ENERGY PERFORMANCE LEVEL IDENTIFICATION OF A MIXED FODDER FACTORY

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Abstract: Knowing energy performance level of an energy consumer is essential for substantiating the decisions for development, operation and maintenance. Energy performance level is highlighted through consecrated indicators which are obtained by means of energy balance. The present paper is a synthesis of electric energy balance that was done within a mixed fodder factory (MFF). In the first part a short presentation of the consumer (MFF) is presented and also analysis methodology. After that we refer to specificities regarding the energy balance model (EB) applied and to characterization elements of typical processes for MFF. An important part of the paper is dedicated to present the obtained results and the energy performance level. In the last part of the paper we present the conclusion of energy audit (EA) and the recommendations to improve the energy performance level.

Keywords: indicators, energy performance, factory, mixed fodder, energy audit.

1. INTRODUCTION

The necessity and utility of energy audit (EA) basis analyzes are well known [1 ÷ 6]. EA elaboration methodology is consecrated [7 ÷ 11] and EB are developed and widely applied [12 ÷ 21].

The present paper synthesizes the elaborated documentation following the electric energy audit (EEA) which was carried out in a MFF from Palota(MFFP) locality, Bihor County. EEA contour is the entire MFFP. Specific processes within MFFP are carried out with equipment which consumes electric energy (EE), fact that implies that an EEA should be done instead of a complex EA.

The main activity of MFFP is the production of mixed fodder for animals from own farms and also for others.

MFFP takes the cereals and some additives introduce them in the technological process (figure 1) thus producing farm fodder. The acquired cereals are stored into bunkers and then are used to produce various quantities of fodder of each recipe. These cereals are weighed, distributed with a special weighing machine and then ground with two mills, each having a 10t/h capacity. The ground product is mixed with help of a masticator together with certain additives specific for each recipe. After mixing process follows the granulation process (pellets) with the help of 2 granulators with a 10t/h capacity. The pellets are stored in bunkers specific to each recipe, to be delivered later to users.

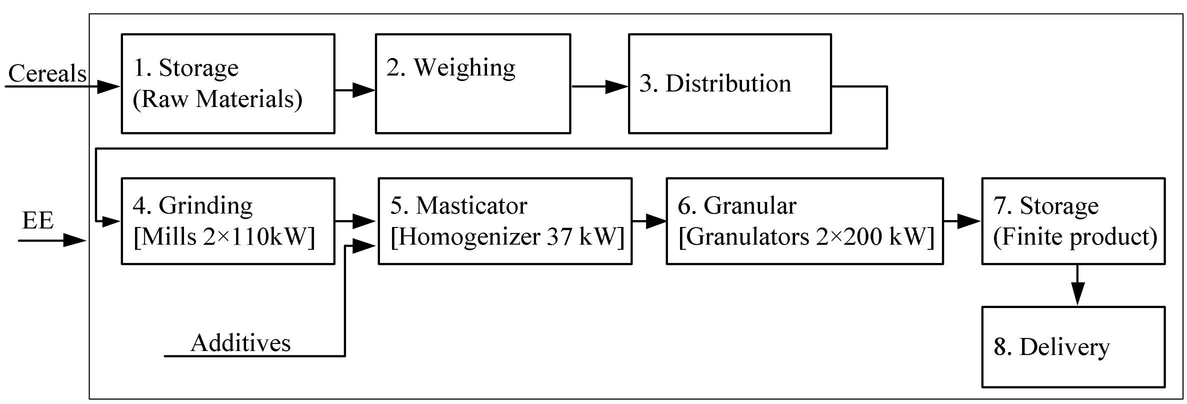


Fig. 1 - The phases of the technological process from MFFP

In figure 1 has been specified also the equipment with the highest installed power. Power receivers of MFFP are grouped in the following categories:

- Power receivers (Equipment) used in production phases (2 ÷ 6). In addition to those five big equipment already mentioned this category include also 33 specific equipment[22] cu rated power [0.37 ÷ 15] kW;
- Power receivers (Equipment) used in additional processes of storage (1, 7), delivery (8) and assuring the conditions for environment comfort. This category includes 39 specific equipment[22] with rated power in the interval [1.1 ÷ 15] kW;

In addition to the categories listed above, EEA contour of MFFP includes:

- Power transformer (PT) cu characteristics: Sn = 1600 kVA; U1n.U2n [24];
- Luminaires, with installed power of 8,26 kW(4,24 kW fluorescent and 3,94 kW LED);
- Internal power distribution network of MFFP [22].

Operating mode of MFFP is continuous. The associated reference unit of power energy balance (PEB) is a working hour. Electricity consumption for average day has been determined based on the records from years 2016, 2017 and 2018 and the variations of electricity consumptions on a normal working day were obtained based on the records for 12.12.2018 date. The load level of equipment and installations, during the measurements is the normal one for the provided service by MFFP. After completing the EB for an average day, we will refer the yearly PEB, based on monthly records regarding electricity consumption.

2. MATHEMATICAL MODEL USED FOR PEB

PEB for the analyzed contour is

$$Wa=W_U+\Delta W_T+\Delta W_L+\Delta W_M+\Delta W_I \qquad (1)$$

where:

Wa – absorbed energy by MFFP on the analyzed contour, determined based on the records.
ΔW_T – electric energy (EE) loses in transformers;
ΔW_L – EE loses in power lines;
ΔW_M – EE loses in electrical drives and various mechanisms within contour;
ΔW_I – EE loses in lighting objects.

Based on equation 1 we can calculate useful energy (W_U) at receptors level.

Referring to power transformers we can use the complete calculation formula which includes active energy losses (in magnetic circuit and in windings) and active equivalent of reactive power for magnetization and for reactive losses through dispersion [11,23].

$$\Delta W_T = \left[\left(\frac{U}{U_n}\right)^2 \Delta P_{Fn} + \lambda \frac{U}{U_n}\frac{i_{on}}{100} S_n\right] T_A + \\ + \beta^2\left[\Delta P_{wn} + \lambda \frac{u_{kn}}{100} S_n\right]\tau \qquad (2)$$

where:

U – Operational rms voltage;
β = S/Sn – relative apparent load;
S – Apparent power;
λ - 0,03kW/kVAr – active equivalent of reactive power;
T_A – Operation duration (analyzed);
τ – Usage duration at S load;

Expression (2) is written considering that the voltage frequency is the rated one.

Considering the presence of harmonic regime, losses within power lines are calculated with formula (3).

$$\Delta W_L = 3\, k^2_f\, I^2_m\, R_L \cdot k_C\, \tau \cdot 10^{-3}\, (1+ K^2_{DI}) \ \ [kWh] \qquad (3)$$

where:

k_f – shape coefficient of function I = f (t);
k_{DI} – distortion coefficient off electric current.

ΔW_M component is calculated applying the equivalent motor model [9, 12]:

$$\Delta W_M = (1 - \eta_e)\ Pae\ \tau \qquad (4)$$

where:

η_e – yield of equivalent motor;
Pae –active power absorbed by group of motors.

Energy losses within lighting receptors are calculated with the relation:

$$\Delta W_I = (1-\eta e)\ k_C\ P_I\ \tau \qquad (5)$$

where:

η_e = equivalent yield f lighting receptors, computed in a similar way, with that of equivalent motor.

The meaning of quantities presented in the relations [2÷5] is well known [9÷12].

3. THE RESULTS OF MEASUREMENTS

Can be grouped – under temporal criteria – in two categories:

- On medium term (one month) and long(one year)
- On short term (hours, days)

Characteristic quantities from the first category were taken from MFFP database (DB). They are shown on table 1.

Table 1 – Characteristic quantities taken from DB of MFPP

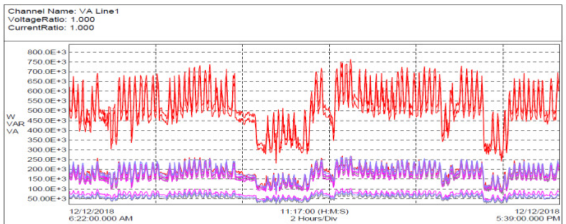
Year / month	Production value		EE consumption	
	V_{FP} [ton]	V_{EP} [thousands of lei]	W_a [MWh]	W_r [MVArh]
2016	103.205	121.587,69	6575	-
2017	97.306	110.933,12	6223	-
2108	94.002	116.528,16	6527	0,183
01	8.207	10.138,45	549	0,02
02	5.961	7.149,16	371	0,01
03	8.403	10.128,6	581	0,02
04	5.137	6.591,17	401	0,01
05	6.999	8.893,97	528	0
06	7.898	10.018,93	553	0,024
07	8.043	10.333,87	609	0,024
08	8.681	10.735,76	608	0,028
09	8.668	9.748,36	582	0,017
10	8.916	11.097,93	593	0
11	8.734	11.036,51	595	0,02
12	8.355	10.655,45	557	0,01

Characteristic quantities from the second category was obtained from the measurements made with network analyzer(NA), on time intervals that covers the cycles of MFFP activities and the variability of load curves [22]. This was made to highlight the consumption characteristics:

- Total consumption, recorded at MFPP, at measuring point 1 (PM1);

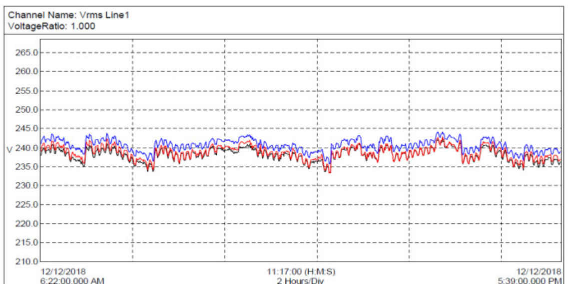
- Total consumption for actual technological process (PM2);
- The consumption of some complementary processes (PM3, PM4);
- The consumption of the two mills (M1, M2);
- The consumption of the two granulators (GR1, GR2).

For example, in figure 2 ÷ 6 are given parts of these measurements.



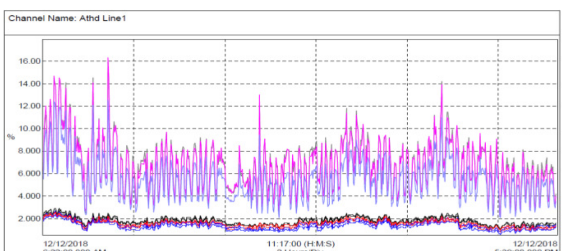
Name	Date	Time	Avg	Min	Max	Units
VA Line1	12/12/2018	6:22:00.000 AM	167.53E+3	78.233E+3	242.84E+3	VA
VA Line2	12/12/2018	6:22:00.000 AM	174.76E+3	79.140E+3	252.23E+3	VA
VA Line3	12/12/2018	6:22:00.000 AM	186.27E+3	90.133E+3	267.64E+3	VA
VA Sum of Phases	12/12/2018	6:22:00.000 AM	528.56E+3	247.51E+3	762.71E+3	VA
VAR Line1	12/12/2018	6:22:00.000 AM	54.278E+3	22.687E+3	78.033E+3	VAR
VAR Line2	12/12/2018	6:22:00.000 AM	72.526E+3	34.099E+3	102.09E+3	VAR
VAR Line3	12/12/2018	6:22:00.000 AM	61.286E+3	28.859E+3	88.962E+3	VAR
VAR Sum of Phases	12/12/2018	6:22:00.000 AM	188.09E+3	85.645E+3	268.83E+3	VAR
W Line1	12/12/2018	6:22:00.000 AM	158.41E+3	74.838E+3	230.00E+3	W
W Line2	12/12/2018	6:22:00.000 AM	158.88E+3	71.351E+3	230.59E+3	W
W Line3	12/12/2018	6:22:00.000 AM	175.81E+3	85.359E+3	252.38E+3	W
W Sum of Phases	12/12/2018	6:22:00.000 AM	493.09E+3	231.55E+3	712.96E+3	W

Fig. 2 – Load curves recorded for MFFP (PM_1)



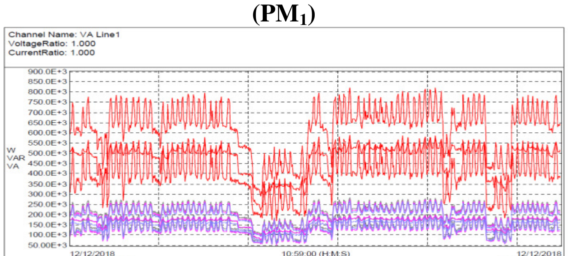
Name	Date	Time	Avg	Min	Max	Units
Vrms Line1	12/12/2018	6:22:00.000 AM	238.17	233.30	242.30	V
Vrms Line2	12/12/2018	6:22:00.000 AM	238.76	233.40	242.80	V
Vrms Line3	12/12/2018	6:22:00.000 AM	240.66	235.80	244.20	V

Fig. 3 – Voltage variation in the secondary of PT – MFFP (PM_1)



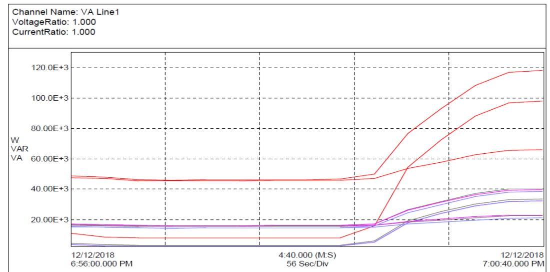
Name	Date	Time	Avg	Min	Max	Units
Athd Line1	12/12/2018	6:22:00.000 AM	6.7218	2.3000	15.900	%
Athd Line2	12/12/2018	6:22:00.000 AM	6.6373	2.2000	16.300	%
Athd Line3	12/12/2018	6:22:00.000 AM	5.4686	2.1000	12.500	%
Uthd Line1	12/12/2018	6:22:00.000 AM	1.7798	1.1000	2.7000	%
Uthd Line2	12/12/2018	6:22:00.000 AM	1.4960	0.800	2.5000	%
Uthd Line3	12/12/2018	6:22:00.000 AM	1.5304	0.900	2.7000	%
Vthd Line1	12/12/2018	6:22:00.000 AM	1.8538	1.1000	2.9000	%
Vthd Line2	12/12/2018	6:22:00.000 AM	1.6298	1.0000	2.6000	%
Vthd Line3	12/12/2018	6:22:00.000 AM	1.3065	0.600	2.4000	%

Fig. 4 – THD variation in the secondary of PT – MFFP (PM_1)



Name	Date	Time	Avg	Min	Max	Units
VA Line1	12/12/2018	6:37:00.000 AM	216.74E+3	102.03E+3	282.54E+3	VA
VA Line2	12/12/2018	6:37:00.000 AM	208.88E+3	96.248E+3	272.98E+3	VA
VA Line3	12/12/2018	6:37:00.000 AM	201.50E+3	91.946E+3	267.18E+3	VA
VA Sum of Phases	12/12/2018	6:37:00.000 AM	627.12E+3	290.23E+3	820.40E+3	VA
VAR Line1	12/12/2018	6:37:00.000 AM	163.16E+3	76.417E+3	194.38E+3	VAR
VAR Line2	12/12/2018	6:37:00.000 AM	164.91E+3	76.740E+3	196.95E+3	VAR
VAR Line3	12/12/2018	6:37:00.000 AM	150.70E+3	68.441E+3	183.52E+3	VAR
VAR Sum of Phases	12/12/2018	6:37:00.000 AM	478.78E+3	221.60E+3	574.46E+3	VAR
W Line1	12/12/2018	6:37:00.000 AM	141.73E+3	62.566E+3	205.04E+3	W
W Line2	12/12/2018	6:37:00.000 AM	127.03E+3	51.086E+3	188.99E+3	W
W Line3	12/12/2018	6:37:00.000 AM	132.77E+3	55.976E+3	195.65E+3	W
W Sum of Phases	12/12/2018	6:37:00.000 AM	401.53E+3	169.63E+3	588.50E+3	W

Fig. 5 – Load curves recorded in PM_2;



Name	Date	Time	Avg	Min	Max	Units
VA Line1	12/12/2018	6:56:00.000 PM	22.345E+3	15.611E+3	40.214E+3	VA
VA Line2	12/12/2018	6:56:00.000 PM	22.289E+3	15.846E+3	39.648E+3	VA
VA Line3	12/12/2018	6:56:00.000 PM	20.969E+3	14.526E+3	38.514E+3	VA
VA Sum of Phases	12/12/2018	6:56:00.000 PM	65.603E+3	45.983E+3	118.38E+3	VA
VAR Line1	12/12/2018	6:56:00.000 PM	17.292E+3	15.299E+3	22.331E+3	VAR
VAR Line2	12/12/2018	6:56:00.000 PM	17.715E+3	15.660E+3	22.839E+3	VAR
VAR Line3	12/12/2018	6:56:00.000 PM	16.101E+3	14.300E+3	20.947E+3	VAR
VAR Sum of Phases	12/12/2018	6:56:00.000 PM	51.107E+3	45.258E+3	66.117E+3	VAR
W Line1	12/12/2018	6:56:00.000 PM	11.707E+3	3.0966E+3	33.443E+3	W
W Line2	12/12/2018	6:56:00.000 PM	10.822E+3	2.3979E+3	32.408E+3	W
W Line3	12/12/2018	6:56:00.000 PM	10.908E+3	2.5325E+3	32.318E+3	W
W Sum of Phases	12/12/2018	6:56:00.000 PM	33.437E+3	8.0518E+3	98.169E+3	W

Fig. 6 – Load curves recorded in M_1;

4. THE RESULTS REFERING TO REAL EBB

4.1. Consumed EE of MFPP distributed over processes

From the measurements it can be seen the following EE consumption mean distribution at MFPP:

- From total consumption:
  - About 87,4% is consumed in technological processes specific(effective and complementary) to production of mixed fodder;
  - About 12,6 % is consumed în auxiliary activities needed to ensure MFPP operation (workshops, offices, external lighting… etc.)

The mean distribution of consumed EE on technological processes is shown on figure 7. For effective technological processes is shown in figure 8.

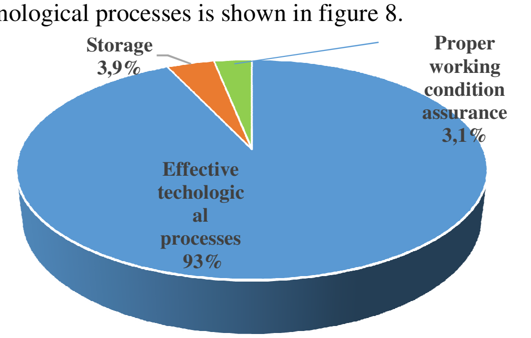


Fig. 7 – Mean distribution of consumed EE by MFPP, on technological processes

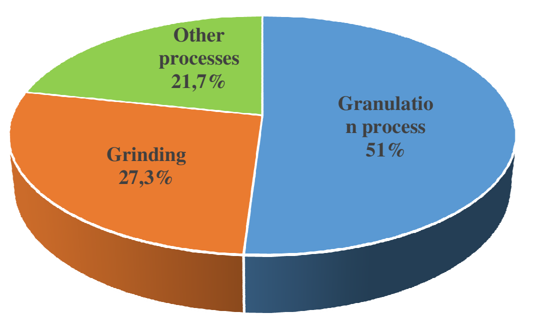


Fig. 8 – Mean distribution of EE consumed in effective technological processes of MFFP

4.2. Real EEB for granulators and mills

The four biggest machines within the contour are the mills (2 pieces) and the granulators (2 pieces). From the records it is noticed that the granulators have the biggest EE consumption.
Based on measurements made on granulators [22] and applying the equivalent motor model, has been done the EEB of this equipment.
At medium load:

$P_{ae} = 56,1+111,2 = 167,3$ kW

$P_{ne} = 2x200 = 400$ kW

$\eta_{ne} = 0,95$
$\cos\varphi_{ne} = 0,85$

$\beta_{Pe}=P_{ae}/P_{ne=0,42}$
$\eta_e = 0,91$
$\cos\varphi_e = 0,63$
$\Delta P_M=(1-\eta_e)P_{ae} = (1 – 0,91)\ 167,3 = 15,1$ kW

Doing similar for the minimum and maximum load we obtained the following results, shown in table 2.

Table 2 – Results regarding real EEB, per hour, of granulators

Characteristic quantities	Load level					
	minimum		mean		maximum	
	[kWh]	[%]	[kWh]	[%]	[kWh]	[%]
A. Energy in [Wa]	112,3	100	167,3	100	198,3	100
B. Energy out [Wi]	112,3	100	167,3	100	198,3	100
1. Useful energy [Wu]	96,1	85,6	146,17	87,4	175,97	88,7
2. Loses [ΔW]	16,2	14,4	21,13	12,6	22,33	11,3
2.1. Power lines [ΔW_L]	2,7	2,4	6,03	3,6	8,43	4,3
2.2. Motors and mechanisms [ΔW_M]	13,5	12	15,1	9	13,9	7

Doing similar, we got the the values of characteristic quantities for the real EEB, per hour, of mills (tabel 3).

Table 3 – Results regarding real EEB, per hour, of mills

Characteristic quantities	Load level					
	minimum		mean		maximum	
	[kWh]	[%]	[kWh]	[%]	[kWh]	[%]
A. Energy in [Wa]	16,27	100	41,63	100	106,5	100
B. Energy out [Wi]	16,27	100	41,63	100	106,5	100
1. Useful energy [Wu]	7,43	46	32,92	79	95,55	89,7
2. Loses [ΔW]	8,84	54	8,71	21	10,95	10,3
2.1. Power lines [ΔW_L]	0,06	0,4	0,38	1	2,43	2,3
2.2. Drives and mechanisms [ΔW_M]	8,78	53,6	8,33	20	8,52	8

4.3. Real EBB for the other processes

The results are synthesized in figure 9.
Knowing the weight of the components of real EBB, hourly, at medium load and the yearly consumption we can establish real EBB, per year. In table 4 are shown the results for years 2016 ÷ 2018, and in figure 10 is presented EBB diagram for year 2018.

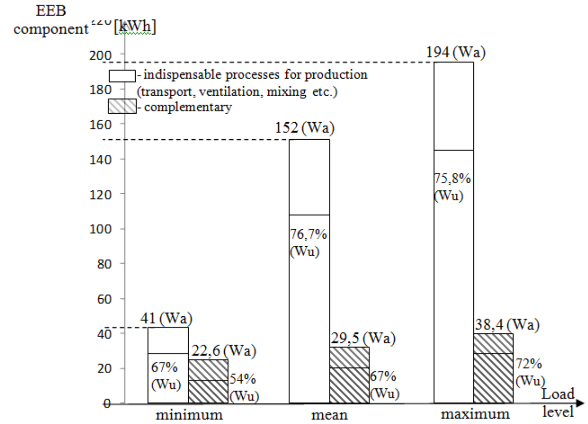


Fig. 9 – Essential components of real EBB, per hour, for processes within MFFP

4.4. Yearly real EEB

Table 4 – Results regarding real EBB, per year, for MFFP

Characteristic quantities	Year			
	2016	2017	2018	
	[MWh]	[MWh]	[MWh]	%
A. Energy in [Wa]	6575	6223	6527	100
B. Energy out [Wi]	6575	6223	6527	100
1. Useful energy [Wu]	5332,3	5046,9	5293,4	81,1
2. Losses [ΔW]	1242,7	1176,1	1233,6	18,9
2.1. Power transformer [ΔW_T]	75	70,9	74,4	1,14
2.2. Power lines [ΔW_L]	230,1	217,8	228,4	3,5
2.3. Drives and mecha-nisms [ΔW_M]	887,6	840,1	881,1	13,5
2.4. Lighting receptors [ΔW_l]	50	47,3	49,7	0,76

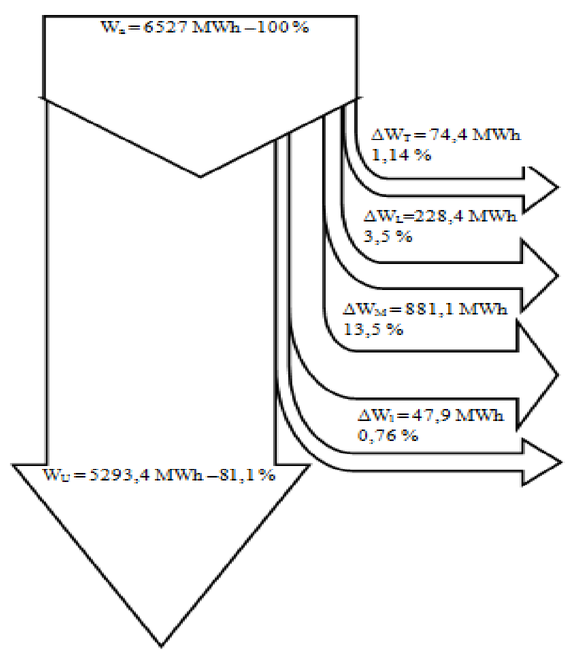


Fig. 10 - Sankey diagram for real EBB of MFFP, per year[2018]

5. MFFP ENERGY PERFORMANCE

5.1. Energy efficiency indicators

Are calculated the following energy efficiency indicators [2, 3, 7]:

- Energy intensity

$I_W = W_a / V_{EP}$ [kWh/leu] (6)

- Energy productivity

$P_W = V_{EP} / W_a$ [lei / kWh] (7)

- Specific energy efficiency

$C_{WS} = W_a / V_{FP}$ [kWh / ton] (8)

where:
V_{EP} –economic value of production [lei]
V_{FP} – physical value of production [ton]
The obtained values are presented in table 5.

Table 5 – Energy efficiency indicators values

Year	Indicator		
	Iw [kWh/leu]	Pw [lei/kWh]	Cws [kWh/t]
2016	0,054	18,52	63,71
2017	0,056	17,86	63,95
2018	0,056	17,86	69,58

5.2. Energy-technological behavior

The measurements and evaluations at EEA of MFFP allow the following defining remarks regarding the impact of energy-technological processes on EE flux:

a) Reactive energy absorbed from national electricity system (NES) is below the value of neutral power factor;

b) Transformation post (TP) have a single transformer of 1600kVA. From the measurements we've made (figure 2) results the values of load factor: β_{min} = 0,15; β_{med} = 0,33 (far from the optimal value β_{opt} = 0,55) and β_{max} = 0,48. Considering yearly EE consumption (table 1, is obtained: k_{med} = 0,44 (in year 2017) and k_{med} = 0,43 (in year 2018), which is much closer to optimal load. Considering the high load variation degree (ΔS = 515,2 kVA, fig. 2) and the necessity to increase the operation safety, we do consider as advisable the installment of a second power transformer of 1000kVA in TP and, eventually, to analyze the possibility to re-use the current transformer (1600kVA) and to replace it with a small one of 630kVA. We estimate that by using a combination of (1000+630) kVA type it might reduce the EE losses on transformers by 7600kWh/year the main advantage being the increase of operation safety. At the actual EE acquisition price, the investment recovery, only by the increase of energy efficiency, can be realized in 31 year – a reasonable timeframe;

c) Referring to EE quality, in the analyzed contour, we found that:

- Voltage RMS value is normal and balanced on the three phases. RMS Voltage variation is in [233,3÷ 244,2] V interval. Considering that interval is above the rated value (230V) it can be tested the reduction of voltage by switching the plot of power transformer;
- The content of harmonics of current and voltage, at TP level, fits in the standards, the values of THD indicators being in intervals THD_U =[0,6 ÷ 2,9]% and THD_I =[2,1 ÷ 16,3]%. We recorded, at consumer group "silos", the value THD_I = 25,6% - which appears to be the cause of high values of THD_I at TP level. We recommend establishing and eliminating the reasons that cause the exceeding of normal limits for THD_I indicators, at the level of these receptors. It is estimated that by doing this operation it might be obtained o decrease of power losses in the power lines with about 1380 kWh/year, recoverable investment in about 12 years.
- The general EE consumption (recorded in PM_1) is relatively balanced, the deviation from the mean value being 5,2 %;

d) The four biggest equipment, granulators (GR_1, GR_2) and mills (M_1, M_2) on which measurement was made were, during the measurements, significantly under-loaded:

GR_1: P_{min} = 6,8 kW; P_{med} = 56,1 kW; P_{max} = 84,6 kW; P_n = 200 kW

GR_2: P_{min} = 105,5 kW P_{med} = 111,2 kW; P_{max} = 113,7 kW; P_n = 200 kW

M_1: P_{min} = 8,1 kW; P_{med} = 33,4 kW; P_{max} = 98,2 kW; P_n = 110 kW

M_2: P_{min} = 8,17 kW P_{med} = 8,23 kW; P_{max} = 8,3 kW; P_n = 110 kW

We found that M_2 is operating in no-load regime. The maximum power that two (of these four equipment) has reached, during the measurements (M_1 și GR_2), lead us to the idea that the rated power of the four equipment is correctly stable, the more so the load regime registered during the measurements is below the usual and, on the other hand there are overloads inherent to equipment starts. We recommend that, to increase the energy efficiency of these machines, to avoid the no-load regimes and increase of load level. We estimate that through these measures (administrative) it could be obtained a decrease of related power losses with about 5%, which represents about 42 MWh/year.

e) Electric lighting is ensured both with efficient lighting lamps (LED) as well as with less efficient lighting lamps (fluorescent). If these fluorescent lighting lamps would be replaced with LED sources, the lighting efficiency would rise with about 30%, which would imply the decrease of rated power of lighting receptors and also the decrease of power losses of lighting systems with about 9180 kWh/year, investment recoverable in about 8 years.

5.3. Resources to improve energy performance

By applying the recommendations above presented, to reduce the power losses, it is obtained the optimized EBB, having the components shown in table 6 and figure 11.

Table 6 – Results regarding yearly optimized EBB for MFFP (reference year 2018)

Characteristic quantities	EEB component values	
	[MWh]	[%]
A. Energy in [W_a]	6466,84	100
B. Energ out [W_i]	6466,84	100
1. Useful energy [W_u]	5293,4	81,9
2. Losses [ΔW]	1173,44	14,66
2.1. Transformers [ΔW_T]	66,8	1,03
2.2. Power lines [ΔW_L]	227,02	3,51
2.3. Motors and mechanisms [ΔW_M]	839,1	12,94
2.4. Lighting receptors [ΔW_l]	40,52	0,62

Energy efficiency indicators values of optimized EEB are:

$$I_W=\frac{W_{aopt}}{V_{EP}}=\frac{6466840}{116528160}=0{,}055\ [\text{kWh/leu}] \qquad (9)$$

$$P_W=\frac{1}{I_W}=18{,}18\ [\text{lei/kWh}] \qquad (10)$$

$$C_{WS}=\frac{W_{aopt}}{V_{FP}}=\frac{6466840}{94002}=68{,}79\ [\text{kWh/t}] \qquad (11)$$

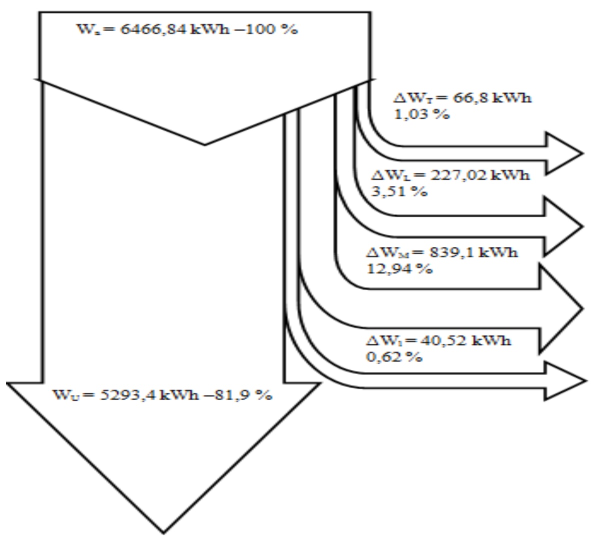


Fig. 11 - Sankey diagram regarding optimized EEB for MFFP

A way less investigated in energetic audits, applicable to increase energetic performance, is that of identifying the optimum production level by applying the "minimum energy specific consumption" criteria [11, 24].
In this case, based on table 1, months of year 2018, it has been identified the power energy characteristics of MFFP, respectively $W_a = f(V_{FP})$ şi $C_{WS} = f(V_{FP})$.
In accordance to recommendations from specialty literature [25, 26], it has been tested three models:

- Linear: $W_a = a\ V_{FP} + b$ (12)
- Parabolic: $W_a = a\ V^2_{FP} + b\ V_{FP} + c$ (13)
- Logarithmically: $W_a = a \ln V_{FP} + b$ (14)

In each case is expressed the specific consumption $C_{WS} = W_a(V_{FP})$ and it is determined the precision of estimation, by calculating the indicator:

$$r=\frac{\sum_{i=1}^{12}(Wai-Wamed)^2-\sum_{i=1}^{12}(Wai-\widehat{W}ai)^2}{\sum_{i=1}^{12}(Wai-Wamed)^2} \qquad (15)$$

where:
W_{ai} - real, monthly consumption (observed);
W_{amed} - mean value (monthly) of consumption;
$\widehat{W}ai$ – Adjusted monthly consumption (given by regression equation).
Estimation is the better the closer is to 1 [25].
The results were:

- Linear model:

$$\begin{cases} W_a = 0{,}065\ V_{FP} + 0{,}03 \\ C_{WS} = 0{,}065 + 0{,}03/V_{FP} \\ r = 0{,}67 \end{cases} \qquad (16)$$

- Parabolic model:

$$\begin{cases} W_a = 0{,}0009\ V^2_{FP} + 0{,}055\ V_{FP} + 0{,}052 \\ C_{WS} = 0{,}0009\ V_{FP} + 0{,}055 + 0{,}052/V_{FP} \\ r = 0{,}75 \end{cases} \qquad (17)$$

- Logarithmically model:

$$\begin{cases} W_a = -2{,}42 + 1{,}45 \ln V_{FP} \\ C_{WS} = -2{,}42/V_{FP} + 1{,}45 \ln V_{FP} / V_{FP} \\ r = -10 \end{cases} \qquad (18)$$

Parabolic model is most suitable.
To identify the optimal production value, we solve the equation:

$$\frac{dC_{WS}}{dV_{FP}}=-\frac{0{,}052}{V^2_{FP}}+0{,}0009V_{FP}=0 \qquad (19)$$

We got:

$$V_{FP}=\sqrt{\frac{0{,}052}{0{,}0009}}=7{,}6 \text{ thousands tons}$$

$$\Rightarrow C_{WSmin} = 68{,}6 \text{ kWh/t} \qquad (20)$$

to which corresponds.
In figure 12 are shown power energy characteristics of MFFP.

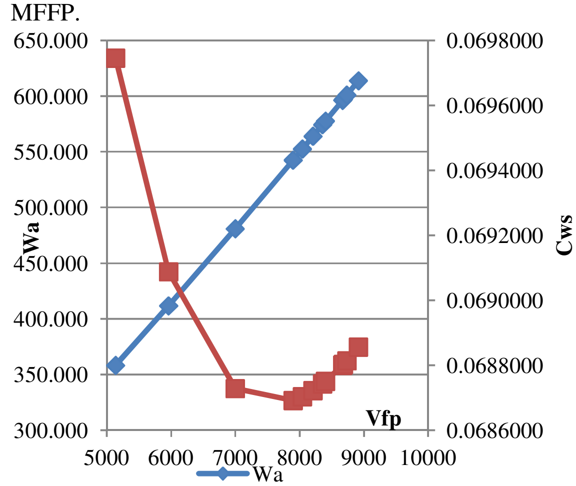


Fig. 12 – Power energy characteristics of MFFP

6. CONCLUSIONS

In the sector of food industry for animals it's consumed a significant quantity of energy, mainly, electric energy (EE). Measurements made, regarding EE, at a mixed fodder factory (MFF) with a capacity of 2×10 tons, reflects a load curve strongly variable, the absorbed active power being in interval [231,6 ÷ 713] kW for the analyzed MFF, EE consumption being structured as follows:

- About 87,4% in effective and complementary processes
- About 12,6% in auxiliary activities(workshops, offices, interior lighting)

Within technologically effective and complementary processes, the grinding processes consumes about 27,3%, granulators processes about 51%, and complementary processes (transport, ventilation, mixing etc.) consumes about 21,7%.

Energetic yield of processes is relatively good (81,9%) – at yearly mean load value, with values significantly lower (72%) – at minim load measured. Specific energy consumption is variable in a reasonable timeframe, respectively [62 ÷ 78]kWh/t, with a mean value of 69,6 kWh/t – in the last one analysis year (2018). The processes from MFF analyzed don't have a major impact on EE quality and the noted effects can be easy corrected. The improvement of energy efficiency measures which is suitable to MFF analyzed are minimal and refers t electric lighting, structural and functional optimization of TP, avoiding of no-load operation of big machinery (mills, granulators) and corrections in EE quality. The improvement of energetic performances of MFF can be realized also by optimizing the level of load, by applying the criteria "minimum energy specific consumption". The parabolic model offers the best approximation of power energy characteristic of MFF analyzed. Applying this model is obtained the value of optimal load (7600 tons), to which the specific EE consumption is 68,6 kWh/ton. Operation in optimized conditions leads to an improvement with an about 2,8% of level of energetic performance of MFFP.

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