of terms of permission of state control bodies in the field of environmental protection... "(Article $77^{-1}$ of the Code of Ukraine on Administrative Offenses "Unauthorized burning of vegetation or its residues"[32]).

In reality, the practice of burning stubble remains and other crop residues as a way of getting rid of them and clean up the field before next sowing is actively continuing (**Fig. 4.1**). At that it seems that nobody is brought to justice for this. Moreover, according to doctor of agricultural sciences, professor of Lviv National Agrarian University **Ivan Shuvar**[33] [34]:

*"Over the last several years, **they have been burning in the fields almost all** that remains after growing crops, especially cereals, corn, rapeseed and sunflower ... Especial concern is connected with mass burning of residues and self-ignition (arson!) of some plots of agricultural land, including peat land, in hot weather. According to various statements, over 90% of fires is caused by human factor! Setting fire to stubble remains and straw was included in a series of*

[30] State-of-the-art of the biofuel market in Ukraine and operation of Lithuanian biofuel exchange Baltpool are described in detail in UABio Position Paper № 18 «Creation of the competitive biofuel market in Ukraine», 2017 http://uabio.org/img/files/docs/position-paper-uabio-18-en.pdf

[31] Criminal Code of Ukraine. Law № 2341-III of 05.04.2001 (amended) https://zakon.rada.gov.ua/laws/show/2341-14

[32] Code of Ukraine on Administrative Offenses. Law № 8073-X of 07.12.1984 amended) https://zakon.rada.gov.ua/laws/card/80731-10

[33] http://shuvar.at.ua/

[34] Ivan Shuvar. Burning of straw and crop residues in the field: is it advantage or harm? Magazine "Agribusiness today" (20.09.2017) (in Ukrainian) http://agro-business.com.ua/agro/ahronomiia-sohodni/item/8996-spaliuvannia-solomy-ta-roslynnykh-reshtok-u-poli-koryst-chy-shkoda.html

*recommendations and farming systems that are developed at the regional level. According to some scientists, burning is an effective measure against disease and pests".*

**Fig. 4.1.** Examples of burning stubble remains, straw and other crop residues in the field in Ukraine[34].

In the scientific-analytical paper of the Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine, it is stated that "nowadays straw is plowed in only on one third of the area of grain crops cultivation in Ukraine. **Massive cases are the burning of straw and stubble remains**, which adversely affects the soil, people and the environment"[35].

The burning of stubble remains, straw and other crop remains in the fields has a number of very **negative consequences**, including the following[34] [36]:

- Destruction and transformation of organic substances of soil under the influence of high temperatures. At a temperature of > 100 ° C, humus burns out at a depth of 0-5 cm, especially when straw lies in swaths, ricks or stacks. In this case, there is an irreversible loss of organic carbon, nitrogen, and oxygen;

[35] «Ecology innovations of the EU common agricultural policy: implementation in Ukraine», 2016 (in Ukrainian) http://minagro.gov.ua/system/files/%D0%95%D0%BA%D0%BE%D0%BB%D0%BE%D0%B3%D1%96%D1%87%D0%BD%D1%96%20%D0%BD%D0%BE%D0%B2%D0%B0%D1%86%D1%96%D1%97%20%D0%84%D0%A1.docx

[36] Yuri Kryvda «State of fertility of soils in Ukraine» (full version).

- water loss in the layer of soil of 0-10 cm;
- deterioration of water-physical properties of the soil, decrease of its biological activity;
- destruction of stubble remains as organic fertilizer and sources for organic matter remediation;
- increased danger of water and wind erosion;
- pollution of the atmospheric air with harmful products of combustion;
- threat of uncontrolled spread of the fire.

Satellite data on the number of fires in the fields of Ukraine were presented at the International Workshop "Open Burning in a National, Regional and Global Context" (07.03.2019, Kyiv) by researchers from the University of Maryland (USA). During 2001-2018, on average 12.5 thousand (!) of such fires were recorded in the country annually, with the highest number in April (~ 2000) and August (~ 3800). Ukraine is the second (!) country in the world in terms of the number of fires per hectare of agricultural land (a bit more fires is only in Russia). According to Dr. Joanne Hall's assessment (a speaker at the seminar), the Fire Radiative Power (FRP[37]) of these fires in Ukraine is **400-1000 GW!** (**Figure 4.2**). Thus, now in the fields of Ukraine, huge volumes of biomass are burned, which negatively affects the environment and creates fire-hazardous situations. Therefore, we see the significant role of bioenergy development among the possible measures to prevent open burning of agribiomass in the fields.

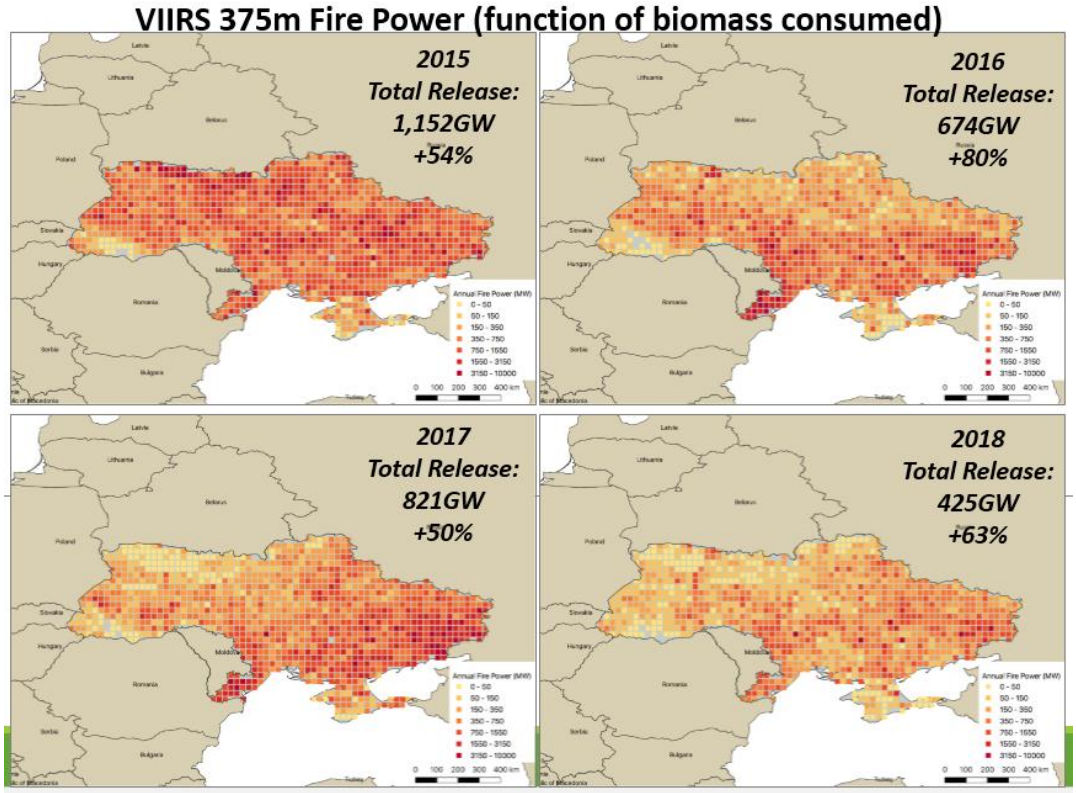


**Рис. 4.2.** Slide from the presentation by Dr. Joanne Hall (University of Maryland, USA) at the Workshop «Open Burning in a National, Regional and Global Context» (07.03.2019, Kyiv).

[37] FRP (Fire Radiative Power) is a measure of the rate of radiant heat output from a fire. http://cedadocs.ceda.ac.uk/770/1/SEVIRI_FRP_documentdesc.pdf

*Suggestions for overcoming the barrier*

Local authorities must pay more serious attention to cases of unauthorized burning of crop remains in the fields. They should inform owners of land and tenant farmers about the administrative and criminal liability for such actions.

A *draft law* "On Amendments to certain legislative acts of Ukraine concerning the immediate reaction to the crisis situation caused by forest fires"[38,39] has been recently developed in Ukraine. Among other things, the document envisages a significant increase in fines for "the unauthorized burning of vegetation or its residues" and the consideration by the National Police of cases of "violation of fire safety rules in forests and when doing farm work".

Undoubtedly, the adoption of such a law will help to phase out the burning of stable remains and other crop residues in the fields. But it seems that in addition to increased penalties, it is also necessary to create conditions under which burning of agribiomass in fields will cease due to the existence of other economically attractive ways to "get rid" of crop residues. It is obvious that an efficient way of clearing fields from straw and other crop residues is harvesting and selling as fuel. One can expect that after the creation of a system for biofuels electronic trading in Ukraine, the owners of biomass will cease burning of residues in the fields since they will be economically interested in harvesting and selling biomass on the biofuel exchange.

***Absence of state policy regarding the use of agribiomass for energy***

Today, in Ukraine, there exists practically **no state strategy** for the use of agrarian biomass for energy needs. Agribiomass as a fuel or raw material for biofuel production is not mentioned at all in the *Energy Strategy of Ukraine until 2035*[40] (2017), as well as in the *State Strategy for the Regional Development until 2020*[41] (2014). In the *Concept of Rural Development*[42] (2015), it is only mentioned about the need to "support energy production from alternative sources" and "promote the formation of solid biofuel sales markets". The draft Integrated Strategy and Action Plan for Agriculture and Rural Development in Ukraine for 2015-2020[43] (supported by the National Council for Reforms in 2015) contains a description of the item 10.4 "Bioenergy" as part of Strategic Priority 10 "Environmental protection and management of natural resources, in particular forestry and fisheries". In this description, which is very common and rather outdated, agribiomass is not emphasized in any way.

Absence of the state policy regarding the use of agribiomass for energy reflects **uncertainty** of the position of related ministries on this issue, such as the Ministry of Agrarian Policy and Food

[38] https://nubip.edu.ua/en/node/57326
[39] sites/default/files/u184/porivnyalna_tablicya_zu-pro_vnesennya_zmin_shchodo_silskogospodarskih_paliv.pdf
[40] Approved by CMU Resolution № 605-p of 18 August 2017
https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80
[41] Approved by CMU Resolution № 385 of 06.08.2014 (amended)
https://zakon.rada.gov.ua/laws/show/385-2014-%D0%BF#n11
[42] Approved by CMU Resolution № 995-p of 23 September 2015
https://zakon.rada.gov.ua/laws/show/995-2015-%D1%80
[43] http://minagro.gov.ua/node/16025

of Ukraine (Minagropolityky) and the Ministry of Regional Policy, Construction and Housing and Communal Services of Ukraine (Minregion).

The search for documents, including those available on the websites of Minagropolityky and Minregion, which would reflect the views of these ministries on the issue of the use of crop residues for energy, produces the following main results:

*Minagropolityky*

- The plan of additional measures for the Sector energy efficiency program for the agro-industrial complex for 2010-2014[44] (Order by Minagropolityky N 480 dated August 2, 2012), among other things, contains provisions for the introduction of several *straw* fired boilers and a line for the production of solid biofuel from *straw* in Vinnytsia region, as well as the introduction of *straw* based heating of administrative and other buildings of agricultural enterprises in Kherson region.
- Description of the Program for reducing energy consumption by budget financed institutions and organizations of agro-industrial complex through rational use of energy resources for 2010-2014, presented on the website of Minagropolityky on 18.03.2013, includes the mention of "Use of solid biofuels for the operation of boiler plants, which supply heat and hot water to budget financed institutions located in rural areas, subject to availability of local resources of biofuels (*straw*, sawdust, peat)[45].
- On the website of Minagropolityky, there is some information concerning the visit of Minister to a plant for the production of *straw pellets* in Vinnitsa region. In one of the articles, one can find the following quotations from the speech of Minister Mykola Prysyazhnyuk[46]: "According to current assessment, the processing of about 2-3 Mt of *straw* a year can give enough resources to replace gas imports... Producing on average 50-55 Mt of grain each year, the country has enough *straw*. For the production of grain, *about 30% of straw remains in fields, and the rest can be processed*".
- The meeting held in Minagropolityky on July 6, 2014 and chaired by Minister Igor Shwaika resulted in making decision that "experts of NAAS of Ukraine should develop recommendations regarding the use of advanced technologies by agricultural enterprises for the production of heat from *straw* and biogas..." [47].

*Minregion*

- The website of Minregion contains information on the implementation and local monitoring of the project "Energy efficiency improvement in the district heating of Ukraine"[48]. In particular, it is noted that Communal enterprise "Miskteplovodenergia" continues to build a thermal power plant with an ORC module in the city of Kamyanets-Podilsky; the TPP will

[44] https://zakon.rada.gov.ua/rada/show/v0480730-12
[45] http://minagro.gov.ua/node/5281
[46] http://minagro.gov.ua/node/5891
[47] http://minagro.gov.ua/node/13983
[48] http://www.minregion.gov.ua/napryamki-diyalnosti/international-cooperation/spilni-zi-svitovim-bankom-proekti/shhodo-realizatsiyi-proektu-pidvishhennya-energoefektivnosti-v-sektori-tsentralizovanogo-teplopostachannya-ukrayini/

produce heat and power with gas and solid fuel boilers. The advantage of the new boiler plant is the use of biofuels: pellets of different types of *straw*, wood chips, peat".

- On the website of the State Fund for Regional Development, one can find TOR of a project on the establishment of energy service company "ESCO" in Rozivsky district of Zaporizhzhia region[49]. The objective of the project is "Creating a local market for *straw* as a biofuel in order to *stop the harmful practice of combustion of straw on fields by agricultural producers* and to reduce the pollution of the territory by coal slag and greenhouse gases emission. Establishment of energy service company "ESCO" to provide decentralized heat supply to local communal institutions based on using the local alternative biofuel – pressed straw". In addition, the website of DFRR contains annotations of a number of other projects related to the use of *straw* for energy[50].

Despite some interest and importance of the above documents and materials, it seems that their availability is not enough to clearly define the position of Minagropolityky and Minregion on the use of agribiomass for energy production.

*Suggestions for overcoming the barrier*

We consider it necessary to develop the **strategy** for the use of biomass of agricultural origin for energy production and to include the strategy in one of the existing strategic documents or to approve it as a separate document. Another option is to develop the **strategy** for bioenergy development in Ukraine with a separate section on the use of agribiomass. Dedicated ministries should explicitly state in their official documents their views on the possibility and optimal use of agribiomass for energy production. This can be done through the development of ***"Recommendations regarding possible volumes of crop production by-products to be used for energy in Ukraine"***.

***Poor dissemination of information about successful projects on energy production from agribiomass***

There are many examples of successful energy production from agribiomass in Ukraine and in the European Union. The most well-known European example is the extensive use of straw as a fuel in Denmark. Today, more than 10,000 straw fired farm boilers and over 55 boiler plants on straw operate in the district heating system of Denmark. In addition, about 8 CHP plants and 4 TPPs co-fire straw with wood chips, MSW or fossil fuels (coal, natural gas)[51]. Of the total volume of straw produced in Denmark, 40% remains in the field, 33% is used in animal husbandry, and **27%** is used for energy production. The straw trading system for energy is well developed (local trade, wholesale trade, tenders) (**Figure 4.3**). In addition, the Danish Straw

[49] http://dfrr.minregion.gov.ua/region-tz?NID=2743
[50] Examples of annotations of projects on the production of solid biofuel from straw:
http://dfrr.minregion.gov.ua/Project-annotation?PROJT=23356
http://dfrr.minregion.gov.ua/Project-annotation?PROJT=11691
[51] Straw to energy. Status, technologies and innovation in Denmark, 2011 (https://issuu.com/mariepoulsen/docs/halmpjeceuk_2011). The brochure is to be updated within AgroBioHeat project financed by the EU Horizon 2020 program (http://uabio.org/uabio-news/3825-agrobioheat-project-press-release). The Bioenergy Association of Ukraine takes part in this project.

Suppliers Organization is actively functioning. The Organization unites farmers for whom the supply of straw as fuel is a priority activity.

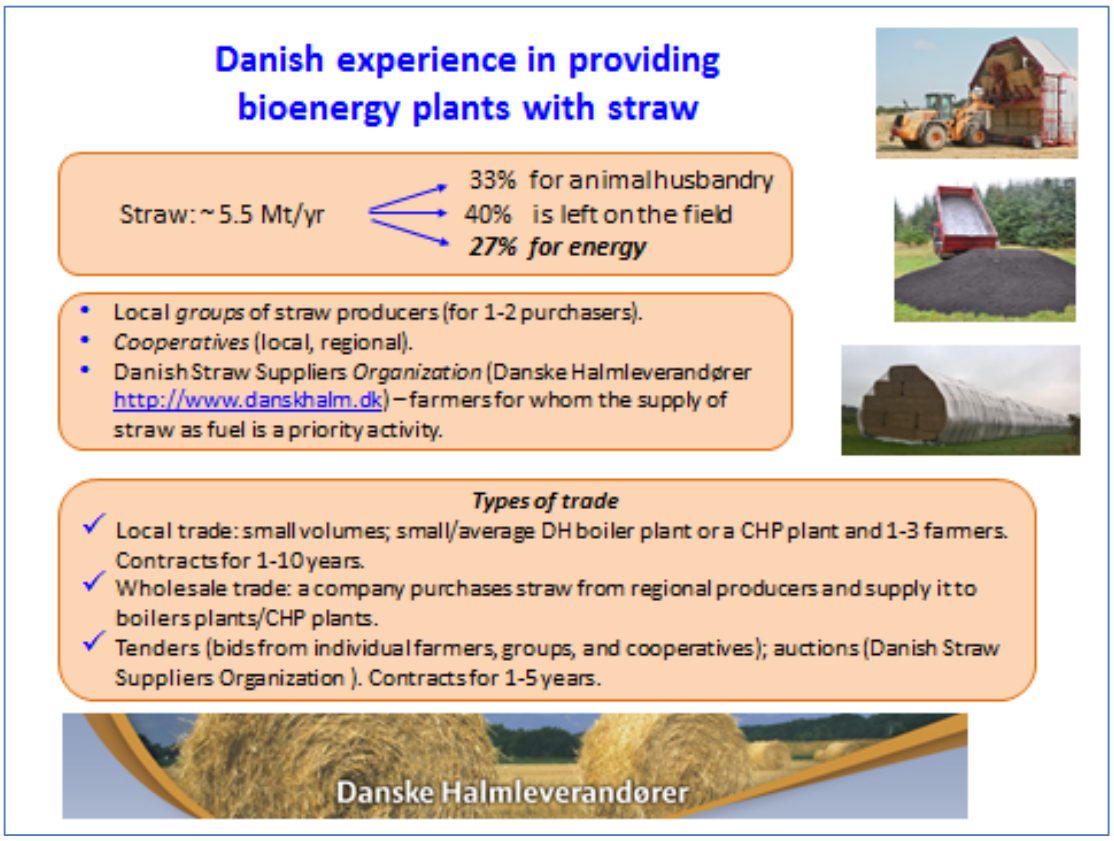


**Fig. 4.3.** Danish experience in trading straw as fuel[52].

Ukraine also has some interesting examples of the successful operation of energy installations on agrarian biomass. For instance, a 10 MW boiler plant on baled straw provides thermal energy to "Dniprovsky" battery farm in the village of Pershotravneve (Nikopol district, Dnipropetrovsk region) (**Figure 4.4**). Two high-efficiency boilers of 5 MW each, manufactured by the Czech company TTS Group, operate at the boiler plant. The straw is supplied from own fields of the enterprise, the average delivery radius being 15 km. The project was implemented in 2012[53].

It should be noted that information about these and other examples of successful projects of using agribiomass for energy, unfortunately, is not actively disseminated in Ukraine. As a result, these examples are known only to a very limited number of specialists and do not reach the target audience – potential investors and project owners, as well as potential consumers of biomass heat.

A positive example of the information dissemination activity is arranging a study tour on March 20-21, 2019 within the framework of the UNDP/GEF project "Development and

[52] Information was obtained during direct communication between UABio experts and Danish specialists.
[53] Video «10 MW boiler plant on straw» https://youtu.be/NnIuTpGkRzk
Video «One fuel supply system for two Vesko-S 5 MW boilers» https://youtu.be/NMwg-CAq5N4
Video «Boiler Vesko-S» https://youtu.be/Yz_clC8ELhg

commercialization of bioenergy technologies in the municipal sector in Ukraine". Among other things, the participants of the study tour (representatives of cities and UTCs - project partners, project experts, and journalists) attended the line for the production of straw pellets AVER-TEKH LLC (Uman town of Cherkassy region) and a line for the production of straw briquettes on the agro-firm "Basis "(Kochubeevka village, Cherkasy region)[54].

**Fig. 4.4.** 10 MW boiler plant running on baled straw at Dniprovsky battery farm (Pershotravneve village, Nikopolsy district, Dnipropetrovsk region)[55].

*Suggestions for overcoming the barrier*

We consider it necessary to systematically hold information and awareness campaigns on the opportunities and benefits of producing energy from biomass of agricultural origin. That includes including organizing study tours and technical excursions for interested parties (stakeholders) to

[54] Video «Seven bioenergy objects in Ukraine within the study tour of the UNDP project» http://www.uabio.org/mm/video/3862-undp-study-tour-2019

[55] Brochure «Preparation and implementation of projects on replacing natural gas with biomass when producing heat in Ukraine». Prepared within USAID project "Municipal energy reform in Ukraine», 2016 http://uabio.org/img/posibnyk-onovlenyi-2016.pdf

successfully operating facilities in Ukraine and EU countries. In the coming years, such work will be carried out by the Bioenergy Association of Ukraine within the framework of the **AgroBioHeat** project - "Promoting the penetration of agrobiomass heating in European rural areas"[56] - funded by the EU Horizon 2020 program.

### 4.3. Economic barriers

***Difficulties in fund-raising for agri-bioenergy projects***

Harvesting agribiomass is a complex and costly activity, the development of which is just beginning in Ukraine. Technology for straw bailing is already more or less widespread and tested, while the harvesting of corn stalks is a problem, starting with the lack of necessary equipment in the Ukrainian market. The practice of implementation of *large-scale* agri-bioenergy projects shows the complexity of this process, especially in terms of reliable providing an energy installation with biofuels. Today, two 5 MW straw fired boilers at the Dniprovsky battery farm are the only example of operation of large-scale energy equipment on agribiomass in Ukraine. It seems that projects of this type need targeted financial support for their preparation and implementation.

A positive example in this area is the launch of the FINTECC (Finance and Technology Transfer Center for the Climate Change Framework) program by the European Bank for Reconstruction and Development[57]. This grant program aims to stimulate climatic technologies, including improvement of energy efficiency, development of renewable energy, reduction of carbon emission and enhancement of water consumption efficiency. The main areas of FINTECC program within the framework of the project on ***Innovations in biomass supply chains in Ukraine*** are as follows:

- partnership among key stakeholders in spreading the use of *agrarian residues for energy production*;
- support for implementing the best available technologies;
- support for preparing projects;
- financing;
- support of legislative and regulatory changes.

Another positive example is creation of Sustainable Agribusiness Forum[58] (SAF) initiated and supported by EBRD. SAF members share the following business principles of sustainable entrepreneurship: focusing on creating long-term value and short-term maximization of profits; promoting the transition to a **green economy**.

*Suggestions for overcoming the barrier*

We believe that the harvesting of agribiomass for energy should receive targeted **state support**, for example, within the framework of the current Minagropolityky's Program supporting

[56] Press release of AgroBioHeat project (2019-2021) http://uabio.org/uabio-news/3825-agrobioheat-project-press-release
[57] EBRD FINTECC http://fintecc.ebrd.com/ru/region/ukraine/
[58] SAF (Sustainable Agribusiness Forum) http://saf.org.ua/

agrarians. This Program provides partial compensation of cost of domestic agricultural machinery and equipment from the state budget[59]. The list of this machinery and equipment is approved by a special commission attached to the Ministry of Economic Development and Trade of Ukraine[60]. We believe that this list should be supplemented with equipment of foreign make for *baling corn stalks*, since domestic analogues of such equipment do not exist. Another option for support may be the opening of a special credit line for companies involved in harvesting and supplying of agribiomass to energy facilities.

### 4.4. Ecological barriers

***Potential risks for soil caused by the removal of crop residues from fields for energy***

For sustainable agricultural development, it is important to adhere to the agrochemical law of returning nutrient, according to which nutrients removed with agricultural crops must be returned to the soil. In order to balance the humus and nutrients in agriculture, different types of organic and mineral fertilizers are used.

Organic fertilizers include manure, manure water, green manure, compost, poultry litter, straw, root and stubble remains, peat, sludge, and others. For a long time, manure has been the most common type of organic fertilizer. But in the period from 1990 to 2017, the number of farm animals has decreased radically, in particular, cattle by a factor of 7, pigs by a factor of 3 (**Figure 4.5**). Accordingly, the amount of manure decreased, which negatively affected the volumes of organic fertilizer application in crop production. In terms of sown area, the introduction of organic fertilizers dropped from 8.6 t/ha in 1990 to 0.5 t/ha in 2017, i.e. was reduced by a factor of 17. At that, in some farms, manure is introduced according to agronomic requirements.

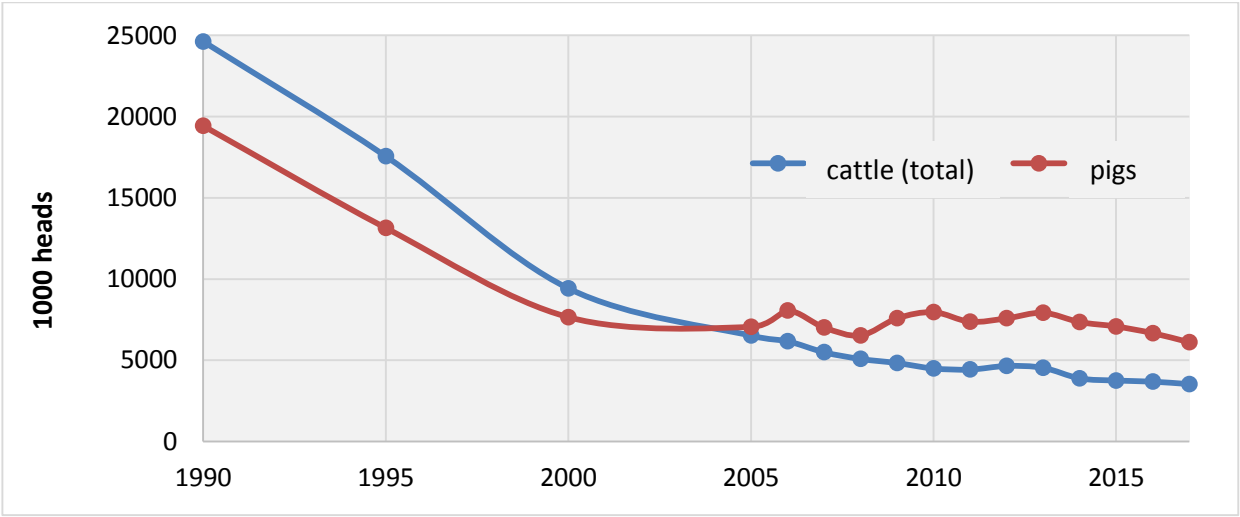


**Fig. 4.5.** The number of farm animals in Ukraine[61].

[59] http://minagro.gov.ua/uk/support_apk?tid_hierachy=1347
[60] http://www.me.gov.ua/Documents/List?lang=uk-UA&id=db6ade26-b223-4214-9caf-b9f8b73b4d28&tag=KomisiiaZFormuvanniaPerelikuVitchiznianoiTekhnikiTaObladnanniaDliaAgropromislovogoKompleksu-VartistYakikhChastkovoKompensutsiaZaRakhunokKoshtivDerzhavnogoBiudzhetu
[61] Statistical yearbook of Ukraine for 2017. SSSU, 2018 http://www.ukrstat.gov.ua/

Rational approach to the use of existing on the farm organic fertilizers is of great importance because often fertilizers are introduced incorrectly, and accordingly, inefficiently. For example, it is known that straw as an organic fertilizer must be used with simultaneous application of nitrogen fertilizers in the amount of 8-10 kg of nitrogen per 1 ton of straw[62]. But in practice, nitrogen is added only on 30-35% of the total area, where straw is ploughed in[13].

It should be noted that a significant part of the total livestock is held by households. In particular, as of 01.01.2018, 67% of cattle livestock (2364.2 th. heads) and 46% of pigs livestock (2806.3 th. heads) were kept by households[63]. In whole, in 2017, 65.4% of households kept farm animals, of which 33.3% was cattle, 40.1% was pigs and 96.4% was poultry[64]. Manure from domestic livestock is not collected or processed in a centralized manner. Therefore this manure is often used homestead land without complying with the required agronomic requirements, which reduces the effectiveness of its use as organic fertilizer (the most effective introduction rate for manure is 30-40 t/ha for row crops and 20-30 t/ha for winter crops[65]). In 2017, 84.1% of households used manure as fertilizer[64].

In global agrarian practice, cultivation of crops to be used as green manure, such as lupine, perco (a hybrid of winter rape), Austrian winter pea, peas, vetch, holy clover, mustard, bittercress, oil radish, rape etc. is an important source of replenishment of stock of organic matter (humus), nitrogen and other macro-and microelements of the soil. The advantage of such crops is also their ability to clear fields from weeds and reduce the amount of pathogenic microorganisms[65]. Today in Ukraine, green fertilizers are not used enough. In fact, over the last decade, the average area occupied by crops to be used as green manure does not exceed 300,000 ha, which is about 15% of the potential area[66].

Organic fertilizers are considered, mainly, as local ones, that is, those that are not transported over long distances, but applied near the places of their generation. Due to underdevelopment of the organic fertilizers market, their supply in Ukraine is currently limited. Therefore, Ukrainian plant-growing enterprises often use only *harvesting residues*[7] *as organic fertilizer*, especially in the absence of developed livestock in the region. At the same time, due to high cost of crop residues management, some farmers *do not properly carry out the necessary technological operations or even burn stubble remains and straw in the field*.

As for mineral fertilizers, their use dropped during 1990-1996, after which their introduction began to increase gradually and in 2017 reached 78% of 1990 level (**Fig. 4.6**).

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[62] http://apk.adm-pl.gov.ua/storinka/vikoristannya-solomi-rannih-zernovih-yak-organichnogo-dobriva
[63] Animal husbandry of Ukraine 2017. Statistical bulletin by SSSU, 2018 http://www.ukrstat.gov.ua/
[64] Main agricultural characteristics rural households in 2017. Statistical bulletin by SSSU, 2017 http://www.ukrstat.gov.ua/
[65] National report on soil fertility state in Ukraine. Minagropolityky, State technology center for soil fertility protection, NAAS of Ukraine, Institute of Soil Science and Agro-chemistry named after O.N. Sokolovsky, National University of Life and Environmental Sciences of Ukraine, 2010 http://www.iogu.gov.ua/wp-content/uploads/2013/07/stan_gruntiv.pdf
[66] Eduard Degodiuk. «The employment of field by vegetation during the growing season is the highest manifestation of concern about the inclusion of invaluable biogenic elements in the biological cycle» (magazine "Ukrainian Farmer", October 2017) http://www.agrotimes.net/journals/article/sideraciya--ce-kultura-zemlerobstva

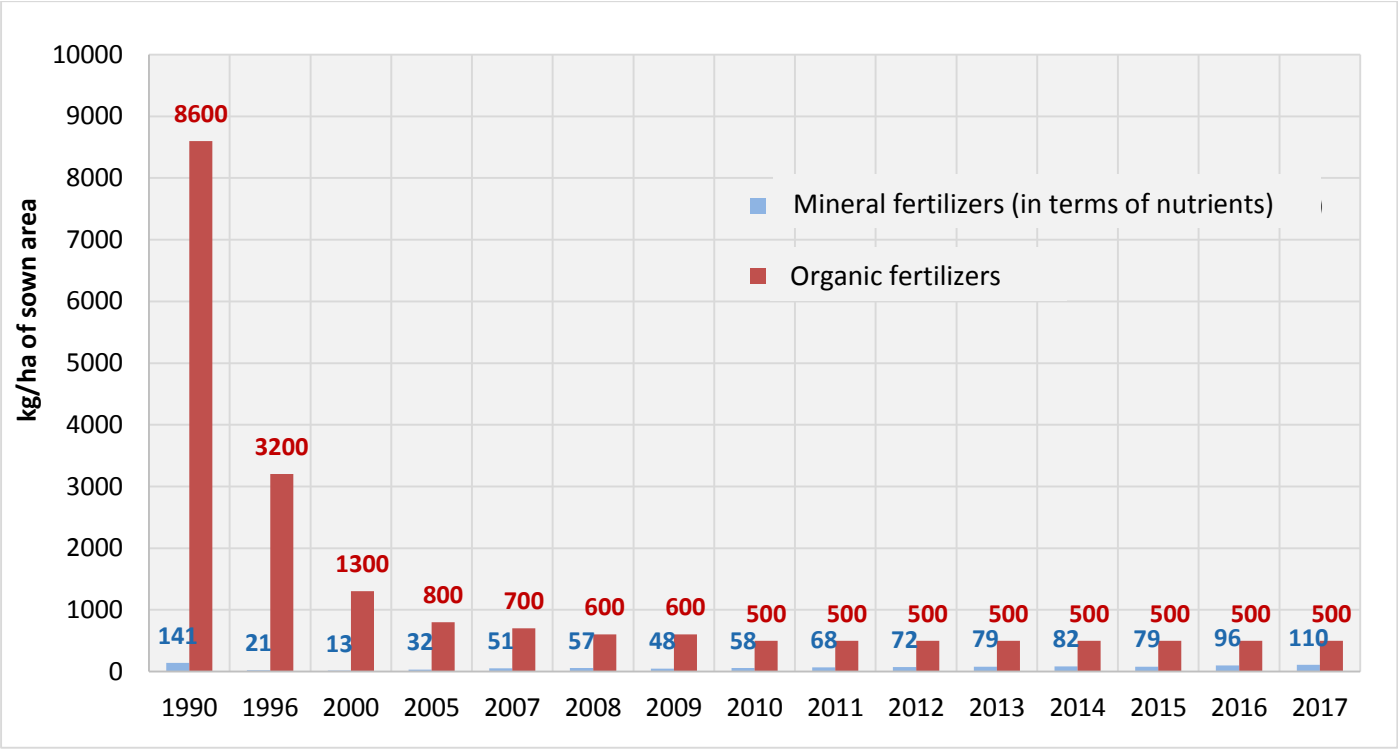


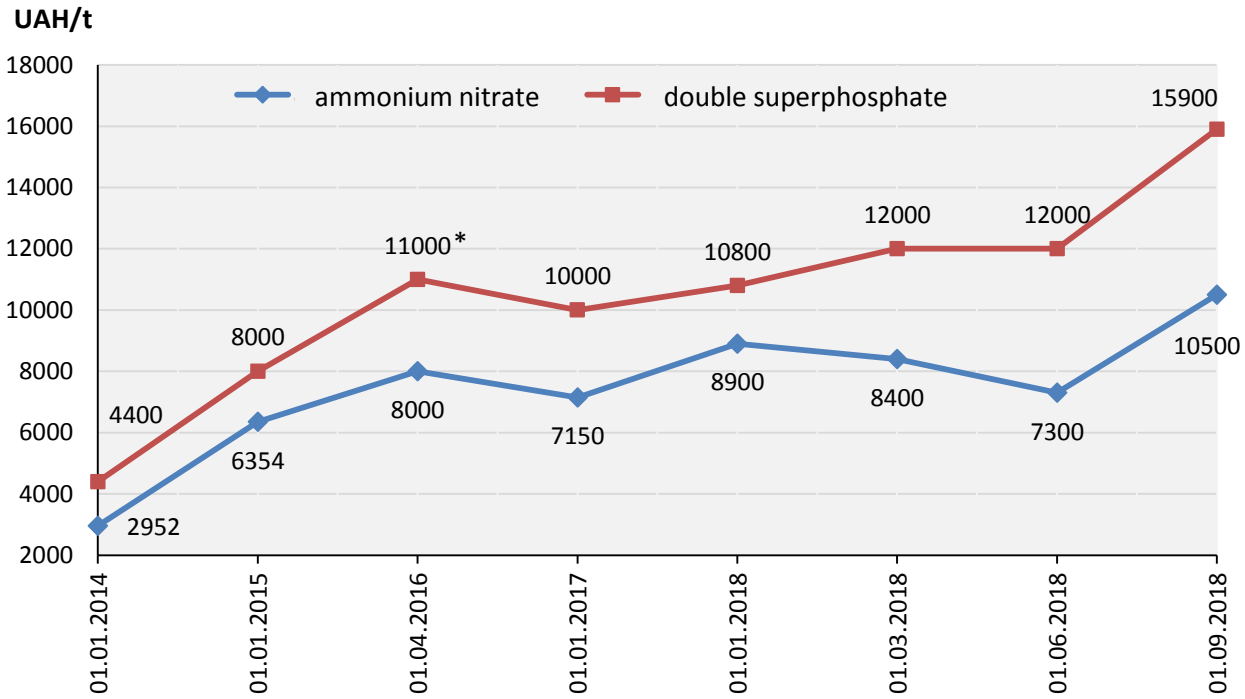

**Fig. 4.6.** Introduction of fertilizers in Ukraine (per sown area)[61].

The volumes of introduction of mineral fertilizers vary considerably over regions of Ukraine. For example, in 2017, agricultural enterprises introduced the minimal amount of mineral fertilizers in Kherson region (in terms of nutrients - 66 kg per hectare of sown area), and the maximal amount was introduced in Volyn region (176 kg/ha) the average figure for Ukraine being 110 kg/ha. In the applied fertilizers, 67.3% of nutrients came from nitric fertilizers, 17.9% from phosphoric fertilizers, and 14.8% from potassium fertilizers[67]. Despite some positive trends of recent years, the current level of use of mineral fertilizers in Ukrainian agriculture remains rather low as compared to the recommendations of scientists and experts, as well as compared to many developed countries[68].

The price of fertilizers (**Figure 4.7**) is one of the important factors that may restrict their use. In 2016, the cost of mineral fertilizers amounted to 20% of all material costs, which were included in the cost of agricultural production by agrarian enterprises[69].

So, today, it so happened that crop residues are often **the only kind of organic fertilizers** used by domestic agricultural producers. Because of this, there exist a negative attitude of soil scientists and some other agro-specialists to the removal of any volumes of crop residues from the field.

[67] Agriculture of Ukraine 2017. Statistical bulletin by SSSU, 2018 http://www.ukrstat.gov.ua/
[68] Yurii Kernasiuk. «Mineral fertilizer market» http://agro-business.com.ua/agro/ekonomichnyi-hektar/item/10772-rynok-mineralnykh-dobryv.html
[69] Expenditures of agri-enterprises on the production of agricultural products in 2016. Statistical bulletin by SSSU, 2017 http://www.ukrstat.gov.ua/




** information from Internet sources*

**Fig. 4.7.** Dynamics of mineral fertilizers price in Ukraine[70].

*Suggestions for overcoming the barrier*

We believe that today it is possible **to remove from the field** for energy up to **20-40%** of crop residues, provided that the *required amount* of mineral fertilizers (NPK) is added to the soil, as well as *other recommendations* for reducing the negative impact on the soil are observes (priority harvesting of corn compared with straw of cereals, returning of ash to the field, etc.).

A positive effect on the soil will also be from the harvesting of only **a part** of the by-products of crop production, for example corn cobs. An additional advantage of cobs harvesting in comparison with stalks is easy integration into existing agro-technological chains, higher profitability of the collection, easy storage (less influence of weather conditions).

In our opinion, crop residues **should not be** the only kind of organic fertilizers that support the soil fertility in Ukraine. Moreover, specialists note that the use of straw has a number of **disadvantages**, including the following: (i) water extract from fresh straw delays the development of plants; (ii) a number of identified phenolic derivatives have a toxic effect on plants; (iii) when straw is decomposing, organic acids (acetic acid, butyric acid, oxalic acid, and others) are formed, which adversely affect the development of the root system of plants, disrupt the metabolism and cause chlorosis[36].

[70] Monitoring of mineral fertilizers prices by state organization «Institute of Ukraine's soil protection» http://www.iogu.gov.ua/monitoring/

It is necessary to develop the fertilizer market and more widely use other types of organic fertilizers, such as manure, manure water, poultry litter, compost, fermented substrate from biogas plants, green fertilizer, etc. It is also important to return ash from the combustion of agribiomass at energy installations to the fields. Such complex actions, together with the revival of the livestock sector and with the general rational management of agriculture, will contribute to ensuring a proper balance of humus in the soil.

This approach is in line with the policy pursued by the European Union. At present, the EU is developing a new fertilizer related legislation to be adopted in 2022. One of the elements of this legislation is the development of the European internal market of standardized organic fertilizers such as fermented substrates, biological coal (biochar) and ash from biomass combustion[71].

**Conclusions**

The use of agribiomass for energy is topical because Ukraine has a large potential of agricultural residues and by-products, and without the usage of this potential it is impossible to attain the bioenergy goals set by the Energy Strategy of Ukraine until 2035.

To remove existing barriers to using agribiomass for energy production in Ukraine, we ***recommend***:

- To create conditions under which a farmer can change the technology and **ensure the harvesting** of crop residues with minimal economic risks.
- Taking into account the best foreign practices, to work out the basic technologies and approaches to establishing **"harvesting-supply" chains**, which are priority for domestic conditions and types of agribiomass[72].
- To use **modern specialized equipment** for burning agribiomass; to follow optimal modes of operation of the equipment and meet fuel quality requirements.
- As soon as possible, to adopt the respective law and start the operation of **biofuel electronic trade** system.
- To create conditions under which burning agribiomass in fields will **cease** due to the existence of other economically attractive ways to clear fields from crop residues.
- To develop **the strategy** for the use of biomass of agricultural origin for energy or **the strategy** of bioenergy development in Ukraine with a separate section on agribiomass.
- Dedicated ministries to develop "**Recommendations** regarding possible volumes of crop production by-products to be used for energy in Ukraine".
- Systematically to wage **informational and awareness raising campaigns** as for the opportunities and benefits of producing energy from biomass of agricultural origin,

[71] Proposal for a regulation of the European parliament and of the council laying down rules on the making available on the market of EU fertilising products (draft) http://data.consilium.europa.eu/doc/document/ST-15103-2018-INIT/en/pdf

[72] An example can be experience of Slovak company «Národná energetická» http://www.narodnaenergeticka.sk ; http://bio.garapena.com/global/nportal/view/61

including organizing technical excursions for stakeholders to successfully operating facilities in Ukraine and EU countries.

- To provide targeted **state support** or to open a special **credit line** for companies involved in harvesting and supplying of agribiomass to energy facilities.
- To develop a **market for organic fertilizers** such as manure, manure water, poultry litter, compost, digested substrate from biogas plants, green fertilizer, etc. **To return** ash from the combustion of agribiomass in energy equipment to the fields.

## Annex 1. Definition of some terms according to DSTU 4884:2007 «Organic and organic-mineral fertilizers. Terms and definitions»

**By-products** are a part of above-ground organic matter of crops which is collected when a combine harvester separates ripe grains. By-products include straw and empty glume.

**Straw** is an above-ground part of crop by-products which is collected when a combine harvester separates ripe grains. Straw consists of stalks and leaves of crops.

**Empty glume** is a part of by-products which consists of outer cover of a grain, fractions of leaves, chaff, etc.

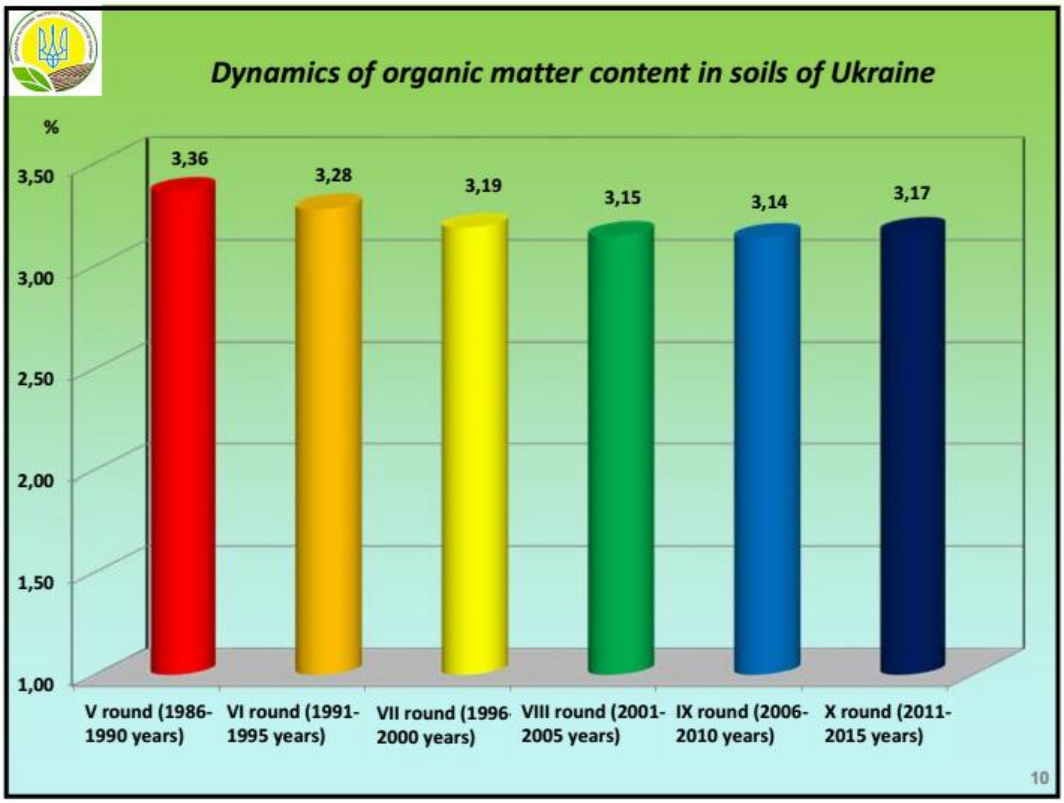
**Crop residues** are a part of above-ground and underground organic matter of crops which is left on field after combine harvester separated ripe grains. **Crop residues** include root system and stubble remains.

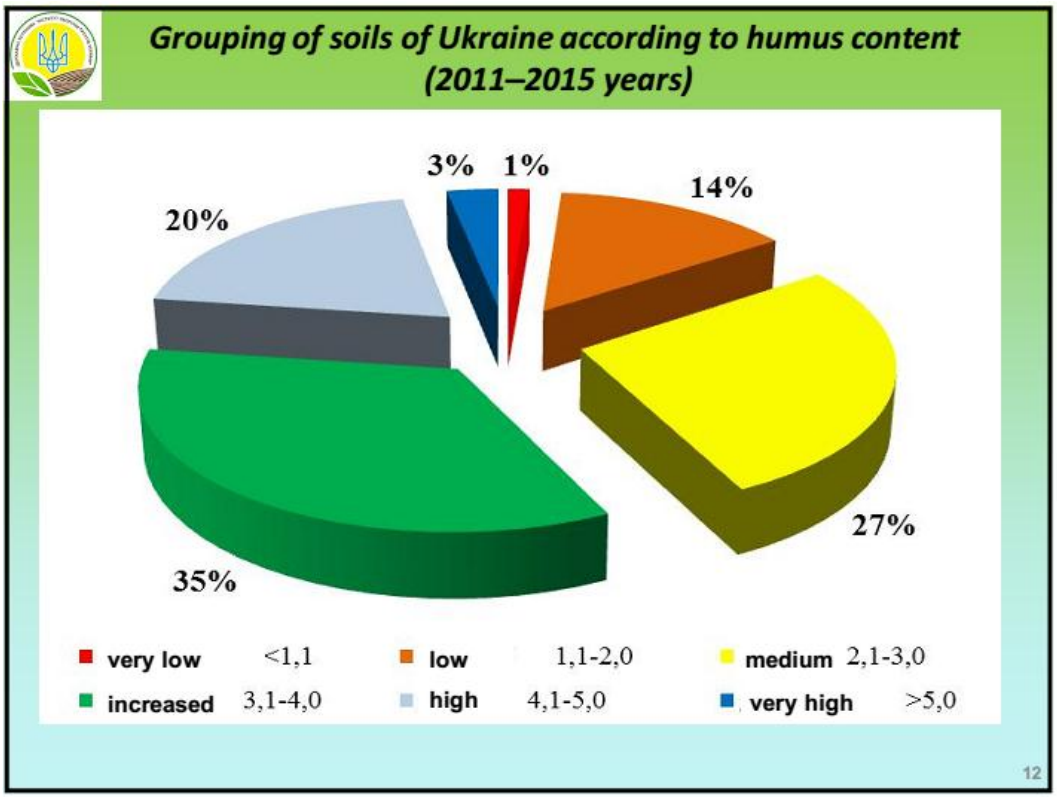
**Stubble remains** are a part of above-ground organic matter of crops which remains after a combine harvester cut a crop and is left in field.

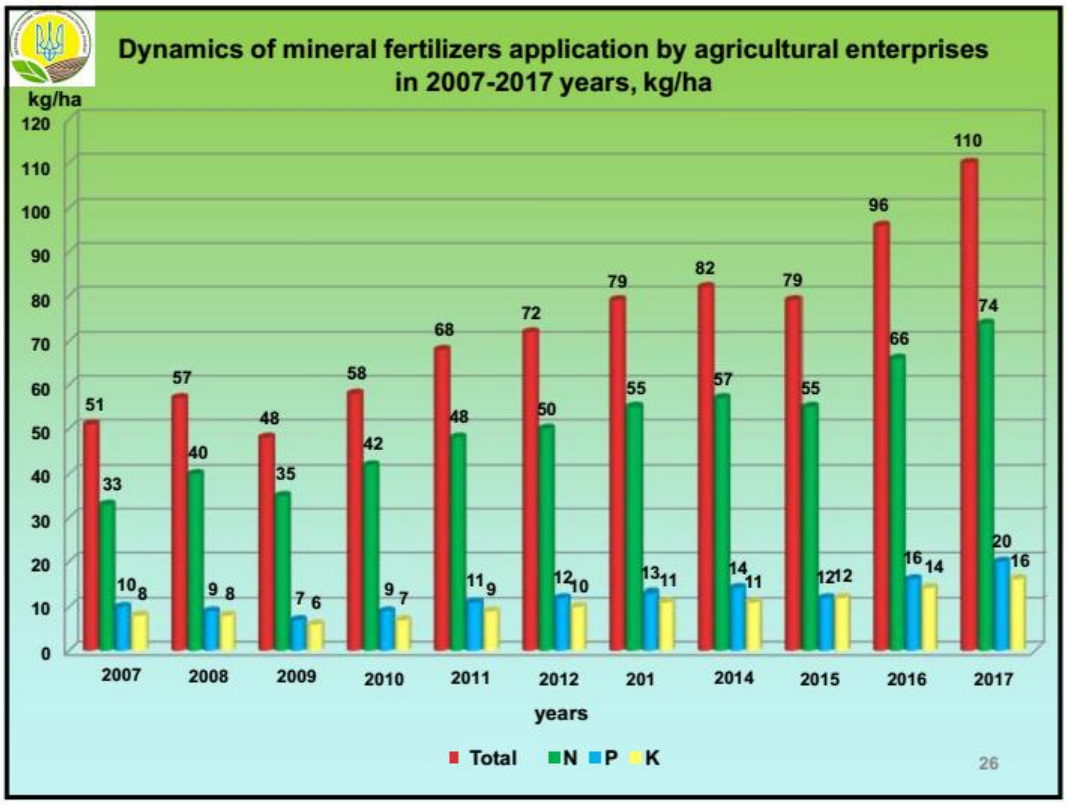
***Note**: In this Position Paper, apart from the above terms we also use their "synonyms" such as crop remains and some others.*

**Annex 2. Selected materials of the International Workshop "Agricultural Residues for Bioenergy. Problems and solutions" (27.09.2018, Kyiv)**

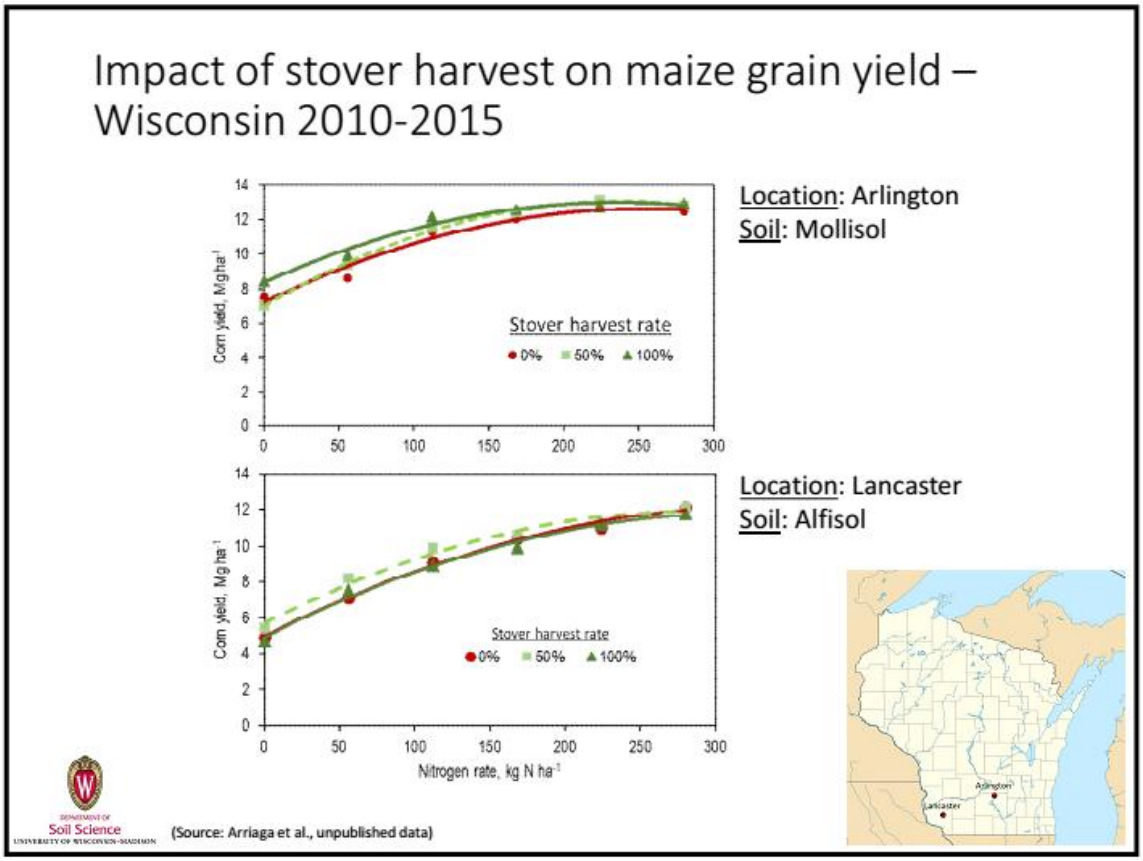
***Yuri Kryvda***, *Director of Cherkasy branch of the State Institution "Soils Protection Institute of Ukraine"*[13]*:*






***Francisco J. Arriaga***, *University of Wisconsin-Madison, Department of Soil Science, USA*[14]*:*



## Maize Residue Harvest Assessment – Yield & Soil Fertility Impacts

| | | Maize Residue Harvest Level | | |
|---|---|---|---|---|
| | County Yield | No harvest | Moderate | High |
| | ---------- Grain Yield in Mg/ha ---------- | | | |
| Mean | 10.2 | 9.8 | 10.1 | 10.1 |
| Range | 2.9 – 13.4 | 1.3 – 16.5 | 0.6 – 16.7 | 0.8 – 16.4 |

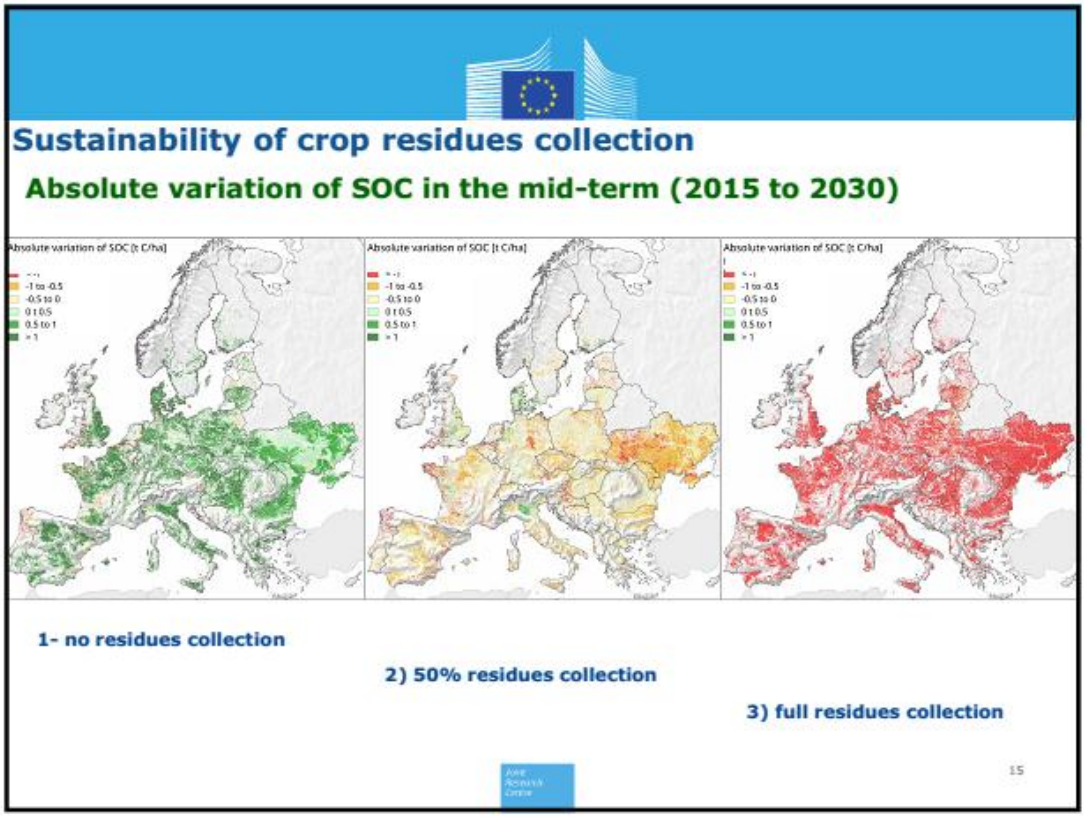
| Tillage Type | Stover Yield | N Removal | P Removal | K Removal |
|---|---|---|---|---|
| | -- Mg/ha -- | ---------- kg/ha ---------- | | |
| | **Moderate Harvest Level** | | | |
| Conventional | 4.1 | 24.0 | 2.6 | 31.9 |
| No tillage | 3.7 | 24.5 | 2.8 | 30.9 |
| LSD (0.10) | ns | ns | ns | ns |
| | **High Harvest Level** | | | |
| Conventional | 7.1 | 43.3 | 4.6 | 59.0 |
| No tillage | 7.3 | 49.7 | 6.0 | 63.8 |
| LSD (0.10) | ns | ns | ns | ns |

(Source: Karlen et al., 2014)

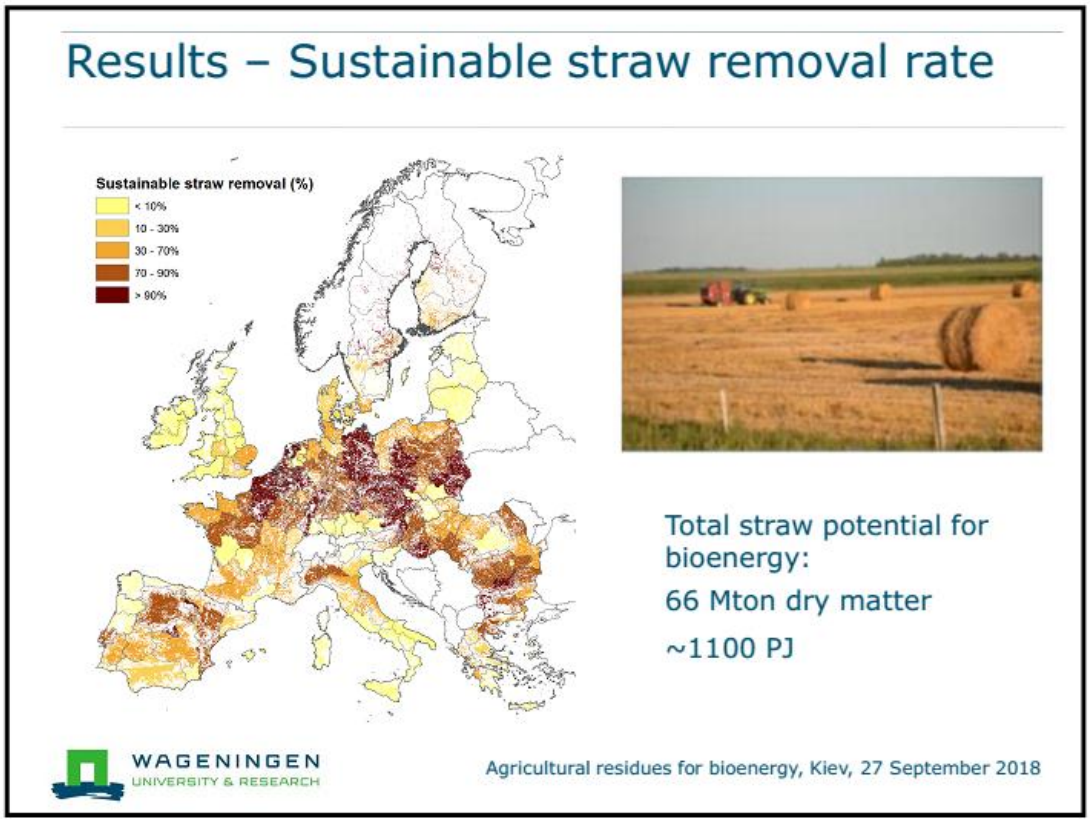
## Overall Recommendations

- Crop biomass harvest can be done with minor impacts to soil and environment when done properly.
  - Consider harvesting only a portion of the biomass and/or use cover crops to protect soil from erosion and provide organic carbon for soil health.
  - Crop nutrients will have to be replaced with commercial fertilizers or manures.
  - There might be a greater risk for soil compaction due to the additional equipment traffic.
  - Runoff and erosion can be a problem in sloping soils, even with reduced tillage practices. Permanent bioenergy crops can be used in these areas.
- Data and model implementation for making informed decisions is key.

***Nicolae Scarlat***, *Joint Research Centre (JRC), European Commission*[15]*:*




***Jan Peter Lesschen***, *Wageningen University and Research (WUR), The Netherlands*[16]*:*



## Strategies to minimize soil quality loss

1. No-till planting – no ploughing
2. Harvesting straw only once every 2-3 years
3. Planting a green manure crop after harvest
4. Increase crop yields
5. Use stems, leaves for the soil (2/3 nutrients left in the field + 1/3 of organic matter)
6. Apply other organic fertilizers: digestate, manure, etc.
7. Better use maize straw not wheat straw
8. Returning ash from straw burning to the field
9. Requiring balanced fertilisation from farmers



## Conclusions

- The sustainable potential of straw for bioenergy is estimated at 60-70 Mton for the EU
- Sustainable removal rate ranges from 0 to 100%, depending on crop yield, soil and climate conditions
- Different strategies are available to avoid negative effects on soil quality

***Abbreviations***

APPR – agricultural pruning and plantation removal
CHP – combined heat and power
CMU – Cabinet of Ministers of Ukraine
DLC – Double Liability Company
d.m. – dry matter
DSTU – State Standard of Ukraine
EBRD – European Bank for Reconstruction and Development
kt – thousand tons
ktoe – thousand tons of oil equivalent
LHV – lower heating value
Minagropolityky – Ministry of Agrarian Policy and Food of Ukraine
Minregion – Ministry of Regional Policy, Construction and Housing and Communal Services of Ukraine
Mha – million hectares
Mt – million tons
Mtoe – million tons of oil equivalent
NAAS – National Academy of Agrarian Sciences
SFRD – State Fund for Regional Development
SSSU – State Statistics Service of Ukraine
TOR – terms of reference
TPP – thermal power plant
UABio – Bioenergy Association of Ukraine
UTC – united territorial community

***Previous publications by UABio***

http://www.uabio.org/en/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".
4. *Position Paper N 4* (2013) "Prospects of biogas production and use in Ukraine".
5. *Position Paper N 5* (2013) "Prospects for the electricity generation from biomass in Ukraine"
6. *Position Paper N 6* (2013) "Prospects for heat production from biomass in Ukraine"
7. *Position Paper N 7* (2014) "Prospects for the use of agricultural residues for energy production in Ukraine".
8. *Position Paper N 8* (2014) "Energy and environmental analysis of bioenergy technologies"
9. *Position paper N 9* (2014) "State of the art and prospects for bioenergy development in Ukraine"
10. *Position paper N 10* (2014) "Prospects for the growing and use of energy crops in Ukraine"
11. *Position paper N 11* (2014) "Prospects of biomethane production and use in Ukraine"
12. *Position paper N 12* (2015) "Prospects for the development of bioenergy as an instrument for natural gas replacement in Ukraine"
13. *Position paper N 13* (2015) "Analysis of energy strategies of the EU and world countries and the role of renewables in their energy systems".
14. *Position paper N 14* (2016) "Analysis of tariff setting in the district heating sector of EU countries".
15. *Position paper N 15* (2016) "Analysis of additional sources of wood fuel in Ukraine".
16. *Position paper N 16* (2016) "Opportunities for harvesting by-products of grain corn for energy production in Ukraine".
17. *Position paper N 17* (2016) "Analysis of criteria for the sustainable development of bioenergy".
18. *Position paper N 18* (2017) "Creation of the competitive biofuel market in Ukraine".
19. *Position paper N 19* (2018) «Opportunities for wood fuel harvesting in forests of Ukraine».
20. *Position paper N 20 (2018)* **"**Analysis of possibilities for the production and use of agribiomass briquettes in Ukraine"

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/en/

Bioenergy Association of Ukraine