

# Biomass consumption in residential sector of Ukraine for the period 2007–2016

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**Abstract.** Residential sector plays a decisive role in the bioenergy sector growth in Ukraine. More than 60% of biomass for households comes from so-called self-production, which is problematic for statistical monitoring. State Statistics do not publish detailed fuel mix reports on a regional level. In this article, we provide detailed data on the fuel mix used by the households at the regional level during 2007–2016 and determine the biofuel self-production amount. The facilities that are direct emission sources and are the final fuel consumers, including individual heating/hot water boilers/stoves out of district heating system and individual cookers are considered in detail.

## 1. Introduction

According to the International Energy Agency, in preventing the global temperature increasing on the Earth more than to 2°C, concerning to the preindustrial period, the most important role in reducing CO<sub>2</sub> emissions in the period up to the 2050 will be playing energy efficiency (40%) and renewable energy (30%). Determination of the biofuel self-production amount in households at regional level concerns both and that is why is actual nowadays.

According to the Energy Strategy of Ukraine until 2035 [1], Ukraine is going to reduce fossil fuels consumption and increase the share of renewable energy sources in the total primary energy production from 4,4% (in 2017) to 25% (in 2035). In recent years, the share of the biomass in the total renewable energy resources of the country accounted for about 80%. In addition, it bases mainly on utilization of woody biomass in heat generation: wood logs and wood pellets mostly for population and district heating, wood chips and residues mostly for industrial purposes, public heating and power production [2]. However, the Ukrainian corn stover has relatively high ash melting temperature-defusing requirements for the boiler additional systems and steel quality. As a result, the Ukrainian corn stover potentially may be used within wood-fired boilers [3,4].

## 2. Objectives of the project

In recent years, biomass consumption in Ukraine shows rapid growth. Analysis of similar data for the period of 2010–2016 shows that the average growth rate of the bioenergy sector in Ukraine is 35% per year by the indicator of the "total supply of primary energy from biofuels and waste". For example, the total supply of primary energy from biofuels and waste was 3,046 ktoe in 2017 (against 2832 ktoe in 2016) [5]. Moreover, the residential sector plays a decisive role in this growth: the final biofuel consumption of households was 1,506 ktoe in 2016 (against 1,097 ktoe in 2015). More than 60% of biomass for households comes from so-called self-production, which is problematic for statistical monitoring. Furthermore, there are large differences between regions in the fuel mix. However, the State Statistics do not publish detailed fuel mix reports on a regional level. The differences are related to mix of causes e.g. gas pipe network availability, coal and peat deposits, forest cover, population density, urbanization level, income level etc.

Therefore, the objective of the present paper is to provide detailed data on the fuel mix used by the households at the regional level during 2007–2016 and to determine the biofuel self-production amount. The present study focuses on the facilities that are direct emission sources and are the final fuel consumers. That includes individual heating/hot water boilers/stoves out of district heating system and individual cookers.

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### 3. Methodology

The main data source of the present study is the State Statistics of Ukraine. The statistical office collects and process data on the gross final energy consumption. The monitoring covers 41 different fuel types and refinery products. These fuels divided into 4 groups: coal (including peat); oil refinery products; natural gas; biofuel and waste.

The required data on specific fuel consumption in different subsectors on the regional level is in statistical reports available by Request for Information only, namely:

- Report on Remains and Usage of Energy [6] (hereinafter, - 4-MTP) and
- Households Living Conditions Survey [7] (hereinafter, - HLCS).



**Fig. 1.** Data Flow Diagram.

The Statistical Survey by Form 4-MTP applies to business entities of all types of economic activity, regardless of size, organizational and legal forms of management and subordination, which use and have in the balances energy materials and products of oil refining [8,9]. All indicators based on the data of the primary documentation and accounting. The 4-MTP include data on the volumes of fuel sold to the population by enterprises and organizations to satisfy their household needs. However, in reality, population (residential sector) utilize more biofuels and wastes than reflected in standard 4-MTP statistical form. The substantial portion of this biofuels is coming from so-called “self-production” or “self-procurement” performed by the households themselves. The fuel self-production volumes based on data from the HLCS.

#### 3.1 Self-production Methodology Extensive Description

In rural settlements, many people are searching for cheap and available firewood due to poverty. Many of them are involved in the self-production of firewood. In order to estimate the self-production amount, the State Statistics uses a specific mathematical model based on statistical sampling.

The HLCS bases on generally accepted international standards and corresponds to the current socio-demographic and economic situation in Ukraine [10].

The HLCS carries out on a separate network of respondents (non-institutional (private) households). The volume of the annual sample of households for the survey in 2014–2018 is 13,029 households.

#### 3.2 Extrapolation (dissemination) on the general population

Sampling formation is performed on the basis of the stratified multi-stage selection procedure. Sampling is carried out in the following sequence: 1) the exclusion of areas that can not be inspected; 2) exclusion of the population not subject to inspection; 3) stratification of the general population; 4) the formation and selection of territorial units of the first degree; 5) formation and selection of territorial units of the second degree in urban settlements; 6) selection of households. The methodological foundations for the sample formation are given in the documents [11,12].

For the dissemination to the entire population of Ukraine (except temporarily occupied Autonomous Republic of Crimea and Sevastopol) the statistical weights are used. The statistical weights are taking into account the probabilities of including the households into the sample and the actual level of participation in the survey, coordination of the survey results with external data, including the data of demographic statistics (number, sex and age structure of the population, according to social statistics on the number and placement of the population, etc.).

In the calculation of the system of weights the problem is that, the representativeness of the sample should be ensured despite the complex sample design, heterogeneous levels of survey rejection (by regions and population groups), complex methods of results evaluation and coordination with available external information.

The main advantages of weighing are following:

- Real probabilities of including units in the sample are taken into account, which is especially important with uneven probabilities of selection;
- Actual levels of participation are taken into account;
- Influence of indiscriminate faults is diminished;
- The quality improves by using complex assessment functions (estimation by ratio, estimation by regression, etc.) and coordination of the survey results with external information (in particular, using calibration procedures);

- combining the results of various sample surveys at lower levels of data aggregation.

At the same time, the process of weighing complicates the processing of data, in particular, requires more time for processing and analysis of data.

It should be noted that for today's sample surveys, the benefits of weighing significantly outweigh the disadvantages.

### 3.3 Data Quality

In the analysis of the quality of The HLCS data, the replicate method of balanced repeat replications (BRR) implemented, which is calculated in the standard WesVarPC program package [13].

Relative standard error (RSE) is often used as an indicator of data suitability.

- $RSE \leq 5\%$  - then the score is considered reliable;
- $5\% < RSE \leq 10\%$  - evaluation is suitable for quantitative analysis, but its reliability not high enough;
- $10\% < RSE \leq 25\%$  - the assessment is suitable only for qualitative analysis and should be used with caution.

In general, for the regional level, the accuracy of the assessments of the indicators under consideration is satisfactory. For 13 regions out of 26 regions (which comprise 60% of population and 50% of territory), the relative standard error of the sampling does not exceed 5% (for all indicators), that is, the estimates are reliable. In other regions, the relative standard error of sampling for all indicators does not exceed 10%. In general, survey data can be used for statistical analysis at the regional level.

## 4. Results and discussion

### 4.1 Standard statistics

Household natural gas consumption shows a stable pattern, explained by the price of gas for households in real terms being almost constant from 2008 until 2013. However, between 2013 and 2016, total gas, coal and oil consumption decreased dramatically (See Fig. 2).

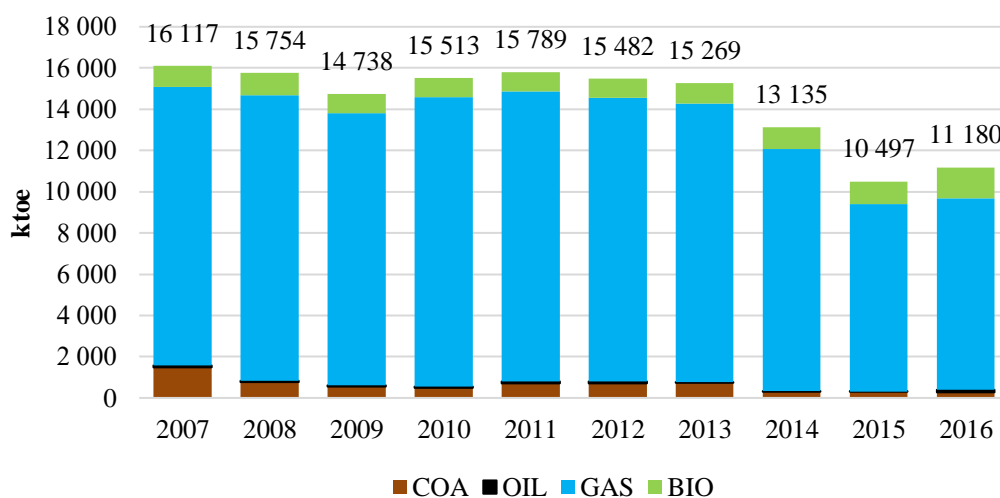


Fig. 2. Residential Fuel Mix of Ukraine 2007–2016.

The key drivers of this decrease are the loss of control over 46.2 th. m<sup>2</sup> of the country's territory (7%), 6 million people (13%) and 20% of gross domestic product. At the same time, households experienced a 119% weighted average USD increase in the tariffs for natural gas while simultaneously experiencing a decline of average per capita income of almost 50% [14]. As a result, the hitherto relatively constant Ukrainian household consumption of natural gas has declined in 2016 by some 31% (from the 2013 level) (-4,228 ktoe), coal consumption shows 62% decline (-456 ktoe).

Since natural gas prices for households raised (up to 70% of the market level), a large share of gas consumers are no longer able to pay bills with new price of natural gas. Therefore, biomass-to-energy utilization became one of the economically reasonable alternative for heat supply of households. The biomass consumption pattern supports the judgement. While consumption of other fuel types show decrease in 2014–2016, the biomass consumption of households increased by 51% for mentioned period (+500 ktoe) regardless military action and statistical data gap (See Fig. 3). Thus, the share of biomass in total final fuel consumption of households increased from 8.1% in 2014 to 13.5% by the end of 2016 (excluding district heating and electricity).

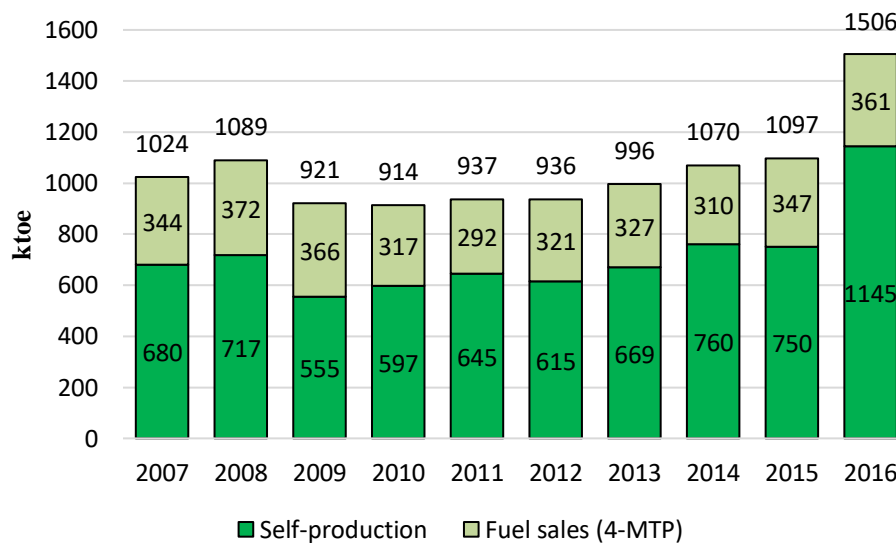


**Fig. 3.** Residential Biomass Consumption of Ukraine.

#### 4.2 Self-production

Along with firewood, a self-production of peat and coal takes place. However, according to data of previous observations the dominant fuel type is woody biomass (own expert judgment suggests that >95% of total self-production comes from biomass). Thus, self-production of the coal and peat may be neglected.

Since 2009, the biomass self-production demonstrates dramatic growth from 555 to 1,145 ktoe/yr corresponding to 62% - 76% of total biomass consumption of the residential sector (**Fig. 4**).



**Fig. 4.** Final biofuel consumption by households 2005–2016.

Noteworthy, that in 2016 a considerable growth of self-production (+70%) coincided with gas consumption drop (-31%) comparatively to 2013 despite the data gap from occupied Donbass and Crimea.

Despite the biomass growth, natural gas remains the most common fuel for each region. However, biomass covers remarkable share in some forest-rich regions: Chernivtsi (29%), Chernihiv (37%), Cherkasy (23%) Zhytomyr (34%), Zakarpattya (29%) and Kyiv (14%) (**Fig. 5**). On the other hand, the coal mining regions show high coal consumption rates: Luhansk (34%), Donetsk (19%).

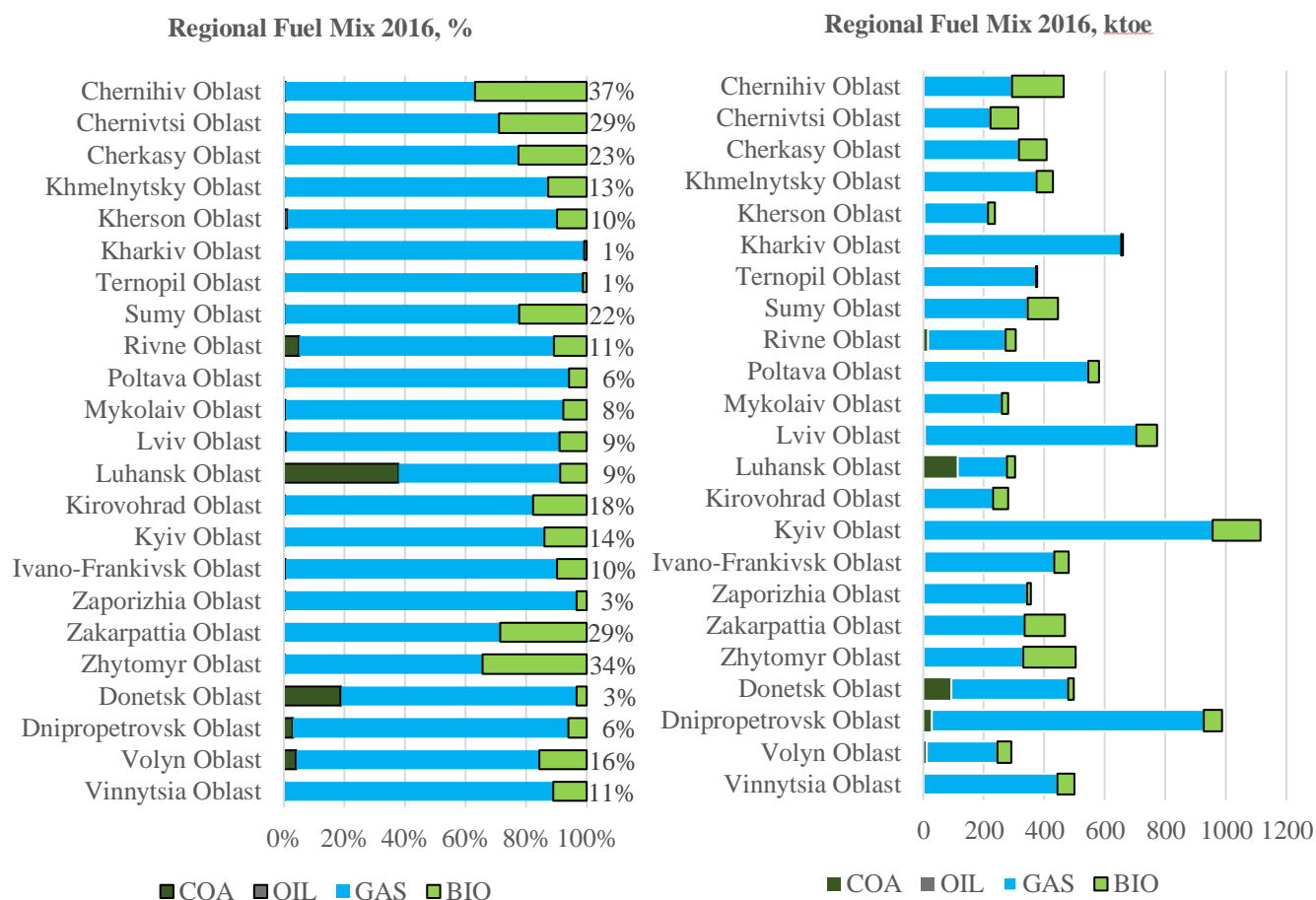


Fig. 5. Regional Fuel Mix in 2016\*.

\* Biofuel breakdown is based only on 4-MTP "Fuel Sales" regional distribution factors. Assume the biomass self-production is around 70% (differs each year) of every region due to no details on the regional level.

At the same time, the six forest-rich regions consume more than 54% of biofuels in the country's residential sector.

## 5. Conclusions

The paper gives a detailed review of fuel final use in the residential sector of Ukraine during 2007–2016 years at the regional level based on official statistical reporting. It gives a clear picture of Residential Sector final energy consumption record for the period 2007–2016 with the deep breakdown by the fuel type on the regional level.

The paper shows a dramatic decrease of gas and coal consumption by households after 2014 (31% and 62%). Simultaneously, the biomass consumption increased by 51%, increasing its share from 8.1% in 2014 to 13.5% by the end of 2016.

At regional level, the biomass covers a significant fuel mix share in some forest-rich regions: Chernivtsi (29%), Chernihiv (37%), Cherkasy (23%) Zhytomyr (34%), Zakarpattia (29%) and Kyiv (14%). The same 6 regions consume more than 54% of biofuels in the country's residential sector.

The study shows that a self-produced biofuel is the main biomass source for residential sector of Ukraine. Biofuel self-production reached a menacing level providing 76% of total biofuel consumption of households. And this activity is illegal and problematic for control and monitoring. Therefore, we could not ensure the sustainability of the biomass self-production that may cause a negative effect. Thus, stricter control of biofuel procurement and trade may be needed. Taking into account a high level of woody biomass consumption, further bioenergy development should be focused on agricultural biomass utilization and this finding could be used for Ukraine energy strategy.

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