German–Ukrainian Policy Dialogue in Agriculture
Institute for Economic Research and Policy Consulting

Policy Paper Series [AgPP No. 31]

Straw use in Ukraine – opportunities and options

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Kyiv, September 2010

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The German-Ukrainian Policy Dialogue in Agriculture is advising Ukrainian state authorities and business associations on reforming agricultural policy and legislation, taking into account international experience of Germany and other countries as well as international practice (EU, WTO), in accordance with principles of market economy. The project is funded by the German Federal Ministry of Food, Agriculture and Consumer Protection under its Cooperation Program and by the German Centre for International Migration.

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Acknowledgement

Writing this paper was only possible with the support of many colleagues, providing relevant information on straw use in Germany and in Ukraine.

Special gratitude should be expressed to:

All FNR colleagues (Fachagentur Nachwachsende Rohstoffe e.V., Guelzow, Germany), who helped the author to gain knowledge on straw use in Germany during two study visits.

Board of directors of Hans-Jürgen Helbig GmbH (Nörten-Hardenberg, Germany) and Mr. Herring, Engineer of Thüringer Landesanstalt für Landwirtschaft (Jena, Germany), for giving support in practical study of district heating facilities in Germany.

Mr. Meyer, managing director of Lange&Meyer (Hilgermissen, Germany), and Mr. Schmidtke, CIS area manager of Amandus Kahl GmbH & Co. KG (Reinbek, Germany), for supporting learning of the process and equipment for making pellets from straw.

Mr. Rohde, engineer of Baubiologie-Altmark (Sanne, Germany), for assisting learning of straw-bale building techniques.

Mr. Losehand, managing director of Strohlos Produktentwicklung KG (Waren (Muritz), Germany), and Mr. Rieke, engineer of Schnick & Garrels Patentanwalte, for giving explanation of straw compression technology.

Mykola Kobets, senior expert of UNDP Blue Ribbon Analytical and Advisory Centre, for advising the methodology on straw potential estimation in Ukraine.

Colleagues of the German-Ukrainian Policy Dialogue in Agriculture for assisting the writing process of this paper.

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Executive summary

- In 2008-2009 Ukraine on average produced about 50 mln t of grains and about the same amount of straw. Straw is used for animal feeding, bedding and for soil fertilization, applying excess of 20-40% of the total straw harvest is possible. This excess straw can be used for producing energy or building materials.

- In this paper three options of alternative straw use are considered. These are straw uses for (1) heating (small-scale and district heating), (2) building, and (3) compression to pellets.

- EU countries do have experience in using straw for heating for many years. For decades some EU countries (the leader is Denmark) have been improving their knowledge in using straw for heating purposes and electricity production by co-firing in power plants. This knowledge has led mostly to large-scale district heating. In Ukraine this development is currently at the beginning. Ukrainian producers mainly use small-scale straw heating systems.

- Applying cost-benefit analysis, we assessed the profitability of two straw-heating plants of 600 kW and 1500 kW capacities based on Danish technology. These example plants are installed for district heating and therefore have a wide piping network. It implies investment costs for pipes even higher than for the heating system itself. Judging by financial profitability indicators, such as internal rate of return, net present value and payback period, both plants are profitable. The pay back period is about 3 years. For 15 years of operation the internal rates of return under applied conditions can be higher than 30%.

- Building with straw-bales has been spreading from America to European countries in the last years. It could provide long-term standing construction with a good structural capability, thermal and sound insulation, fire, moisture, earthquake and vermin resistance, breathability and good health impact for comparable lower costs than conventional brick structures have. The main bottleneck for straw-bale building in Ukraine is lack of expertise and experience.

- Using compressed straw is possible for outside building and internal furnishing. Stramit-like technologies have been already applied for more than 70 years since they were invented in Sweden. Similar technology modernized and altered by one German producer proposes to compress straw without using high temperatures and dangerous chemical elements. Final products are cheap and can be of any dimension and shape to be used as building panels, furniture elements and even for piping systems. Production rests can be compressed to pellets. However, production costs of this technology are very high.

- Cheaper straw compression methods are used in direct pellets and brickets production. It is a profitable and competitive business in the EU. In Ukraine pellet making technologies of up to 2 t/h capacities are used. They are often of soviet design. In future it is expected that new opportunities for Ukrainian pellet producers arise. Ukrainian producers will use high-quality reliable European equipment and feedstock suppliers will propose better quality straw bales for processing, which together will lead to better quality of Ukrainian straw pellets. This development may offer interesting opportunities on export markets.

- This paper does not present and discuss the production of biofuels from straw. A comprehensive second paper is under preparation to assess the perspectives of so-called second-generation biofuels using cellulosic feedstock including straw.

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1. Introduction

Ukraine annually produces about 50 mln t of grains and pulses. It means about the same quantity of straw as a by-product. It is primarily used for soil fertilization and for animal breeding. According to different agrarian practices different amounts of straw are used to fertilize soils.[1] Modern animal husbandry use water-wash systems in cattle-sheds and mixed fodders to feed animals. It implies that lower straw amounts are applied for animal bedding and feeding as animal breeding practices improve. About 20 to 40% of straw can be annually used for further processing. We assess three options of alternative straw use. They are (1) heating (small-scale and district heating), (2) building, and (3) pellets production.

One of the ways to use straw is to burn it to obtain heat for district heating production. It provides autonomous independent heating systems. Such systems can be of small or large scales, and can be used either for private houses or for large districts. In Ukraine small scale boilers are more spread than large scale ones. Due to economies of scale, costs per unit of energy decrease with capacity increase. Using German experience, economies of scale will be analyzed based on two sample straw-bale burning systems of 600 and 1500 kW capacities. The methodology applied is cost-benefit analysis. It comprises production and operation costs and compares them with benefits from sale or own use of heat. The calculation is made in sub-chapter 3.1. The conclusions on profitability are based on internal rate of return, net present value and payback period indicators.

Straw can also be used for construction. For this purpose straw bales of smaller sizes (up to 20 kg weight) should be used. There are two most spread technologies to build with straw: a functional straw bale structure and load-bearing beams. Straw-bale building is widespread in the USA and in many European countries. This experience in straw-building can be used in Ukraine. Based on German expertise, the technology of building with straw, approximate costs and several issues related to it are described in sub-chapter 3.2. The methodology used here is comparison of costs with performance characteristics that define a benefit for straw-bale construction.

Pellet production is a proven technology in Europe. The reason of the growing share of pellet production is high energy density combined with good storage and transport capabilities. Straw prices are higher in the EU than in Ukraine, giving the latter an incentive to export. A straw pelletizing market is developing in Ukraine, using soviet compression technologies of small capacities. Giving sometimes lower Ukrainian feedstock (straw bales) quality, outdated equipment adds to lower quality of produced pellets. To be competitive on international markets, modern automatic equipment should be used. In sub-chapter 3.3 we provide costs and benefits for producers. After describing pellet and pelletizing equipment markets in Germany and in Ukraine, we conclude about further development of pellet market in Ukraine.

One of the options of straw pellet market development in Ukraine is to increase its export share in EU markets, foreseeing future benefits from increased European demand for straw as a feedstock for second-generation biofuels development. The technologies of second generation biofuels are innovative and still under development, thus, are very costly. The description of different second-generation biofuels technologies, tendencies, international attitude and company involvement on this market will be presented in a separate upcoming paper.

[1] Bogdanovich R. and Predolyak M. "Biological activity of typical chernozem in view of different options of soil fertilization and cultivalion". National University of life and environmental sciences of Ukraine, Kiev 2009. Published in KHNAU Bulletin # 3, 2009, Pedology.

2. Estimation of straw potential in Ukraine

There are different views on straw potential estimation in Ukraine. This estimation became relevant only with the appearance of demand for straw. Until recently, no one cared about the excess of straw that was burnt at fields. Some researchers argue that huge amounts of straw are necessary to feed animals. However, in modern animal husbandry not much straw is used for feeding. Use of straw for animal bedding has also decreased for the last years with the increase of water-wash systems application.

A lot of applied foreign and domestic research was undertaken to define the best amount of straw needed to fertilize soils. They proved that it is not necessary to use large straw quantities to maintain soil quality. Some researchers propose to apply the amount of straw equal to grain yield in a certain district[2] or to mix straw with manure and other stubbles[3]. Good soil performance was achieved mixing 4-8 t/ha of straw with natrium, potassium and phosphorus.[4]

Taking into account different views on amounts of straw actually used for animal feed and bedding, and to maintain soil fertility, the ratio of taking straw harvest 1:1 equal to the grain harvest is widely spread. This simple estimation is accepted because it is difficult to estimate how much straw was used in each region differentiating between different agrarian practices applied, different sorts of grain grown and different yields received. Taking the 1:1 ratio, 80% of this straw amount is assumed to be used and 20% is assumed to be in excess and, therefore, available for alternative use. Based on 2009 total grain harvest in Ukraine, straw potential by this 1:1 methodology is estimated in column 2 of Table 2-1.

The 1:1 methodology is used by many market actors who are planning to use straw. However, as was noticed above, some actors are rather pessimistic, and some are rather optimistic. Pessimism was discussed above and is mainly applied by conservative agrarians. Optimistic views are typical for companies aimed at investor attraction and are used in correspondent business plans. For instance, a company in Ivano-Frankivsk region that operates a pellet plant and wants to attract additional investment for plant capacity enlargement claims that there is about 1.5-2 tons of straw available per each ton of grain.[5] It refers to Ukrainian experts' point of views.

We consider this optimistic estimate as realistic. There are a lot of other interesting methodologies. For example, evaluation of straw potential based on energy efficiency of agricultural technologies was proposed by an agrarian researcher.[6] Using his methodology to estimate the total grain straw value for Ukraine, we sum up the amount of straw, calculated by given regression equations for each crop type in 2009. Finally, based on above mentioned reasoning, 20% of total grain straw potential is calculated to deduct the straw potential available for alternative use (see Table 2-1 column 1).

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[2] Likhochvor V. Fertilization with straw. Lviv State Agrarian University.

[3] Gamayunova V.V. and Sydyakina O.V. Current status of Ukrainian step soil fertility and ways of its improvement. Scientific research, vol. 107, nr. 94, April 2009.

[4] Bogdanovich R. and Predolyak M. "Biological activity of typical chernozem in view of different options of soil fertilization and cultivalion". National University of life and environmental sciences of Ukraine, Kiev 2009. Published in KHNAU Bulletin # 3, 2009, Pedology.

[5] S.I.V. Holdings Ltd. Management Presentation. The future of energy. January 2010.

[6] The methodology of Yu. Tarariko accounts for energy equivalents of agrochemicals, irrigation, solar radiation, anthropological factors (accounting for crop rotation), labor, fuel, machinery, soil fertility, etc. After forming a ratio between all these energy equivalents, regression equations for each crop depending on yield range are made. These are simple linear equations made for winter rye, winter and summer wheat, barley, oats, millet, corn and buckwheat. For example, equations defining straw amount of winter rye are $x = 1.8y + 3.8$ (when yields are 1-2.5 t/ha) and $x = y + 25$ (when yields are 26-40), where x is straw amount and y is rye amount in tons. For other crops equations and methodological details see Tarariko Yu. Sustainable agricultural ecosystems formation. Monograph. Kiev, 2007.

Table 2-1. Straw potential in Ukraine

	Available straw* for heating, building and other purposes in 2009	
	calculations by energy equivalents **	calculations by 1 to 1 ratio
Ukraine	**13596.82**	**9205.66**
Crimea	492.60	332.49
Vinnytsa	853.55	618.45
Volyn	207.07	127.94
Dnipropetrovsk	873.22	563.45
Donetsk	556.05	344.86
Zhytomyr	364.53	247.52
Zakarpattia	93.54	60.34
Zaporizhzhia	665.63	426.14
Iv.-Frankivsk	117.76	80.40
Kyiv	688.24	496.52
Kirovohrad	732.85	506.84
Luhansk	372.00	211.09
Lviv	247.69	164.50
Mykolaiv	700.27	493.02
Odessa	823.94	567.74
Poltava	1099.22	765.97
Rivne	210.86	139.26
Sumy	592.17	401.00
Ternopil	438.06	314.78
Kharkiv	770.27	505.48
Kherson	557.56	353.78
Khmelnytsky	482.45	340.32
Cherkasy	851.93	638.99
Chernivtsi	142.86	94.97
Chernihiv	618.41	409.79

Note:
* 20% of total straw harvest after its use for soil fertilization, bedding and feeding is left for alternative use.
**only winter rye, winter and summer wheat, barley, oats, millet, corn, buckwheat.
Source: Own calculations.

According to the 1:1 methodology Ukraine had about 9.2 mln t of straw available for alternative use in 2009. Based on energy equivalents methodology this amount was 13.6 mln t. Following both methodologies, Poltava, Cherkasy, Vinnytsa, Odessa and Dnipropetrovsk regions were leaders in straw production that together provide more than 1/3 of total straw production in Ukraine.

3. Use of straw

3.1. Heating

Ukrainian practice of straw use for heating started with the installation of a straw-fired boiler of 980 kW/h capacity in Kiev region to heat the farm in 2000. The technology was based on Danish experience. Soon after this pilot operation the Ukrainian company UTEM started to produce similar boilers under a licensing agreement with the Danish Passat Energy. Initially, UTEM exported produced boilers to the European markets. In 2006 the first straw boiler of Ukrainian production origin of 250 kW/h capacity was installed in Vinnytsa region to heat the mill. It was the beginning to start straw use to heat not only farms but also schools, kindergartens and small districts. The majority of boilers that are currently installed in 9 oblasts of Ukraine are produced by UTEM. They have capacities from 150 to 860 kW and are mainly used to heat public buildings and agricultural enterprises. In total UTEM has set up 27 boilers in Ukraine.[7]

European countries (the leader is Denmark) can provide district heating for large territories. Denmark has above 60 operating district heating plants. They have an obligation to supply with the heat anyone in that area and because of this are not liable to pay tax. However, some plants are switching their activity to other feedstocks (wood residues) or to waste-fired combined heat and power plants.

Combined heat and power plants (CHP) are also known as co-generation plants since they use energy conversion process, where electricity and useful heat are produced simultaneously in one process. CHP heat can be used either for district heating or for industrial processes. CHP plants do not require cooling water, therefore, they can be located decentralized near large cities that have a distribution net and require district heating. However, being involved in district heating, CHP plant cannot achieve as high electrical power efficiency as coal-fired power plant. Straw-fired CHP plant has a specific electrical power efficiency of 20-30%. The complete thermal efficiency by using of straw in CHP plants is although higher. There are ways to improve CHP efficiency that started to be successfully applied in Denmark.[8]

Ukraine already has an experience of using straw for small-scale heating in plants with power capacities up to 1 MW . Following the example of European countries to install large-scale straw-fired plants, the introduction of district heating in Ukraine may be intensified. Provision of district heating can be efficient in rural areas with non-utilized straw and high demand for heat.

According to market evidence, heating with straw is less expensive than heating with gas. The saved difference between using gas and using straw for heating allows to pay the straw boiler back in about three years.[9] However, heating with straw is more troublesome. Thus, when large-scale heating systems are installed, owners prefer to have a gas boiler too for the case of emergency or when additional supply of heat is needed. Some market operators install smaller than required straw boilers and a complementing gas boiler.

The main difficulty in using straw to obtain heat is to deliver and store the feedstock. Straw bales, used to heat, are of about 300-500 kg weight and up to 2 m^3 of volume. During storage they should be well protected from absorbing excess moisture and from long lasting direct sun rays to keep the quality at more or less stable level and to avoid fire.

There are various producers supplying good straw bales burning equipment. According to German market operators, they prefer to use Danish LIN-KA systems.[10] LIN-KA supplies standard systems of 60 to 1500 kW and can make individual projects for higher sizes. The most demanded systems are of 200, 400, 600, 800, 1000 and 1500 kW. LIN-KA plants are fully automated, have rubbish filtering and automatic ash removal that ease the use of this system. General description of the system is given in Annex A.

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[7] Information from UTEM company: http://www.utem.com.ua/
[8] The Centre for Biomass Technology. Straw for Energy Production: Technology – Environment – Economy. 1998.
[9] Simple calculations for small-scale boilers are done here: http://www.viche.info/journal/1405/
[10] http://linka.dk

In Germany a system of 600 kW can, for instance, supply heat to a large farm with 25 thd chicken. A system of 400 kW is installed at the farm that specializes at selling small piglets (under 3 month). New-born piglets are kept with a mother pig in hot water that is supplied by straw hot-water boiler. This farm keeps 1200 mother pigs. In winter time they need more than 400 kW/h of heat. Thus, they use 200 kW gas boiler additionally. A smaller system of 200 kW is enough to supply heat for the farm that holds 3000 pigs and in total consists of 5 buildings (2 of which are 2-floor large houses of about 150-200 sq.m each). A system of 48 kW is enough to supply with heat two 2-floor large houses. However, these are individual German cases. So, how much heat is needed for an individual project in Ukraine and the needed capacity of a boiler depends on a lot of factors. Among these factors are the quality of isolation of a building with a plant and pipes distributing hot water to the objects. All this influences costs of producing heat.

It is relevant to compare two different capacities of straw burning hot-water plants and observe economies of scale. We will compare LIN-KA plants of 600 kW and 1500 kW. To make the cases realistic we assume two different models based on pig complexes that installed straw-burning LIN-KA equipment in Germany (as described above). They need boilers for 200 kW and 600 kW of heat. However, we assume that they installed larger plants of 600 kW and 1500 kW and supply the excess of heat to the nearby village.

The first model assumes installation of 600 kW straw-burning equipment (plant). It is set up in a pig complex with 3000 heads which are placed in two buildings. The pig complex territory consists of 5 buildings, 3 of which are administrative. The complex needs 200 kW of heat; the excess of heat will be supplied to the school that is 3 km far from the pig complex. Total length of the piping network is 4450 m.

The second model assumes 1500 kW straw-burning plant and provides heat to a larger pig complex. It consists of 5 buildings, 4 of which are buildings where pigs are kept. The complex needs 600 kW of heat mainly for 1200 mother pigs with piglets. The excess of heat will be supplied to the village that has a school of 2500 sq. m, two kindergartens of 500 and 1000 sq. m, hospital of 750 sq. m, library of 250 sq. m and village council of 1000 sq. m. The total length of piping network is 7150 m.

Estimation of profitability for these two models is made based on cost-benefit analysis. Conclusions are derived from the values of Net Present Value, Payback Period and Internal Rate of Return.[11]

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[11] Payback period refers to the period of time required for the return on an investment to "repay" the sum of the original investment. Payback period as a tool of analysis is often used because it is easy to apply and easy to understand for most investors. However, it is considered as a method of analysis with serious limitations for its use, because it does not properly account for the time value of money, risk, financing or other important considerations such as the opportunity costs. There is no formula to calculate the payback period, excepting the simple case of the initial cash outlay and further constant cash inflows or constant growing cash inflows. Thus, alternative measures of "return" preferred by economists are Net Present Value (NPV) and Internal Rate of Return (IRR).

NPV is defined as the total present value (PV) of a time series of cash flows. It is a standard method for using the time value of money to appraise long-term projects (we consider 15 years for our project). It measures the excess or shortfall of cash flows, in present value terms, once financing charges are met. In general, if NPV value exceeds zero we conclude that our project will generate profit in the future taking into account cash flows discounting by the current discount rate for credits in UAH that we take at the level of 23%.

The internal rate of return (IRR) is a rate of return used to measure and compare the profitability of investments. In the context of savings and loans the IRR is also called the effective interest rate or the annualized effective compounded return rate that can be earned on the invested capital. In more familiar terms, the IRR of an investment is the interest rate at which the costs of the investment lead to the benefits of the investment. This means that all gains from the investment are inherent to the time value of money and that the investment has a zero NPV at this interest rate. Therefore, we should compare the received IRR value to the current market interest rate (which is considered as a cost of capital rate) that is currently about 23% in Ukraine. This ensures that investment which IRR exceeds its cost of capital adds value for the company.

Source: Description of the terms Net Present Value (NPV), Payback Period (PP) and Internal Rate of Return (IRR) are taken from the Online Free Encyclopedia "Wikipedia". For details see:
http://en.wikipedia.org/wiki/Internal_rate_of_return
http://en.wikipedia.org/wiki/Payback_period
http://en.wikipedia.org/wiki/Net_present_value

According to the Law of Ukraine # 1391-VI "On amendments to some Laws of Ukraine as for stimulation of production and consumption of alternative fuels" from May 21, 2009 equipment that is used to build plants to produce biofuels, including code 8403 "Boilers for central heating" is exempted from import duty from January 1, 2010 to January 1, 2019. Also this Law introduces changes to the Law of Ukraine # 334/94-VR "On enterprise profit tax" from December 28, 1994 that exempt enterprise profit, received from heat production using alternative fuels, from profit tax for 10 years starting from January 1, 2010.

Total equipment cost consists of the cost of equipment itself, trailer, transportation, montage, start up and personnel training. Standard price is given for the trailer of 15 m length. If additional meters are needed (as in the case for 1500 kW plant), extra cost should be added for each 3 meters length. Trailer can be built in 2-floors construction to economize the space. Here we use the costs given by German supplier of LIN-KA systems to Ukraine.[12] They provide us with costs for the equipment itself, trailer, start-up, montage and transportation (delivery) of the equipment.

After a preliminary project is known, a project engineering office can work out a detailed project to supply a district with heat.[13]

After the project outline is ready, building itself comes. Heating equipment needs 114 sq. m and 273 sq. m building respectively to put straw burning equipment of 600 kW and 1500 kW there (with a trailer for straw and having free space to store a certain amount of straw). There are no strict requirements for building. It can be of any not highly inflammable material of about 4-6 m height with a good insulation to avoid loss of heat. Ukrainian builders[14] propose to make metal construction of sandwich panels using mineral wool or to make standard brick building. Since large doors (to allow tractor coming in) are needed, extra cost of 4-10 thd. UAH must be added. Large outside doors are proposed to be built from profiled sheet with mineral wool insulation. According to market information prices to construct such a building varies among 2000-6000 UAH per square meter. We take 3200 UAH/sq.m assuming that all building materials (including doors) are included in this price. We also assume buying additional land to construct a building near the pig complex where the straw heating plant will be placed. The land area should be larger than the building itself. Thus, we take 200 and 350 square meters for 600 kW and 1500 kW plants respectively. In our calculation we take current market price for land about 100 km far from oblast centers that equals about 200 USD per 100 square meters ("sotka"), assuming that all accompanying land sale costs are included in this price (legalization costs and payment to realtor).

One of the most expensive positions of the production costs are the hot water pipes. Their total cost consists of the cost of a pipe itself, insulation of pipes, chutes for pipes, heat-chambers and montage of the whole piping system. Modern pipes can be supplied already insulated.[15]

As for personnel to service the plant, one well-qualified person (engineer) spends 1 hour a day to supervise the equipment (plant) work and to put straw bales to the trailer.

Regular costs include feedstock and equipment maintenance costs. Straw as a feedstock is not very expensive (about 200 UAH/t in straw bales). However, it should be available at most in 50 km area. The bales are large enough, so no more than 40 bales are possible to deliver by large truck. That is why straw delivery becomes a rather expensive item in plant operation. Besides, here we should account for 10% of heat loss, by adding extra 10% of straw needed for a plant operation.

Also, maintenance costs must be accounted for. They are about 3% of total installation and piping work. Moreover, a plant consumes electricity that amounts to about 1.5% of total cost.

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[12] Hans-Jürgen Helbig GmbH (Germany): http://www.helbig-gmbh.de/

[13] We use the data for project work costs provided by Ukrainian building company "Ukrbud" that has six project institutions throughout Ukraine: http://www.ub.com.ua

[14] http://averbud.com.ua and http://adivision.ucoz.com/

[15] Ukrainian companies that make set up and montage of heating systems, Teplomaster and Rosmar (http://www.teplomontag.com.ua/ and http://rosmar.com.ua/) provide us with the costs for the piping system as described in the text.

Profits from plant operation can be obtained from heat sale. Heat is sold by standard tariff calculated as Ukrainian average by regional level information given by the Ministry of Housing and Communal services of Ukraine. This tariff for commercial consumers (with VAT tax included)[16] is 610.13 UAH/Gkal or 0.5246 UAH/kW*hour. We assume that heat is produced 24 hours during the heating season (in Ukraine from October 15 to April 15) and the rest of the year the heat is needed only for pigs. We assume 8 hours of producing heat during the rest half of the year.

Ash is obtained as a by-product during the straw burning process. It can provide additional benefits from its use as a plant fertilizer at fields. It can have a certain monetary value. However, in most cases it creates more problems than benefits. If the straw heat producer does not have his own fields, no one is eager to buy ash as a fertilizer. Absorbing water, ash turns into stones. Therefore, straw consumers often try to make an agreement with straw suppliers so that the latter take ash from their straw back free of charge.

The results of the cost-benefit analysis are given in the table below.

Table 3.1-1. Profitability indicators for straw heating plants of 600 kW and 1500 kW capacities.

	Costs:	**Heat production capacity, kW/h**	
		600	**1500**
1	Total equipment cost* (equipment, trailer, transportation, montage and start up)	1,423,014	2,380,635
2	Total piping work* (pipes, chutes, heat-chambers and their montage)	1,810,400	5,548,200
3	Total annual personnel cost*** (1 person, assuming 10% wage increase in years 2-14)	39,600	39,600
4	Design and construction cost* (projection and design work, land purchase and construction of the main building where the equipment is placed)	909,864	1,692,064
5	Feedstock cost**** (feedstock, transportation and 10% efficiency losses)	292,874	732,185
6	Other costs** (electricity consumption is up to 1.5% of total cost; plant maintenance cost is 3% of total equipment and piping cost)	159,692	310,292
	Benefits:		
7	Total profit from heat sale (Given as the value for 2-14 years, Profit tax is 0%)	1,825,608	4,564,020
	Profitability characteristics:		
8	Payback period, years	3.13	2.77
9	Net present value, UAH	1,301,647	4,650,418
10	Internal rate of return, %	31%	36%
	Important indicators:		
11	Straw bales price, UAH/t (without transport costs)	200	200
12	Heat sale tariff, UAH/kW*hour	0.52	0.52
13	Interest rate for loans, %	23%	23%

Note: All costs and benefits are given in Ukrainian hryvnas.
* Fixed costs, effective for installation year (year 0, when all preparatory works are made and a plant does not operate).
** Fixed costs, effective for all 15 years.
*** Variable cost, changes starting from 2nd year. Given as a value for 2-14 years of operation.
**** Assumed to be fixed and effective for all years except installation year.
Source: Own calculations.

With the increase of capacity of a straw boiler, the profitability of investments into the plant grows indicated by the rise of NPV and IRR, and shortening of payback period. Due to the economies of scale effect, payback period for 600 kW plant is 3 years and 3 month, and for 1500 kW plant is 2 years and 9.5 month. Profit from providing heat to the pig complex and a village that can be obtained for 15 years (assuming current discount rate for credits at 23% and expressed as net present value) is 3.6 times higher for 1500 kW plant and equals 4.6 mln UAH. The internal rate of return is 5% higher for the plant with 1500 kW capacity and equal to 36%.

[16] See http://www.minjkg.gov.ua/activity/tp/tp-stats/. Tariffs are taken by the state of June 1, 2010.

Conclusions:

Both projects, installing 600 kW or 1500 kW straw burning plants are profitable. The pay back period is about 3 years. Their internal rates of return prevail by 8% and 13% respectively over the current Ukrainian discount rate of 23%. Their NPVs are positive, amounting to 1.3 mln UAH and 4.7 mln UAH respectively.

3.2. Building

Straw can effectively be used for building either directly applying straw bales or compressed straw. Buildings are mostly made from straw bales. Compressed straw in building is used for interior furnishing (to warm or to make partitions inside).

First houses made from straw bales are dated by the 18th century. From that time the principle of building remained the same, however, the technology is constantly improving. In modern times building with straw bales is widespread in USA, Canada and Europe.

There are two major kinds of straw bale buildings: load-bearing and a post and beam framework (another name is in-fill or timber-framed).[17]

Load bearing construction (taken mostly from Nebraska houses) means that the bales are used as the structure for the building and they bear the load of the roof. Thus, little wood is required. Wood is needed to add windows and doors to the building, to frame the roof and the actual box it attaches to on top of the bales. Care must be taken to consider the possible settling (compression) of the straw bales as the weight of the roof. The most obvious reason to choose a load bearing structure is the simplicity of the construction. Load bearing structures have simple designs. Simple design could mean saving money and time, and can be self-built instead of using hired help. In the Western World people build load bearing houses not even thinking of economic reasons. There are a lot of books and organized seminars that provide interested people with details of such building. For example in Germany there is an ecovillage Sieben Linden[18] where people try to use renewable resources in building, heating, etc. They also organize different workshops on ecoliving including building of straw bale houses where not only theoretical details can be taught but also practice of building is included. There are various organizations in Europe that can give theoretical as well as practical knowledge for straw building.[19] Often they gather people to build small simple load-bearing structures that can be constructed by a group of people in a few hours.

Post and beam framework is used by those who prefer designer long-term standing houses. Here another structural system supports and attaches the roof and the bales are either inserted as in-fill material between the columns of a structural framework, or the bale walls wrap a structural framework. Any design as for wood or brick houses can be chosen. The width of the straw bales allows other design brushstrokes such as broad window seats, corners or long wall benches. This is also the only straw bale construction that many building authorities allow in many countries.

Building with straw has many benefits. Among them are savings on heating and cooling costs due to great insulation value and internal thermal mass evenly distributed through the building, strength and durability, carbon locking for possibly centuries, fire resistance, as well as the ability to be finished in an almost unlimited range of textures and styles (see Table 3.2 – 1).

There are a lot of details needed to know to make a straw bale construction. Straw bales are natural materials that can easily absorb water or become inflammable. To prevent this, straw bale walls must be covered with a surface material. It will allow any water vapor getting into the wall to migrate out again readily, i.e. the wall must "breathe" but not leak. To use any sort of building paper or membrane between straw bales and plaster is not recommended since it can trap moisture or limit its movement. For instance, stucco plaster is regarded as secondary weather protection since it is very difficult to guarantee leak free and 100% water exclusion. Dense stucco plaster is also not a particularly good "breathing" coating (especially if painted). Softer plasters

[17] http://www.greenhomebuilding.com/strawbale.htm
[18] http://www.siebenlinden.de/english2035.html
[19] For example, http://glassford.com.au/main/

such as lime, gypsum or earth are better.[20] According to market information, covering coat of a straw bale house must be applied in two layers. After making this, the straw bale house becomes protected from water and from fire. There have been made a lot of tests to prove fire and water resistance of straw bale constructions (see EU examples below). According to German straw bale building company being under fire straw bale house can stand about 5 hours.[21]

To summarize, here are strawbale houses properties that make them competitive in comparison with other constructions.

Table 3.2 - 1: Performance summary of a strawbale buildings

Property	Description
Appearance	Rendered straw bale walls are not visible. They are smooth and not distinguishable from rendered blockwork. Sometimes European consumers prefer to live small part of the house not rendered to show their attitude to ecobuilding to surrenders.
Structural capability	There are examples of up to three floors in load-bearing structure and timber-framed multi-storeys.
Thermal mass	Pure straw bales have very low thermal mass. When they are earth rendered (with a coat of up to 75 mm), a significant thermal mass can be achieved.
Thermal insulation	Straw bales are among the most cost effective thermal insulation available.
Sound insulation	The overall insulation value for straw bale construction exceeds the values of any conventional walls in the most cost-effective way.
Fire resistance	Straw bale constructions survived during Californian bush fires while conventional structures were destroyed. Cement covered high-dense straw bale walls are nearly airless, and fire cannot burn without oxygen.
Vermin resistance	Even if vermin manage to get inside the straw bale wall, densely packed straw makes it hard for them to navigate through the space.
Durability and moisture resistance	With a water content not exceeding 15%, straw bale constructions can have a lifetime of 100 years or more. Nebraska and Alabama historical experience show that the best way to prevent rot in a finished structure is to create breathable walls.
Toxicity and breathability	There is no toxic end to straw bale constructions cycle. Covered with earth or earth-lime, straw bale walls breathe better in contrast to the walls with high cement to sand ratio.
Environmental impacts	Straw bales are biodegradable. Using them for building reduces air pollution, stores carbon and produces minimal waste from this material use.
Buildability, availability and cost	There is a very active and informative international network as for straw bale building that constantly explores ways to improve and quantify bale construction technologies. Straw bales are low-cost material that is available in Ukraine in large quantities (see chapter 2).
Ease of construction	Straw bale walls can be built easily and quickly. It is better to use professional organizations, experienced in straw bale building, to avoid any pitfalls.
Earthquake resistance	Well-braced timber-frame straw bale construction generally has sufficient stability to withstand lateral wind and earthquakes.

Source: Own presentation based on Your Home (http://www.yourhome.gov.au/) and Smarter Homes (http://www.smarterhomes.org.nz) publications.

The EU has strict standards to approve any material for building. Straw bales got a permission at the EU level to be used in construction. All construction products are classified into one of seven Euroclasses (A-F) according to their reaction to fire performance in fire tests. According to ISO standards, straw bale specimens are checked for non-combustibility (EN ISO 1182 based on ISO 1182). Products with appreciable combustibility can be assessed using a simple ignitability test by EN ISO 11925-2.[22] *Straw bales used in construction in general satisfy E class for ignitability.*[23] It means normal ignitability. To prove this essentially flat specimens are used with dimensions of 250 mm x 90 mm and maximum thickness of 40 mm. These specimens are required to be 15 seconds under exposure, and the flame height should not exceed 150 mm within 20 seconds after the start of the test.[24] *Check of straw bales for fire resistance according to EN 1365-01 and EN*

[20] More details on protection from moisture can be found in http://www.earthbuilding.org.nz/articles/strawmoisture.pdf
[21] Baubiologie-Altmark: http://baubiologie-altmark.de/
[22] http://www.wpif.org.uk/uploads/PanelGuide/05_%20Section%202_2%20BRE%20V3%2021_04.pdf
[23] Presentation "European technical approval (ETA) for straw bales" accessed at German national organization of straw bale building: http://fasba.de
[24] Efectis Nederland. "EN ISO 11925-2:2002 - The Ignitability test", January 2007. http://www.efectis.com/nl_en/Downloads/techn_productfolder_ignitability_test.pdf

1363-1 showed their resistance during 90 minutes. As for the resistance against biological influence according to ON 6010 / DIN EN ISO 846 EOTA CUAP, quantifying of fungus growth, straw bale specimens received 25%-50% of probability for that (class 2-3). For example, according to the tests made upon German and Austrian projects, they got a permission to be implemented in building. The first one "Strohballenbau in der Altmark" was aimed at regional development of straw bale building using the bale sizes of length 50-100 sm, width – 46-50 sm and height – 36-40 sm with gross density of 90-130 kg per cub. m and straw moisture content of less than 15%. The material used showed thermal conductivity (λ) of 0.04 W/mk in fibre-direction and 0.065 W/mk against fibre-direction[25]; for fire behavior straw bales were referred to class B2[26]; for resistance against the impact of biological agents – classes 2 and 3 and for resistance against fire – F-30 – F-90 (that means 30-90 minutes). The second project, Austrian "Stroh kompakt", used bale sizes of 60-90 sm length, 46-50 sm width, 36-40 sm height with gross density of 80-90 kg per cub. m[27] and moisture content of less than 15%. Tests show straw bales thermal conductivity of 0.046 W/mk and fire behavior according to B2 class.

According to European experience of applying straw bales in building these houses appear to be not much less costly than conventional ones. The main material used (straw bales) is of low cost. However, straw bale buildings require labor-intensive construction techniques. Thus, the essential part of the cost is labor that is costly in EU. In Ukraine labor is cheaper. However, international expertise, needed for first straw bale projects Ukraine, will add to the cost. Moreover, straw bales of special small sizes are required for building. Since Ukraine does not use straw for building, there are no such sizes of straw bales proposed to the market. Thus, it is additional cost "to produce or find" such bales. Straw bale construction appears to be low-cost only for owner builders (as Australian experience justifies). In this case, the cost per square meter is from 100 USD[28], while it can achieve 1000 USD for architect designed houses.[29] Different internet resources, aimed at attracting people to build with straw bales, claim prices in the range of 10-50 thd. USD for the whole house[30]. It is possible to achieve during own making of load-bearing simplest structure. According to German market information on average a price for a straw bale house for 2-3 people can be 100 thd. USD. Therefore, to choose between straw bale or conventional structure to build, one should focus on properties of a "home" he or she wants to get instead of costs that are possible to minimize using simple load-bearing structures and own participation in building process.

There are available technologies on the market on how to use compressed straw for building. Using straw property to be compressed under high temperature, Stramit technology was invented in Sweden in 1935. High-compressed straw panels can be produced by this technology. After the original compressed agricultural fibers (stramit) patents have expired, numerous companies using this process have sprung up worldwide. This technology is known in Australia, UK and several European countries. A lot of buildings have been built using stramit-like technologies.[31]

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[25] Basically it is the test for insulation material that in general for straw equals 0.05 W/mk. It observes how the steam (in Watts) comes through the wall (linearly) per 1 m. It is the measure of heat flow rate by conduction through a unit of distance in the material per unit of area per degree of temperature difference (see http://www.proz.com/kudoz/german_to_english/tech_engineering/2330-u_wert.html). For wood λ=0.17. The less λ value – the better. A better option is to check the whole wall (not only insulation material as λ does). U-Wert or U-value does it. It measures thermal transmittance that for straw bales plastered at both sides equals 0.12 W/m2K. For wood U-value is higher. The lower U-value – the better.

[26] In category B there are B1, B2 and B3 classes. B1 is not easily flammable, B2 is just flammable and B3 is easily flammable. See "Fire testing to building material – Germany Standard DIN 4102-1" at http://firetc.com

[27] According to German market information (Baubiologie-Altmark company, more than 20 straw bale houses built) use of straw bales with the density of less than 90 kg per cub. m is not desirable.

[28] http://www.strawbale.com/cost_of_straw_bale_construction

[29] Environment Society of Australia: http://enviro.org.au/StrawBale.asp

[30] See Solar Heaven: http://www.solarhaven.org/StarterStrawBale.htm and A House from Straw: http://www.ahouseofstraw.com/expenses.htm

[31] http://www.buildinggreen.com/auth/article.cfm/1995/5/1/Straw-The-Next-Great-Building-Material/ Using Stramit process, Australian company "Ortech" under the brand "Durra Panel®" produces standard straw panels of width 1187 mm, length – 1800-3600 mm, nominal thickness 50 and 58 mm, and nominal weight – 18-22 g/m2 from rice straw fibers. Durra manufacturing process combines extreme heat and compression in a dry extrusion process to form the solid panel core. A natural polymer in the straw fiber is released during the procedure, and a water based PVA glue is used to encapsulate the finished core with a high strength recycled Kraft paper liner (having no toxic waste). These panels have distinguishing acoustic and thermal insulating properties, proven durability, and high impact fire resistance. They contain

There are various international companies that offer compressed straw products.[32] However, there is no stable demand for straw compressed products. Thus, many companies exited this market. At the same time the research in straw compression has not stopped. A company in Germany produces not only panels, but also square and round forms from the compressed straw. These products can be used for different buildings construction, to make furniture, decorative elements and even pipes for water (since these materials are water and high-temperature resistant).[33] It has a patient for a special technology to compress straw without using high temperatures and any unhealthy chemical elements applying special feedstock mixture. Compressed by this technology straw products (according to DIN 55666) have formaldehyde content (cohesive element) of 0.06 ml/m3 (while compressed wood-based products 0.1 ml/m3).[34] The rests of the material can be compressed to pellets at the same plant. All final products produced by this technology are cheap to buy and reliable in use. However, initial investments are high. A full set of such equipment costs 18-20 mln Euros for 30-50 thd m3 annual production.

Conclusions:

In construction straw can be used in the form of straw-bales or compressed products. If straw bales are used, then we can consider either load-bearing or timber-frame structure. Both of these structures can provide long-term standing constructions with a good structural capability, thermal and sound insulation, fire, moisture, earthquake and vermin resistance, breathability and good health impact. However, the costs associated with using straw bales for building are not always lower than for conventional structures, especially if designer timber-frame projects are considered. According to market information, people choose straw-bale building mostly because of house quality characteristics and not costs. It is possible also to use compressed straw products in construction or internal furnishing. There are several companies in the World that produce such products. In most cases these products are innovative, rare and still not-commonly used that implies higher production costs for them than for their analogues. It is a technology for the future that can be considered by Ukrainian producers of offering domestic or international market opportunities.

3.3. Pellets production

For heating a satisfactory level of quality is easier to maintain in compressed straw in the form of pellets or briquettes. Pellets are small particles typically created by compressing straw. Briquettes have larger size and lower density in comparison with pellets.

Pelletizing is closely related to briquetting except that it uses smaller dies (approximately 30 mm) so that the smaller products obtained are called pellets. Standard straw pelletizing process consists of seven stages. First, straw bales are freed from heavy contaminant and then grinded. Second, the particle size is adjusted to a uniform maximum dimension to be produced (about 85% of the minimum thickness of the pellet). Sometimes drying is necessary. Third, feedstock is conditioned (more often steam is used). Forth, the particles are moved to a pellet mill. Fifth, hot pellets are immediately air quenched down to 25°C. It sets up the lignin and hardens the product. Sixth, pellets are screened, residual fines are separated and then re-used in the process. Finally, dust free pellets are directed for storage (if in bulk) or go to automatic packing (in small or big bags).

There are two main types of pellet presses: flat die and ring die types. The flat die type have a circular perforated disk that contains two or more rotating rollers and force the material through

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no formaldehyde or additional chemical binders. They have commercial, industrial and residential applications in walls and ceilings, and can be used in low cost housing/buildings. For details see: http://ortech.com.au/durra/durrapanel.html

[32] Lists can be found at footnote 31 table 4 or at http://www.austinenergy.com/energy%20efficiency/Programs/Green%20Building/Sourcebook/engineeredSheetMaterials.htm For example, Agriboard Industries, a division of American Ryan Development Company LLC, compress wheat straw to produce special panels that can be used in industrial building (for details see: http://www.agriboard.com/panels_from_agriboard.htm). Meadowood Industries Inc since 1977 develops and manufactures primarily from ryegrass decorative and structural boards, panels, and molded products for building. They are used for interior design as well as architectural elements (for details see: http://www.meadowoodindustries.com/).

[33] Strohlos Produktentwicklung KG: http://strohlos.com/

[34] Tests results as for other properties of materials produced can be found under: http://strohlos.com/strohlosentwicklungendetails/index.php

the holes. The ring die press features a rotating perforated ring on which rollers (normally two or three) press on the material to the inner perimeter.[35] Disk diameters and track surfaces of rollers are larger for flat die types in comparison with the ring one. Pellet press capacity is not restricted by the density of the raw material as in the case of piston or screw presses used for briquetting.[36] The flat die pellet machines were the first design to be used that originally applied to produce animal feed, and later was adapted to process other raw materials including biomass pellets. Flat die pellet machines are of a much simpler design than ring die pellet ones. The ring die pellet machines are second generation designs that have been widely adopted in large scale animal feed and wood pellet production. There are quite a lot of pros and cons of both types of pelletizing machines.[37] The choice should be made based not on the type but on characteristics of the equipment, which are better suitable for a certain quantity and quality of pellets aimed to produce.

The full set of the equipment can be supplied, installed, set up and supervised by one company. This company gives a guarantee to produce pellets of a certain quality to adjust to recommended conditions. The complexity of the needed equipment / plant depends on the properties of the existing raw material. German large pellet equipment producer Amandus Kahl[38] recommends to use wheat straw. However, first, it states that other straw types (such as rye, oats, barley, triticale and rape straw) can be processed too but with some capacity deviation from the nominal one. Second, the bales used should be of rectangular shape (with possible dimension of 0.7 x 1.2 x 2.0 m). Other bale shapes and bulk straw can be processed too but in this case the capacity will be lower than the nominal one. Third, average moisture content in straw bales should be lower than 12-14% by weight. Moisture of up to 20% in the bale edges must not be exceeded. Also the straw bales must not be rotten and enrooted. Binding ribbons (wires, foils, etc.) on straw bales have to be removed manually on the feeding belt. Impurities of more than 0.5% can cause higher wear and reduce the capacity. Finally, the input feedstock must be free from foreign matters (such as stones, glass, nails, ferrous and non-ferrous metals, etc.). Sticking to listed necessary conditions for pellet production, the bulk density of a final product (pellets of diameter 10 mm or 6 mm) is 450-550 kg/m3.

In most cases big international pelletizing equipment suppliers specialize on large plants. For example, Amandus Kahl prefers to supply to Ukraine pelletizing plants from 3t/h capacity.[39] A straw pellet producer in Germany[40] has a plant of 1.5 t/h capacity. He reported to previously use Amandus Kahl equipment. After renovation he switched to Buhler[41]. Good quality of equipment used contributes to better quality of pellets produced that are sold for horse-bedding[42] for higher price. It gives the possibility to provide good profitability of straw pellet production.

Pellets have been actively used from 1980th in USA and Canada, from 1990th – in Austria and Scandinavian countries, from 1999 – in Germany. For Ukraine it is the new market.

In 2009 in Ukraine work 13 pellet producers with straw and 51 with wood.[43] According to market information[44] there are about 30 pellet and briquette producers from straw, wood and sunflower husk who work on a permanent basis, and only about half of them propose pellets to the market; others work by contact and produce directly for a particular consumer. Total pellet and briquette

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[35] EUBIA. "Analysis of the technical obstacles related to the production and utilisation of fuel pellets made from agricultural residues", 2002.
[36] http://www.eco-ventures.org/files/Briquetting%20docs/briquetting_technologies.doc
[37] http://mydiyhometips.com/2009/12/01/pellet-mill-die-details-and-greenhouse-gases-and-carbon/
[38] http://www.akahl.de/akahl/en/products/biomass_pelleting/straw_pelleting/
[39] A preliminary cost of German Amandus Kahl equipment (EXW, Reinbek) for Ukraine is about 1.2 mln Euro for 3 t/h capacity to 4.4 mln Euro for 18-20 t/h capacity. Service costs about 12-13% of the equipment price.
[40] Lange&Meyer: http://strohpellets.de/
[41] Buhler is known as a company that installed Europe's first wood pelleting plant (1982 in Sweden), the world's largest straw pelleting facility (2003 in Denmark) and the biggest wood pelleting plant in the world (2008 in the USA): http://www.buhlergroup.com
[42] Pellets used for animal bedding must be of higher quality (do not contain dangerous for animal health elements) and, therefore, have higher price. Burning of such clean straw pellets is also allowed in Germany. But the price for such pellets is too high to use them for heating. Thus, German consumers prefer wood pellets that for the same price give higher energy output.
[43] http://pellets-wood.com/
[44] Interviews with pellet traders and Ukrainian producer association on solid biofuels (http://uavatp.org).

production in Ukraine is estimated at about 250 thd t per year. 50% of this amount are pellets and briquettes from straw and sunflower husk. The majority of producers are export oriented, mostly to the European market. 85% of Ukrainian pellets are exported and constitute about 2.5% of the European pellet market. Annual growth of this market in Ukraine is 15-20%.[45]

The major problem of Ukrainian pellets is its high ash content. Some producers[46] achieve ash content up to 1% in wood pellets and up to 5% in straw pellets; others finish with up to 3% and 8% respectively.

Straw pellet prices in Ukraine currently vary between 60-125 Euro/t, wood pellets – from 80 to 160 Euro/t.[46] The price depends on pellets sort and quality (mostly ash content), and on terms of delivery. Wood pellets in Ukraine are produced from pine, oak, poplar and different sawdust. Straw pellets are produced from grain straw. Standard supplied size is in majority of cases 8 mm, sometimes 6 mm is also proposed. Moisture content is up to 10%. Content of other elements satisfy European standards. Majority of produced in Ukraine pellets are able to satisfy German DIN standard, and they are on the way to satisfy European EN Standard[47] like EN 14961-2.

There are a lot of companies in Ukraine supplying pelletizing equipment. Much of the equipment is produced or assembled in Ukraine.[48] Many producers use modernized soviet technologies that are proved over time and preferred over recently developed Ukrainian designs. Some Ukrainian companies use imported details or technologies, and make pelletizing line assembling in Ukraine. For example, Ukrainian company "Grantech"[49] uses Italian technology while Ukrainian company "Zenako" [50] uses soviet technology. The price difference is considerable.

According to market information Ukrainian producers of pellets prefer using small capacities equipment installed in several places instead of setting up a large pelletizing plant. Having not enough finance and facing high interest rates for loans, they often choose the cheapest option of equipment. Knowing these market tendencies and Ukrainian consumer preferences as for pelletizing equipment, companies that supply high-quality foreign equipment to Ukrainian market propose capacities of up to 2 t/h.[51]

The quality of pellets produced in Ukraine does not completely meet EU requirements yet. In any case, homogeneity of pellets regarding size, water content and particle density (all that is relevant for automatic combustion) seems quite a well controlled factor in the pelleting process. Content of ash and other unnecessary chemical elements in pellets can be overcome by not only controlling of feedstock used but also partly by a range of combustion processes and flue gas cleaning techniques used. Despite the lower quality of currently produced Ukrainian straw pellets due to lower straw bales quality and the quality of the equipment used, some are exported quite successfully. According to market information, the export prices are about 50% higher than the prices on domestic Ukrainian markets.

A straw pelletizing market is slowly developing in Ukraine. However, the amount of pellets produced is increasing each year. In future, Ukrainian pellet producers will most likely switch to modern equipment and higher capacities, benefiting from economies of scale.

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[45] http://ecotech.zenako.ua/products_mar.htm

[46] Interviews were made among Ukrainian pellet producers and traders listed at Global Trade Database: http://www.alibaba.com Also some prices are listed here: http://price-list.kiev.ua/word/43/6743/index.html

[47] About quality standards DIN and ONORM: http://uavatp.org/index.php?option=com_content&view=article&id=57&Itemid=61 About EN quality standards see EUBIONET publication on New European Pellet Standard EN 14961-1: http://www.foex.fi/bioenergy/images/temp2/Alakangas_Pellet_standard_EN14961-1.pdf

[48] Information is given by Ukrainian Association of alternative solid fuel producers: http://www.uavatp.org/

[49] Grantech's pelletizing equipment with the capacity of up to 2.2 t/h will roughly cost about 350 thd Euro (granulating press price is about 1 mln UAH, drying complex – 1.6 mln UAH, cooler – 68 thd UAH, other costs – up to 80 thd UAH. All prices are VAT included): http://crystal.kiev.ua/en/granteh/site/content/devices/linesICKGroup

[50] One of Ukrainian leaders in solid biofuel market is Zenako. Its pelletizing equipment of the capacity 2 t/h costs about 200 thd Euro (including all associated with its setting up and start up costs): http://ecotech.zenako.ua/

[51] For example, Ukrainian company "Atagos (Ploeger)" trades English-making palletizing equipment. They can supply high capacities. Taking into account Ukrainian preferences of small pelletizing plants they propose 1 t/h equipment to the market for the price of roughly 215 thd English pounds. http://www.atagos.com.ua

<u>Conclusions:</u>

Costs of pellets production mainly depend on the cost of feedstock and technology used. The use of different equipment (technologies) and improvement in straw market organization allow satisfying market standards as for the quality of straw pellets. To meet market requirements concerning the quality of pellets is important for being competitive and get higher profits. Larger difference between costs and benefits can be achieved in two ways: (i) by reducing the production costs applying better technology, and (ii) by increasing benefits by offering the produce to international consumers. In European market straw as a feedstock is more expensive than in the Ukrainian market. Therefore, final straw products including pellets are more expensive too. So, exporting straw pellets and briquettes to the European market offers interesting opportunities for Ukrainian producers if quality standards are met. The transportation costs must therefore to be considered. Under some conditions they can significantly reduce the benefit of expanding to the EU markets.

5. Annexes

ANNEX A: Short description of LIN-KA straw burning plant operation

A straw plant (system) consists of the LIN-KA straw shredder with shredder drums which pull the straw upwards, preventing stones and other foreign objects are passed back into the shredder drums[52], from where they can be removed. The straw shredder is available in a range of sizes depending on boiler size and is controlled by the load placed on the shredder drums. This means gear and motor overloading is avoided, ensuring that the straw volume set for the boiler plant is always correct. Shredded straw is transported from the shredder in a closed pipe system directly to the combustion chamber, where it passes through a cell sluice before being fed into the combustion hearth by a worm drive.

A straw conveyor with height-adjustable legs is supplied, the length of which can be determined by boiler size and customer requirements.

Feed procedure

The 'on-demand' function of the boiler will activate the feed procedure, i.e. the straw shredder and worm drive will start producing and feeding the appropriate of amount of straw into the boiler for the desired effect. Straw volume is controlled by an oxygen gauge which constantly monitors oxygen percentage in the flue gas.

LIN-KA boiler

The hot water boiler is a cylindrical, efficient, 3-phase pipe boiler designed for burning straw. It features a smooth flame channel, water-cooled rotation chambers and is dimensioned to achieve full combustion and efficient utilisation of radiated heat in the flame channel, whilst convection heat is utilised to the maximum in the two subsequent flue gas sections.

At the end of the boiler combustion chamber is a cylindrical water- and air-cooled combustion hearth, which helps avoid slag formation. Preheated air is added from the sides and top to create the correct amount of turbulence in the combustion area, and completely burning off the gases developed.

Thorough insulation of the boiler with 100mm mineral wool means that heat loss is minimal. The boiler is a fully welded, gastight and sealed unit, supplied with nozzles, flanges and counter-flanges for feed and return, plus safety nozzles. A cleaning hatch at the end of the combustion chamber makes inspection and cleaning simple.

The boiler exterior is of blue plastic-covered steel modern design panels. It is available in sizes ranging from 60-1500kW for straw, with the standard version designed for a maximum operating pressure of 4 bar, and maximum operating temperature of 110º C.

Automatic ash extraction

A stainless steel, laterally-mounted worm drive is fitted in the base of the boiler to transport ash out to the inclined worm drive, which takes it onwards, including outside the building, to an ash container.

Automatic flue cleaning

A number of pressure tanks are mounted on the boiler with air injection valves fitted to inject air into the boiler flue to keep it clean. This means that manual cleaning of the flue is rarely necessary.

Electronic control and monitoring system

[52] Market operators claim that different rubbish is often found in straw bales during its processing. Thus, LIN-KA systems advantage is that this rubbish is "filtered" before straw comes into firing module. In the systems with manual straw bales feeding directly to the firing module, rubbish burns together with straw reducing operation life cycle of a plant.

Control and monitoring of the straw plant is based on a Programmable Logic Controller (PLC) system. This ensures controlled regulation of fuel feed to maintain maximum heat production. All set points can be read off and reprogrammed via a display and the oxygen percentage is continuously shown on the display. There is also an alarm outlet on the control system.

The control panel can be connected to the internet if the boiler room has a fixed IP address to facilitate remote support from LIN-KA when commissioning, trimming and in the event of disruption to production.

A straw heating plant of sizes from 1,500 to 3,000kW can be built in many ways, depending on customer and operating requirements. LIN-KA has three basic construction methods depending on boiler size. They are basically built as small outdoor plans, with a straw shredder. When large quantities of straw are to be burned, a feeder system with belts at 2 or 3 different levels can be installed with an elevator to lift the bales down to the shredder. Alternatively, a straw crane can be installed which brings the bales to the shredder.

When a heating plant of higher capacity, from 3,000 to 8,000 kW, is required, plants are constructed with a straw cutter as feeder unit and where a crane is usually used. A traverse crane picks up the bales and takes them to a safety box which is also located in the barn. The bale will then be hydraulically fed into the cutter which turns the bale onto its edge before a slice is cut off hydraulically and fed into the boiler for incineration.

A system is also available that works on the cigar principal, which works best for plant sizes from 8,000 to 10,000 kW. A crane and safety box are used to move the bale into a drawer which is offset in the bale's width in relation to the boiler. When the drawer closes, the bale is directly aligned with the boiler inlet, and is slowly fed into the boiler as it burns.