Theses of doctoral (PhD) dissertation

ENERGETIC EFFICIENCY ANALYSES CONCERNING THE TECHNOLOGY OF CATTLE FARMS

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1. INTRODUCTION

Justification of the topic

Cattle breeding is one of the most significant agricultural sectors in Hungary, however it has been shrinking during the recent decades. Nevertheless, this tendency has reversed as of 2011 and an increase is present in both the beef cattle and dairy sectors. Changes are realised slowly within the cattle sector due to the long life cycle of the animals.

Termination of the quota system of the European Union has brought a significant decline in terms of market prices, further intensifying the struggles of cattle farms. However, growing competition created opportunities for efficient, modern production units for further improvement. Domestic farms are not falling behind within the EU competition in terms of average production.

In cattle farms, various forms of energy are required, which could be provided – in conformity with current trends – by renewable resources. The advantages of this approach – besides climate preservation – are stable income (saved energy costs) and job creation / preservation. Application of renewable energy is becoming available in a wider scale in Hungary (e.g. biogas, solar cells, solar collectors, solid biomass heating); producers are starting to realise the practical advantage of these new methods. This area has been stressed by the modernisation subsidy calls of livestock units during the recent years; application of renewable energy was awarded by extra scores during evaluation. Consequently, different types of renewable energy are already applied at many production locations or there are developments in progress. The significance of all of the above is the fact that energy saving decrease the production cost of milk which contributes to the competitiveness of dairy farms and their long-term presence on the market.

Aim of the research

The general objective of the research is the energetic, technological and efficiency evaluation of the dairy sector.

Therefore, relevant technical literature has been studied, with the help of which the domestic and national situation of the dairy sector, characteristics of the Hungarian and EU energy production and the most important modern and energy-saving technical devices and technologies of dairy farms are introduced.

As for the territorial relevance of the research, Hajdú-Bihar County has been selected as research location. In Hungary, both cattle population and the amount of produced milk are the highest in Hajdú-Bihar County.

The thesis aspires for using the most recent statistical data and technical literature sources as well as for the comparison of results and their validation with technical literature data.

Limiting factors of the research are mostly the data supply attitude and possibilities of cattle farms, therefore such a list of questions has been elaborated for which complete and accurate replies could be expected.

For achieving the general objective, the following clear objectives have been set up:

- Evaluation of the major production properties of cattle farms involved in the analysis, calculation of their efficiency indexes and their comparison with the technical-technological setup.
- Analysis of the energy and labour consumption of dairy production, determination of the proportion of each energy resource on the basis of the mentioned data.
- Assessment of the spread of the most important technical-technological elements, and analysis of their connection to farm size. Elaboration of a methodology determining the technological modernity of dairy farms.
- Analysis of the application of renewable energy sources and the spread of energy saving solutions.
- Analysis of the investment project system concerning dairy farms and introduction of their practice of applying for funding.

2. MATERIAL AND METHOD

In the course of the research, dairy farms have been contacted. Data has been collected by means of n-site tours, systematic observation and the completion of data sheets during the interviews of farm managers. Due to the large amount of time required by data collection, research was narrowed on the basis of the following aspects:

Hajdú-Bihar County has been the territorial focus of the research. In terms of the dairy cattle population and milk production, Hajdú-Bihar County is the first in Hungary (KSH, 2017b). However it is similar to the country average in terms of the average cow population / farm and milk production / dairy cattle (ÁT Kft, 2016a).

2.1. Introduction of the representative nature of data collection

According to the data of KSH, the number of dairy cows in Hajdú-Bihar County has been 31 750 in December 2016, the total dairy cow population of the analysed 20 farms is 12 355 which is a proportion of 39%. However, the KSH data includes cows with dual functions (mainly Hungarian spotted cows) and the small dairy farms which mostly produce for their own consumption, since this approximately 32 thousand cows are owned by 1294 farms (average number of cows per farm: 24.5). In my opinion, in terms of medium and large scale production the cow numbers controlled by *ÁT Kft.* are standard, where 52 farms kept 20 565 cows in 2016 (397 cows/farm). Approximately 60 percent of these cows have been analysed, data is shown in *Table 1* (ÁT Kft, 2016a-l).

The most accurate statistics can be acquired from the county-level lactation list of the Association of Holstein Friesian Cattle Breeders (Holstein-fríz Tenyésztők Egyesülete, hereinafter *HfTE),* since it includes each dairy farm (where Holstein Friesian cattle are bred and which are members of the association – however this is common, except for the smallest farms).

Table 1. Share of examined farms compare to Hajdú-Bihar county by different aspects

Aspect	Data source	H-B county	Examined farms	Share *[%]*
Number of dairy cows in 2016.	KSH, and own data collection	31 750	12 355	39%
Annual milk production 2016. *[thousand liter]*	KSH, and own data collection	203 053	108 429	53%
Number of performance tested dairy farms, average 2016.	ÁT Kft, KSH, and own data collection	52	20	38%
Number of performance tested cows in 2016	ÁT Kft, KSH, and own data collection	20 656	12 335	60%
Number of dairy farms above, 50 lactation in 2016.	HfTE	44	22[1]	50%
Number of total stand. lactation in, 2016.	HfTE	19 331	11 960	62%
Estimated annual milk production in 2016. (number of lactations x lact. average) *[tons]*	HfTE	179 864	115 154	64%

Source: Own editing on the basis of KSH, 2017; HfTE, 2017; ÁT Kft 2016a-l and own data

2.2. Questions used in data collection

For the elaboration of the data sheet, previous relevant data collection experience has been used and I aspired for asking question which can mostly be answered by the farm managers themselves. In the case the question concerning technical data, my objective was to receive unified data that is easy to provide; sub-questions have been defined in advance in terms of technical parameters.

Questions of the interviews have been classified into 8 groups which are the following:

1. Production data, indexes (e.g. number of cows, annual milk production)
2. Human resources (e.g. number of employees, qualification of the farm manager)
3. Energy consumption data (e.g, annual energy consumption, required hot water, heated area)
4. On-site technology (e.q. milking equipment, cow identification, feeding, cowshed technology)

[1] In the course of data collection, 20 farms have been visited, but they appear as 22 farms, since in 2 cases a farm included 2 separate production units. They are considered one in every further case as linked farms.

5. Renewable energy consumption (solar cell, solar collector, biogas plant, biomass use)
6. Energy saving, energy recycling technologies (e.g. heat recycling milk cooling, frequency driven vacuum production, manure transport via built-in technology)
7. Subsidies, projects (EMVA ÁTK I-V, VP Modernisation of cattle farms)
8. Others (short term development plans, other comments)

2.3. Statistical analysis of the data

Data of the visited dairy farms is displayed without their actual names; they are referred to with the codes T01, T02 … T20. T stands for the Hungarian word for cow/cattle farms (tehenészet), while the numbers represent the cattle population of the farms in a *decreasing order*.

Due to the small sample size and the different properties of the farms, cluster analyses have been carried out with 3 clusters for data comparison. Where the nature data allowed, correlation analyses have been carried out. Calculations have been based on functions elaborated in MS Excel.

2.4. Methodology of the analysis of spreads of technological elements

Concerning technological modernity, numerous elements have been examined at the dairy farms. Aspiring for transparent and clear comparison, 30 of these technological solutions have been highlighted in present thesis, classified into 5 groups.

Examination of the spread of technological elements resulted in the distinction of two types of spread: On the one hand, there are technologies where spread is on a yes/no or there is/there is not basis, just like in the case of farm management software. On the other hand, there are technological elements where a percentage-based distribution is applied in proportion of available space, due to the different equipment level of the cowsheds, e.g. freestall barns with cubicles. In terms of the equipment level of cowsheds, 100% of the available space is meant by the total number dairy cows.

3. RESULTS

3.1. Number of cows, production level

Size and production level of the examined 20 dairy farms are shown in *Figure 1*.

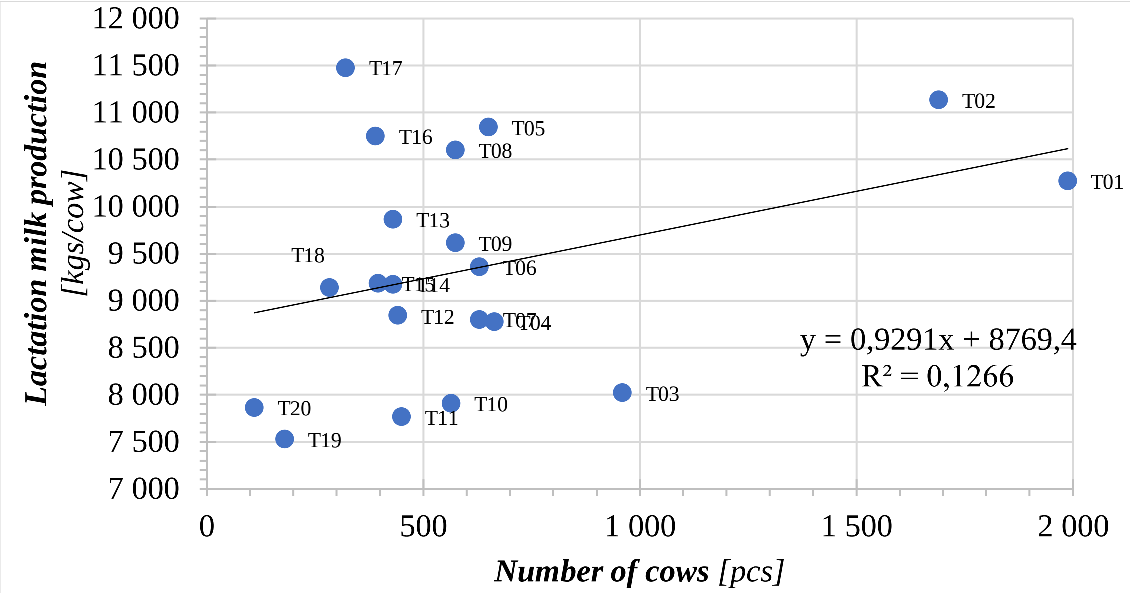

Figure 1. The distribution of examined farms by cow number and lactation milk production

Source: own editing

3.2. Number of employees, labour productivity

Questions of the data sheet concerned the number of physical and clerical employees, the number of employees with higher education qualification, and the qualification of the farm manager. Number of employees included the people working directly on the farm. *Figure 2* shows the number of employees and the number of cows at the examined dairy farms. There are more the 50 employees at the two largest farms (T1, T2), while 5 people work at the two smallest farms (T19, T20). A total of 475 employees work at the examined 20 farms.

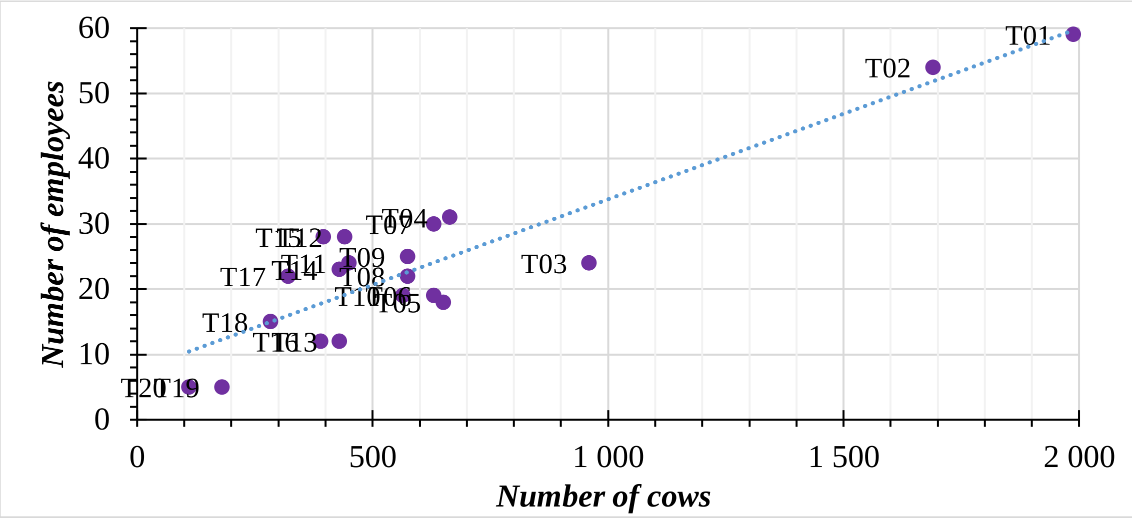

Figure 2. Correlation between number of cows and number of employees

Source: own editing

Value of Pearson correlation between the two series of data is 0.899, which indicates strong correlation. Deviation from 0 of the correlation coefficient is not by accident with 99.9% probability.

Comparison of the values of number of cows / manual worker to technical literature data has been carried out in the doctoral dissertation of VÁNTUS in 2004 through dairy farms located in Hajdú-Bihar County (VÁNTUS, 2006). The farms have been classified into three clusters on the basis of their size – for unified comparison, the same cluster classification is used in the following Table 2 for my own data. During the 12 years, the index increased from 23.1 to 30.5 in Hajdú-Bihar County.

Table 2: Comparison of number of cows per manual worker in, 2004 and 2016

VÁNTUS, 2006. (data from year 2004)					
Cluster	**Number of dairy farms**	**Cow number treshold**	**Average**	**Minimum**	**Maximum**
Cluster1	*11*	*40-160*	*18,5*	*12,0*	*41,7*
Cluster 2	10	161-500	23,4	15,6	37,9
Cluster 3	14	above 501	24,1	16,7	37,7
Cluster 2 & 3	**24**	**above 160**	**23,8**	**15,6**	**37,9**
All dairy farms	*35*	*above 40*	*22,1*	*12,0*	*41,7*
Own data collection (data from year 2004)					
Cluster	**Number of dairy farms**	**Cow number treshold**	**Average**	**Minimum**	**Maximum**
Cluster1	*1*	*40-160*	*27,5*	*27,5*	*27,5*
Cluster 2	9	161-500	26,9	16,1	45,0
Cluster 3	10	above 501	33,7	22,5	53,3
Cluster 2 & 3	**19**	**above 160**	**30,5**	**16,1**	**53,3**
All dairy farms	*20*	*above 40*	*30,1*	*16,1*	*53,3*

Source: VÁNTUS, 2006 and own editing based on own data

POSTA, (2007) defines an interval between 15 and 30 for the number of dairy cows treatable by one worker.

The average *working hours projected to 100 litres of milk* at the examined farms are 1.07, the minimum ones are 0,55, and the maximum value is 1,67. A study published in 2006 in Ontario State, Canada determines the average for *working hours projected to 100 litres of milk* as 1.42. According to the quoted research the minimum value was 0,72 hours the maximum value was 2.27 hours. (I1 – RODENBURG).

As for the examined dairy farms, *working hours projected to 100 litres of milk* calculated to *labour cost,* indicates a more visible difference in terms of the efficiency of the farms. For the enterprises in Hajdú-Bihar County the average monthly cost (including taxes) for a full time agricultural worker was 235 551 HUF in 2015. The cost for 1 working hour: 235 551 HUF/month / 174 working hours /month = 1 354 HUF/a working hour:

- The best farm: 0.55 hour/100 litre = 1 354 * 0.55 / 100 = 7,51 HUF/litre
- Average of the farms: 1.07 hour/100 litre = 1 354 * 1,07 / 100 = 14,43 HUF/litre
- The less efficient farm: 1.7 hour/100 litre = 1 354 * 1,67 / 100 = 22,63 HUF/litre
  - The difference between the most and less efficient farms in terms of the labour cost of manual workers for 1 litre of milk is 14.9 HUF.

3.3. Energy consumption

In terms of the energy consumption of the dairy farms, the usage of electricity, natural gas, propane-butane gas (*hereinafter PB-gas*), diesel oil, and biomass in 2016 has been assessed in natural units of measure and HUF. There was no available data about all energy types in the case of four farms; therefore they have been excluded from the calculations.

Natural gas connection was available in 8 farms, therefore they didn't use the more expensive PB gas. HORVÁTH, (2003) found, that the proportion of dairy farms with natural gas connection was above 50%, by examining all dairy farms in Hajdú-Bihar County.

Average annual electricity consumption per cow is 481 kWh, the value of relative deviation (variation coefficient) is 44%; the average electricity cost is 13 959 HUF, relative deviation is 38%. Compared to technical literature data, (POSTA, 2007) calculates with 50-70,000 kWh annual consumption for 100 cows. In the case of the examined dairy farms, average electricity consumption for 100 cows is 48,134 kWh, the confidence interval p=95% is between 36400 and 59800 kWh, therefore the value seems to be valid.

The average PB-gas, natural gas and firewood consumption per cow is 940 MJ, *relative deviation is* 54%; the average cost is 3 056 HUF, relative deviation is 50%.

Average annual consumption of diesel oil per cow is 82 litre, the value of *relative deviation* is 34%; the average cost is 21 322 HUF, relative deviation is 33%. 80% of fiscal duties in agriculture can be reclaimed; according to the reclaiming system effective until 2007, the fiscal duties of **85 litres of diesel oil** could be reclaimed even for **1 cow** (216/1997 Korm. rendelet).

Figure 3 shows the total annual energy consumption for 1 litre of produced milk by energy type. Direct energy demand varies between 414 and 1 159 kJ/ litre, its average is 703 kJ/litre, the relative deviation is 31%. In comparison, energy content of cow milk is 3 040 kJ/kg (SCHMIDT, 2015).

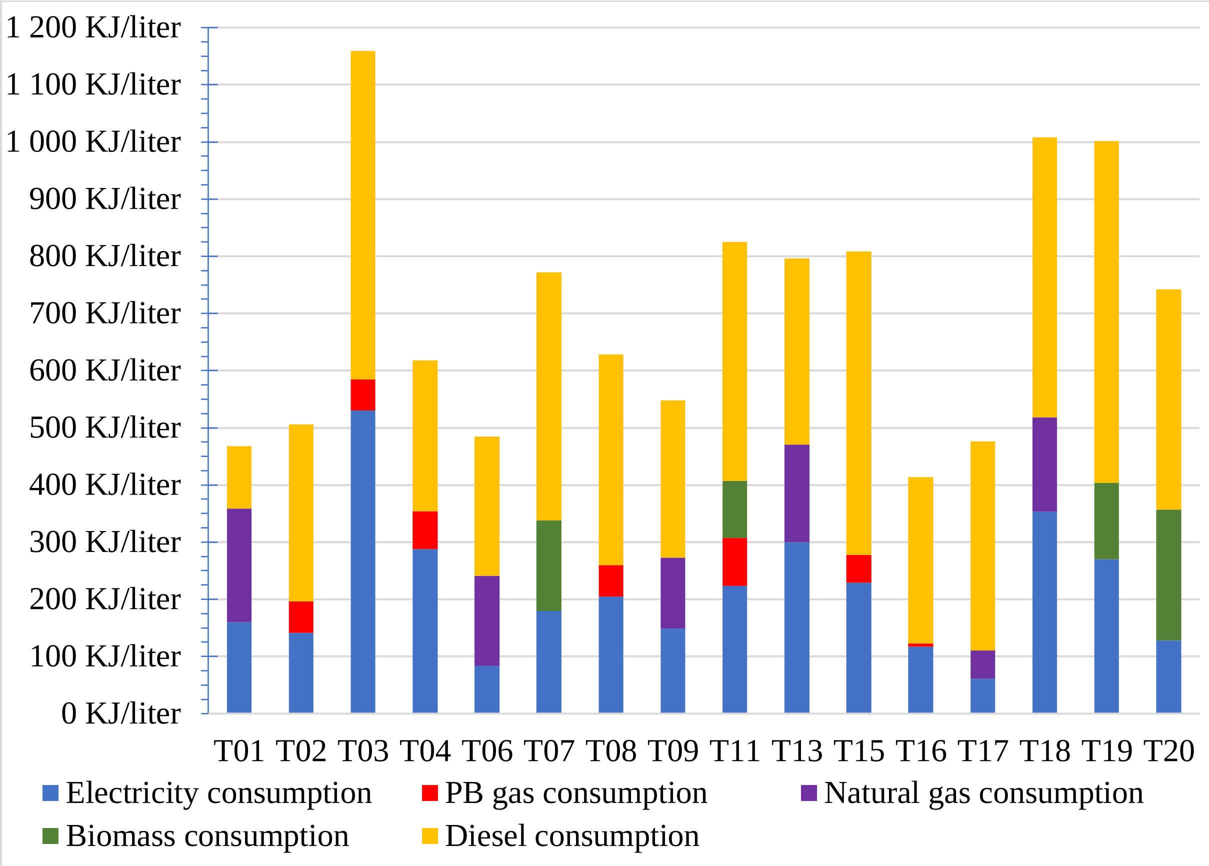

Figure 3: Distribution of energy consumption by type, in 1 liter of milk

Source: own editing

Distribution of the energy consumption of dairy farms by energy type (*on the basis of weighted average*) is the following:

- Electricity: 31,9%
- PB-gas: 4,4%
- Natural gas: 11,0%
- Biomass: 2,5%
- Diesel oil: 50,2%

Diesel oil is amounts almost to the half of the annual average consumption and even more in the case of certain farms.

Energy cost 1 litre of produced milk varies between 2.5 and 7.5 HUF/litre, while its average is 4.7 HUF/litre. Energy costs (PB-gas, natural gas, electricity, biomass and diesel oil) amount to only several percent of the total costs of milk production. According to the data of the test system of the Research Institute of Agricultural Economics, prime cost of milk production as 88.7 HUF/litre in 2011 (BÉLÁDI et al., 2017).

3.4. Analysis of the spreads of technological elements

For analysing the spread of certain technological solutions, dairy farms have been classified into 3 clusters on the basis of cow number, aiming for a similar sample size. Cluster classification is shown by *Table 3*. The spread of each technology is displayed by technology group for every cluster in distributions based on number and percentage.

Table 3. Defining clusters by farm size

Clusters	Number of diary farms	Cow number treshold	Average cow number	Minimum	Maximum
Cluster 1	6	under 400	**280**	110	396
Cluster 2	7	401-600	**495**	430	574
Cluster 3	7	above 601	**1 030**	630	1 988
All diary farms	**20**	**-**	**618**	**110**	**1 988**

Source: own editing

3.4.1 Milking technology

The first group is formed by 7 milking technology elements; spread data is shown by *Table 4*.

Table 4. The spread of milking technology elements in examined dairy farms

Clusters	Cluster 1		Cluster 2		Cluster 3		Sum	
Number of dairy farms	6		7		7		20	
Average cow number	280		495		1 030		618	
Spread of technological element	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*
Carousel milking parlours	0%	0	14%	1	30%	3	**15%**	**4**
Milking device automatic take-off	67%	4	100%	7	100%	7	**90%**	**18**
Milking robot or robotic carourel milking parlour	0%	0	0%	0	0%	0	**0%**	**0**
Crowd gate	17%	1	57%	4	44%	4	**40%**	**9**
Heat recovery from refrigeraton compressors	50%	3	86%	6	86%	6	**75%**	**15**
Refrigeraton compressors waste heat for milking parlour air heating	17%	1	29%	2	29%	2	**25%**	**5**
Vacuum pump with variable frequency drive	17%	1	71%	5	82%	6	**59%**	**12**

Source: own editing

The first technological element is the *carousel milking parlours*, which I came across at 4 farms. *Automatic milking device take-off* was present at almost all of the dairy farms except for two, which belonged to Cluster 1 (T17, T20). None of the examined farms had *milking robots*. The T4 farm has a modern 3 year old, shed with cubicles, that is able to accommodate

540 cows, which can be upgraded with a milking robot system. 9 farms had *crowd gates*, primarily medium and larger production units.

3.4.2 Cowshed technology

The group of cowshed technology consists of 8 technological elements; spread data is shown in *Table 5*.

Spread of the relatively modern freestall barns with cubicles showed an increasing tendency in terms of the clusters. In Cluster 1, 8% of the available space was this type, while 37% in Cluster 2 and 69% in Cluster 3.

Active elements of ensuring a proper shed climate are ventilation fans, humidification and mobile sidewalls, since these require operation and energy consumption. Passive elements include insulated attic and open ridge exhaust system. *Shed ventilation fans* have been present in 17 farms, which covered 67% of the available space. Fans are equipped with built-in temperature sensors at every farm. Humidification has been applied at 9 farms, almost one-third of the available space. Due to the moisturising effect of humidification, perforated pipes have been placed towards the feeding lanes. *Mobile sidewalls* allow the regulation of shed temperature. Spread of mobile sidewalls is 19% for Cluster 1 and above 40% at Cluster 2 and 3. Sandwich composite, insulated slate roofing, barn attic sheds and reed roofing have been considered *Insulated attic*. Concerning the insulated attic, 25% share has been measured for Cluster 1, 75% for Cluster 2 and 29% for Cluster 3. Regarding the *Open ridge exhaust system*, 55% spread has been measured for Cluster 1, 66% for Cluster 2 and 89% for Cluster 3.

Table 5. The spread of cowshed technology elements in examined dairy farms

Clusters	Cluster 1		Cluster 2		Cluster 3		Sum	
Number of dairy farms	6		7		7		20	
Average cow number	280		495		1 030		618	
Spread of technological element	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*
Freestall barns with cubicles	8%	1	37%	3	69%	6	39%	10
Ventilation fans	61%	6	58%	5	81%	6	67%	17
Humidification	31%	3	29%	3	32%	3	31%	9
Mobile sidewalls	19%	2	42%	4	43%	4	36%	10
Insulated attic (sandwich panel, reed roofing)	25%	2	75%	7	29%	3	44%	12
Open ridge exhaust system	55%	4	66%	6	89%	7	71%	17
Built-in manure removal	0%	0	18%	2	35%	3	18%	5
Electric cow cleaning brushes	0%	0	8%	1	17%	3	9%	4

Source: own editing

Electric cow cleaning brushes as primarily animal welfare equipment appeared at 4 farms and involved 9% of the available space.

3.4.3 Feeding technology

The group of feeding technology is formed by 6 elements; spread data is shown in *Table 6*.

The first parameter, *feeding in a covered place* was available at 18 farms, with the exception the T10 and T20 farms. Its spread is around 70% in Cluster 1 and 2 and in Cluster 3 98% of the available space is suitable for feeding in a covered place. *Free table feeding* was available at 12 farms; in the proportion of available space, its average spread was 50% in Cluster 1, 23+ in Cluster 2 and 73% in Cluster 3. In my opinion, the reason for the significantly lower spread at Cluster 2 was in those farms which are the descendants of the old specialised animal farms, where there was no major cow number change consequently, there was no bigger investment or cowshed reconstruction needed, that's why the mangers remained. HORVÁTH, 2003, confirms this assumption, because according to his results the farms with cow number between 300-500 were the most obsolete, in terms of building reconstruction.

There have been 9 farms where potential mechanised feed pushing was an option. 3 of these farms had actual *mechanised feed pushing*.

Table 6. The spread of feeding technology elements in examined dairy farms

Clusters	Cluster 1		Cluster 2		Cluster 3		Sum	
Number of dairy farms	6		7		7		20	
Average cow number	280		495		1 030		618	
Spread of technological element	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*
Feeding in covered place	68%	5	70%	6	98%	7	79%	18
Feed table instead of manger	50%	3	23%	2	73%	7	49%	12
Mechannized feed pushing in feed table	0%	0	14%	1	26%	2	14%	3
Automatic fodder distribution for cows	0%	0	0%	0	0%	0	0%	0
Calf milk feeding automat - RFID based	0%	0	0%	0	0%	0	0%	0
Milk - taxi (calf feeding)	17%	1	14%	1	43%	3	25%	5

Source own editing

Automatic fodder distribution has not been used at any of the farms. Also, I did not come across *calf feeding automats* capable of the milk feeding of calves at any of the farms. 5 farms used *milk-taxi* for the facilitation of *calf feeding* and 3 farms expressed their intention of purchasing it in the near future or have already ordered it.

3.4.4 IT solutions – Precision Livestock Farming (PLF)

Spread of information technology *(IT)* and *precision livestock farming* solutions are shown in *Table 7.*

Table 7. The spread of Precision Livestock Farming in examined dairy farms

Clusters	Cluster 1		Cluster 2		Cluster 3		Sum	
Number of dairy farms	6		7		7		20	
Average cow number	280		495		1 030		618	
Spread of technological element	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*
Cattle management software	100%	6	100%	7	100%	7	**100%**	**20**
Cow identification system - RFID based	17%	1	57%	4	57%	4	**45%**	**9**
Individual daily milk yield recording	17%	1	57%	4	57%	4	**45%**	**9**
Cow heat detection - activity measurement system	17%	1	57%	4	43%	3	**40%**	**8**
Automatic selection gates	17%	1	43%	3	25%	2	**29%**	**6**
Individual milk conductivity - somatic cell count measurement	0%	0	0%	0	43%	3	**15%**	**3**

Source: own editing

Cattle management system is used at every examined farm. A secondary cattle management system is used at multiple farms; in such cases the primary software is used for registration while the secondary software belongs to the milking system or the activity measurement unit.

Spread of the ***primary*** *cattle management software*: RISKA 16 pcs., TALP 4 pcs.

Comparing the found distribution with the data of BALOGH, (2014), the author examined the spread of cattle management software at all of the Holstein Friesian breeding farms of Hajdú-Bihar county

- RISKA 21 pcs.
- TALP 6 pcs.
- DeLaval ALPRO 4 pcs.
- No cattle management software 17 pcs.
- ***Total:*** ***48 pcs.***

Cow identification and individual milk yield recording have been used at 9 farms, in medium and larger production units *(Cluster 2 and 3). Cow heat detection and activity measurement units* have been utilised at 8 farms. The system was completely set up at all of the 8 farms, namely a sufficient amount of activity measurement units have been available for the monitoring of every cow which have not been considered pregnant yet. *Automatic selection gates* have been utilised at 6 farms, for the selection of cows leaving the milking unit with health and reproductive biology reasons. Cows to be released to the treatment room by the selection gate can be indicated within the cattle management system. *Individual milk conductivity* measurement for the detection of subclinical mastitis has been applied at 3 farms only.

3.4.5 General farm technology

Camera surveillance system has been present at 17 examined farms for working discipline and property security reasons.

3.5. Determination of technological modernity

Technological modernity has been intended to be determined through the effect caused by them on the following 3 parameters: *increase of milk production, work efficiency, and the decrease of energy consumption.*

Weights for the 30 technological elements introduced in the previous chapter have been determined with the values between 0 and 5, depending on how much effect they have on the above three parameters in terms of the entirety of the given farm (*pl. 0 – no effect, 3 – medium effect, 5 – outstanding effect*). Modernity weight numbers of each technological element are shown in *Table 8.* The technological score of the farms is based on the sum product of weights and the spread of the given technology.

Table 8. Modernity weights for technological elements

	Technology topic	Technological element	Type	Milk production	Work productivity	Energy efficiency	Average
1.	Milking	*Carousel milking parlours*	yes-no	0	3	1	**1,33**
2.	Milking	Milking device automatic take-off	yes-no	1	2	1	**1,33**
3.	Milking	Milking robot or robotic carourel milking parlour	yes-no	3	5	3	**3,67**
4.	Milking	Crowd gate	yes-no	0	2	0	**0,67**
5.	Milking	Heat recovery from refrigeraton compressors	yes-no	0	0	5	**1,67**
6.	Milking	Refrigeraton compressors waste heat for milking parlour air heating	yes-no	0	0	2	**0,67**
7.	Milking	Vacuum pump with variable frequency drive	yes-no	1	0	4	**1,67**
8.	Barn	Freestall barns with cubicles	percentage	3	2	2	**2,33**
9.	Barn	Ventilation fans	percentage	2	0	0	**0,67**
10.	Barn	Humidification	percentage	1	0	0	**0,33**
11.	Barn	Mobile sidewalls	percentage	1	0	1	**0,67**
12.	Barn	Insulated attic (sandwich panel, reed roofing)	percentage	2	0	3	**1,67**
13.	Barn	Open ridge exhaust system	percentage	1	0	1	**0,67**
14.	Barn	Built-in manure removal	percentage	1	3	2	**2,00**
15.	Barn	Electric cow cleaning brushes	percentage	1	0	0	**0,33**
16.	Feeding	Feeding in covered place	percentage	2	1	1	**1,33**
17.	Feeding	*Feed table instead of manger*	percentage	0	3	2	**1,67**
18.	Feeding	Mechannized feed pushing in feed table	percentage	0	1	0	**0,33**
19.	Feeding	Automatic fodder distribution for cows	percentage	1	1	1	**1,00**
20.	Feeding	Calf milk feeding automat - RFID based	yes-no	0	3	1	**1,33**
21.	Feeding	Milk - taxi (calf feeding)	yes-no	0	2	0	**0,67**
22.	IT solutions	Cattle management software	yes-no	1	1	0	**0,67**
23.	IT solutions	Cow identification system - RFID based	percentage	1	1	0	**0,67**
24.	IT solutions	Individual daily milk yield recording	yes-no	1	0	0	**0,33**
25.	IT solutions	Cow heat detection - activity measurement system	percentage	2	2	0	**1,33**
26.	IT solutions	Automatic selection gates	yes-no	1	2	0	**1,00**
27.	IT solutions	Individual milk conductivity - somatic cell count measurement	yes-no	1	1	0	**0,67**
28.	General	Energy saving lighting (LED, Compact Fluorescent Light Bulbs CFL)	yes-no	0	0	2	**0,67**
29.	General	Energy-saving light swich (motion sensor, day-night swich)	yes-no	0	0	1	**0,33**
30.	General	CCTV surveilance system	yes-no	0	1	0	**0,33**
	All	**-**		***27***	***36***	***33***	***32,00***

Source: own editing

Each technological score and the resulting modernity score (sum of the 3 technological indexes) is shown by cluster in *Table 9*. The table shows that both *the **total modernity score*** and each index have increased with farm size.

Table 9. Distribution of average modernity scores by clusters

Clusters	Number of cows	Milk production modernity score	Work productivity modernity score	Energy efficiency modernity score	Cumulated modernity index
Cluster 1	280	7,04	7,01	10,00	**24,06**
Cluster 2	495	11,93	10,80	17,29	**40,02**
Cluster 3	1 030	13,89	14,71	18,59	**47,19**
All clusters	**618**	**11,15**	**11,03**	**15,56**	**37,74**

Source: own editing

Examining the correlation between farm size and modernity, distribution of farms by farms size and cumulated technological score is shown in *Figure 4*. The value of Pearson correlation between the two series of data is 0.612, which indicates a close correlation; deviation from 0 of the correlation coefficient is not by accident with 95% probability. The resulting linear regression function: 23.99+0.022x.

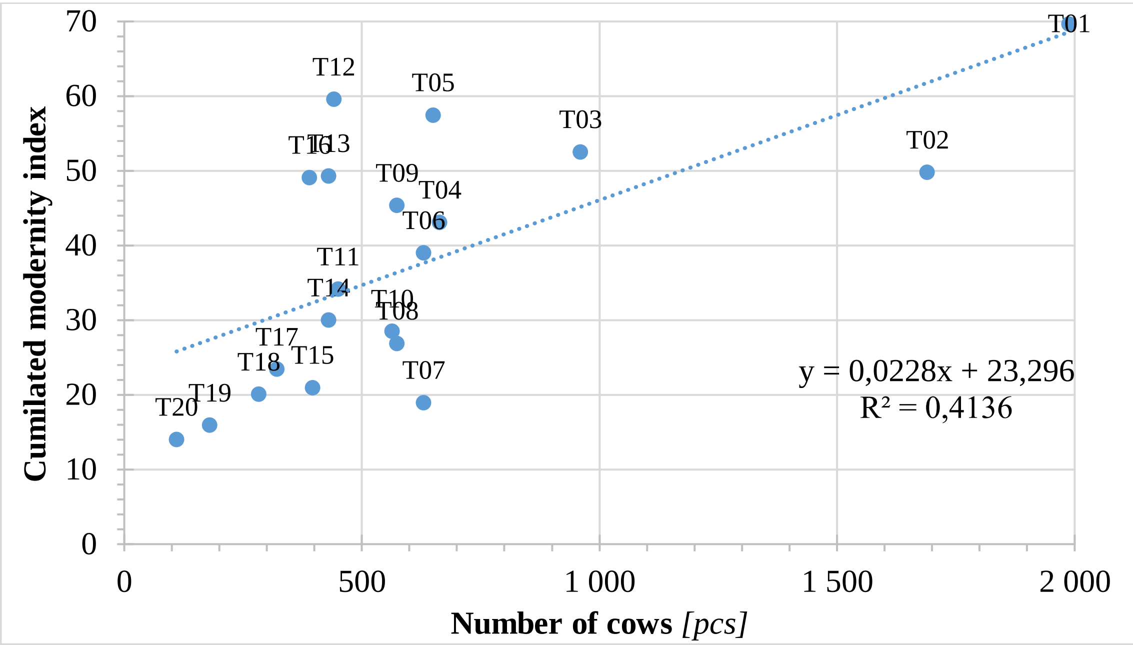

Figure 4. Correlation between cow number and cumulated modernity index

Source: own editing

3.6. Application of renewable energy

Spread of certain types of renewable energy production at the dairy farms is demonstrated by clusters in *Figure 5*.

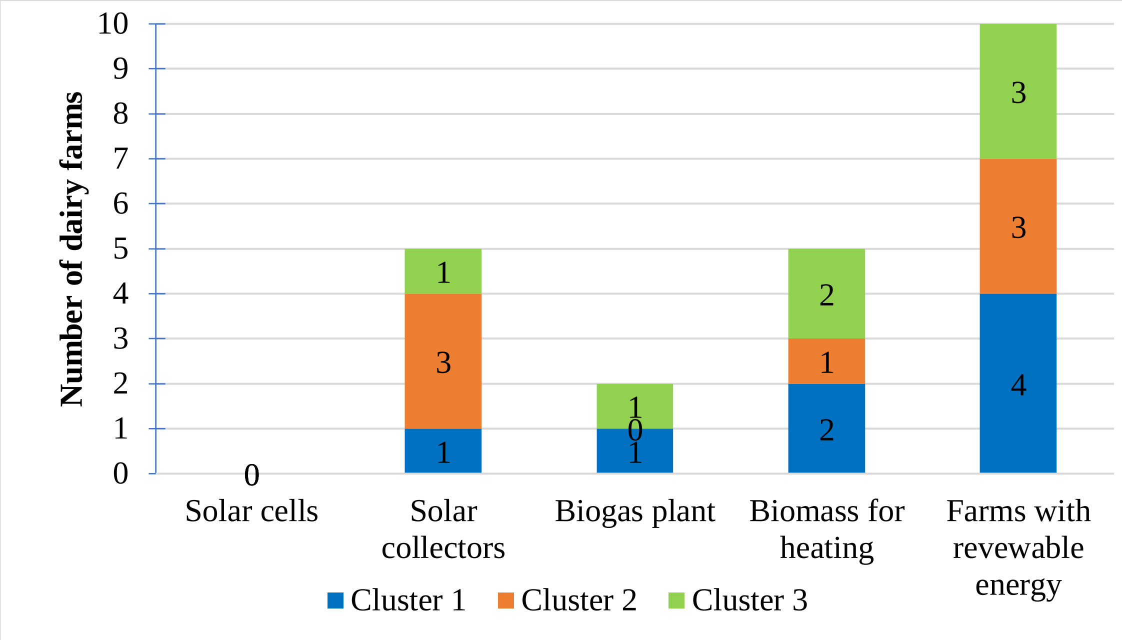

Figure 5. Renewable energy in examined dairy farms

Source: own editing

Solar collectors are mounted on the roof of the milking unit at all 5 farms, for hot water production. Technological details of the solar collectors are included by *Table 10*. Flat plates are used at 4 farms, while evacuated tube type collectors are used at 1. Every solar collector system is based on project funding.

Table 10. Comparing the solar thermal collector systems in examined dairy farms

Farm	Natural gas available	Heat recovery for milk cooling	Number of panels	Collector type	Hot water storage tank	Heating system in milking parlour	Hot water system in milking parlour	Age of system	Grant fund
T04	No	No	15 pcs	Flat plate	2000 liter, 3 heat exchangers	Gas furnace (PB)	solar thermal collector	3 years	ÁTK IV. 40%
T11	No	Yes	6 pcs	Flat plate	1 500 liter, 2 heat exchangers	Gas furnace (PB)	heat revovery + sollar thermal coll. + electric hot water boiler	8 years	ÁTK III. 50%
T12	Yes	Yes	3 pcs	Flat plate	1000 liter, 3 heat exchangers	Gas furnace (natural gas)	heat revovery + sollar thermal coll. + electric hot water boiler	3 years	ÁTK IV. 40%
T14	Yes	Yes	2 pcs	Evacuated tube	1000 liter, 2 heat exchangers	Gas convector heater (natural gas)	heat revovery + sollar thermal coll. + electric hot water boiler	4 years	ÁTK IV. 40%
T16	No	Yes	6 pcs	Flat plate	1800 liter, 3 heat exchangers	Gas furnace (PB)	heat revovery + sollar thermal coll. + electric hot water boiler	3 years	ÁTK IV. 40%

Source: own editing

Biomass heating was present at farms where natural gas is not available. Technological details of biomass boilers are contained by *Table 11*. In the case of biomass heating, the primary aspect of their use was cost reduction compared to the alternative of PB-gas. The specifically more expensive PB-gas (6.5 HUF/MJ) is a more important facilitating factor of biomass use than cheaper natural gas (3.0 HUF/MJ), therefore it is possible that every boiler is situated at farms where natural gas is not available. Project funding was not utilised in any of the cases.

Table 11. Comparing the biomass furnaces in examined dairy farms

Farm	Capacity	Type of furnace	Raw material	Controlled air stream	Building	Age of system	Grant fund
T04	3 pcs (60-60-100 kW)	small bale furnace	straw, corn stalk small square bales	**Yes**	Office + worker's building + machine workshop	**3 years**	**No**
T07	1 pcs *(55 kW)*	small bale furnace	wood and wood waste	**Yes**	Worker's building + milking parlour + milk room	**3 years**	**No**
T11	1 pcs *(20 kW)*	mixed fuel furnace	wood *(black locust)* and wood waste	**Yes**	Worker's building	**3 years**	**No**
T19	2 pcs	mixed fuel furnace	wood and wood waste	**No**	Worker's building + milking parlour + milk room	**10+ years**	**No**
T20	1 pcs	mixed fuel furnace	wood and wood waste	**No**	Worker's building + milking parlour + milk room	**10+ years**	**No**

Source: own editing

Biogas plants have been found at two dairy farms (T01, T18), technological details are shown *Table 12*. Biogas plants count as external factors in terms of their energy consumption, because produced electricity means expenditure saving on the level of the entire enterprise not on the level of the dairy farm. Both biogas plants utilise mixed cattle and pig manure, they have a mesophilic system. As for their capacity, the plant belonging to the T18 farm is the larger.

Table 12. Comparing biogas plants in the examined dairy farms

Farm	Type	Fermenters	Storage tank	Gas engine	Raw material	Operation started	Grant fund
T01	mesophilic	3 pcs 1 500 m^3	3 pcs 5000m^3	1 pcs - 637 kW 12 000 cm^3	cattle + pig slurry	**2011.**	**ÁTK I. 75%**
T18	mesophilic	3 pcs 2 900 m^3	3 pcs 6000m^3	2 pcs 625+400 kW	cattle slurry (only from milking parlour) + pig slurry	**2011.**	**ÁTK I. 75%**

Source: own editing

With regard to ***further plans related to renewable energy***, multiple dairy farms plan investments in the future. None of the dairy farms have a solar cell system currently, but investments are planned in the near future at 3-4 farms, to be mounted onto the roof the cowsheds. Solar collectors are planned at 3 farms beyond the already mentioned 5.

3.7. Energy preserving farm solutions

17 of the 30 elements involved in the technological comparison have a positive effect on energy saving, which means that their energy efficiency modernity weight is 1 or more *(Table 19)*. However, most of such elements have effects on other factors as well, like more efficient milk production or labour saving. In the case of 5 of the examined 30 technological elements, energy saving is the sole or primary parameter. The spread of these solutions is summarised in *Table 13*.

Heat recovery milk refrigeration system is operated at 15 examined dairy farms. In Cluster 1, 50% of the farms apply this energy saving method, while in the case of Cluster 2 and 3, 86%. *Waste heat of refrigeration compressors* are led into *the milking parlour* at 5 farms with the help of large diameter insulated pipe(s) and ventilation fans for the *heating of its air*. *Vacuum pumps with variable frequency drive* has been present at 12 dairy farms. This energy saving method is used at 17% of the farms in Cluster 1, 71% in Cluster 2 and 82% in Cluster 3..

Table 13. The spread of energy saving solutions in examined dairy farms

Clusters	Cluster 1		Cluster 2		Cluster 3		Sum	
Number of dairy farms	6		7		7		20	
Average cow number	280		495		1 030		618	
Spread of technological element	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*	*[%]*	*[pcs]*
Heat recovery from refrigeraton compressors	50%	3	86%	6	86%	6	75%	15
Refrigeraton compressors waste heat for milking parlour air heating	17%	1	29%	2	29%	2	25%	5
Vacuum pump with variable frequency drive	17%	1	71%	5	82%	6	59%	12
Energy saving lighting (LED, Compact Fluorescent Light Bulbs CFL)	100%	6	100%	7	86%	6	95%	19
Energy-saving light swich (motion sensor, day-night swich)	50%	3	86%	6	71%	5	70%	14

Source: own editing

In the case of the questions related to illumination, there was no differentiation in terms of the spread within the farm, only a *yes/no* type (0-100%) spread has been assessed. LED lighting, reflectors and modern, high-performance sodium lights, compact fluorescent lamps and mirror fitting fluorescent lamps have been considered energy saving lighting types. I came across these solutions in the case of 19 of the 20 dairy farms. LED lighting has been primarily used for external reflectors and less for conventional socket lamps.

Energy saving lighting control has been carried out with motion sensors and day/night switches. Primarily the latter has been used for the control of cowshed lighting and room illumination. At 14 of the 20 dairy farms some sort of an energy-saving control solution has been used.

The primary objective of farm management in terms of energy consumption is not the increase of the share of renewables, but the reduction costs, including energy costs. In my opinion, this is the reason why energy efficient or energy reclaiming solutions aiming for cost reduction are more frequent than renewable energy production systems.

3.8. Investment projects of the farms for technology development

The practice of project proposals and funding has been analysed through the number of submitted, won and implemented projects on farm level. The number of submitted, won and implemented projects of each dairy farm in the last 10 years is shown in *Figure 6*. Every dairy farm has submitted and won at least 2 projects, and implemented at least 1 during the examined period.

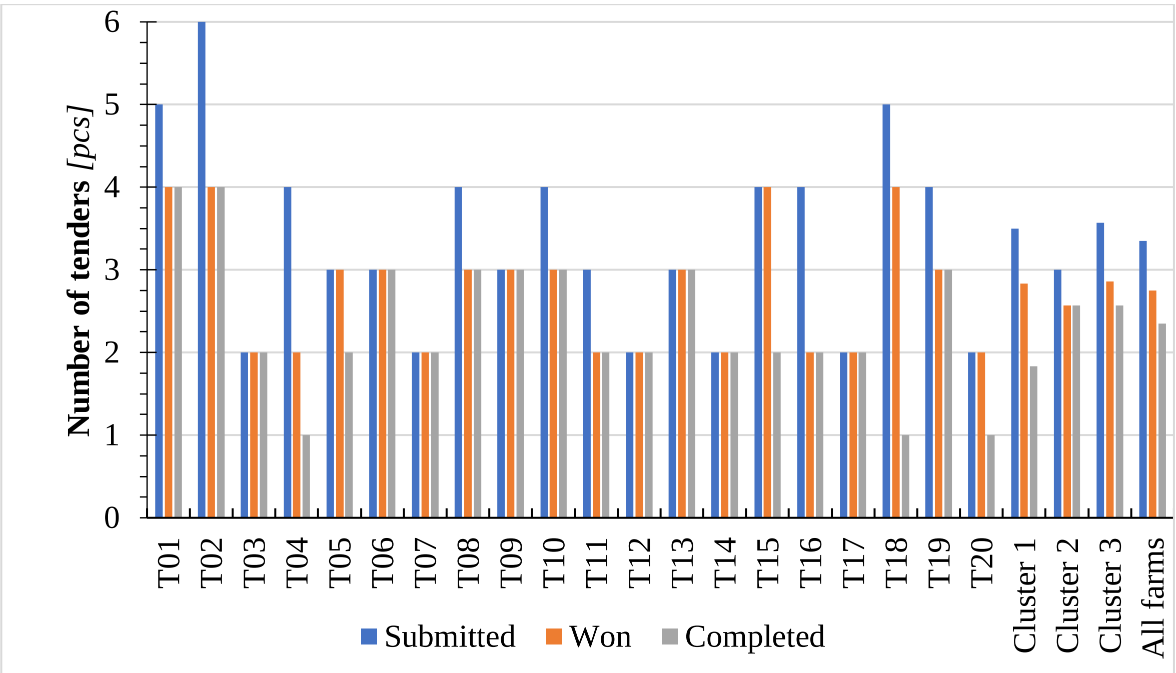

Figure 6. Number of tenders in examined dairy farms between 2007 and 2017

Source: own editing

Distribution of project proposals by programme and cluster is shown in *Figure 7.* In the case of the last 2 funding programmes grey lines indicate that the given activity has not finished yet.

Table 14. Distribution of tendering programs by cluster

Tendering program	Result	Cluster 1	Cluster 2	Cluster 3	All clusters
EMVA ÁTK I.	Submitted	3	3	6	12
	Won	3	3	6	12
	Completed	3	3	5	11
EMVA ÁTK II.	Submitted	3	3	3	9
	Won	3	3	3	9
	Completed	1	3	3	7
EMVA ÁTK III.	Submitted	2	3	1	6
	Won	2	3	1	6
	Completed	1	3	1	5
EMVA ÁTK IV.	Submitted	2	4	6	12
	Won	2	3	6	11
	Completed	0	3	6	9
EMVA ÁTK V.	Submitted	6	6	3	15
	Won	6	6	3	15
	Completed	6	6	3	15
VP Building manure containers	Submitted	2	0	3	5
	Won	1	0	1	2
	Completed	*0*	*0*	*0*	*0*
VP Modernisation of dairy farms	Submitted	3	2	3	8
	Won	*0*	*0*	*0*	*0*
	Completed	*0*	*0*	*0*	*0*
All	Submitted	21	21	25	67
	Won	17	18	20	55
	Completed	11	18	18	47

Source: own editing

ÁTK I and ÁTK II programmes have been very popular, 11 and 7 projects have been implemented by the dairy farms respectively. In the case of ÁTK III, low submission activity might be caused by the call conditions (previous projects had to be closed) and by financial issues (implementation and payment of loan instalments is a huge burden for the dairy farms). Popularity of the ÁTK V programme has been confirmed by the data of the examined farms, since 75% of the farms have implemented machinery and equipment development with the help of project funding. Project proposals for the call "VP Construction of manure storage buildings" have been submitted by 5 farms, 2 of them has won, they are planned to be implemented in 2017-2018. Fewer proposals have been submitted for the new "VP Modernisation of cattle farms" call.

In the scope of Chapter *3.6 Application of renewable energy*, connections between renewable energy investments and the funding system have been introduced. 2 biogas plants have operated in relation with the examined dairy farms; both of them have been constructed in the scope of the ÁTK 1 manure management programme at a funding rate of 75%. Solar collectors have been operated at 5 dairy farms; all of them have been based on project funding. Biomass boilers are used at 5 farms and although it was an eligible expenditure in funding programmes, all of them are based on own resources.

Project activity of the examined dairy farms has been compared through two factors. First, the correlation between cow number and the number of implemented projects has been analysed; this is shown in *Figure 8*. Results of correlation and regression calculation have been the following: Value of the Pearson correlation between the two series of data is 0.643, which indicates a close, positive correlation. The value 'mr' is 0.131, its treble, 0.393 is lower than the absolute value of the correlation coefficient, therefore correlation is confirmed. The critical 't' is 2.101 at (P<0,05%) level of significance, the calculated 't' value is 3.56, which is higher than the critical 't' values, therefore the deviation from 0 of the correlation coefficient is not by accident with 95% probability. Thus, farms with a higher number of cows implemented more projects. The resulted linear regression function is the following: 1.16+0.0012x, the function fits medium.

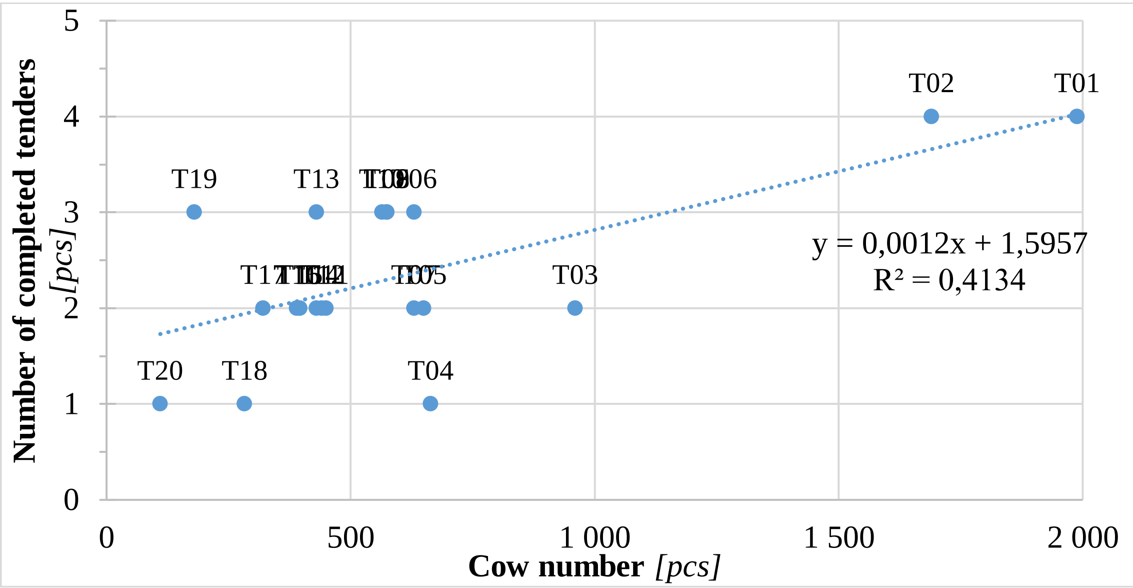

Figure 8: Correlation of cow number and implemented projects

Source: own editing

4. CONCLUSIONS, SUGGESTIONS

The following chapter includes the introduction of conclusions and suggestions drawn up in the scope of present thesis.

There are significant differences among the examined dairy farms in terms of the efficiency of labour use. The most efficient farm required one-third of the working hours for the production of 100 litres of milk than the less efficient farm. This is a 15.1 HUF difference I in terms of the cost of milk per litre, which is very important for the competitiveness of the farms. Dairy sector and the accompanying forage production have important roles in the preservation of rural jobs, since these farms demand long-term and a higher number workforce during the entire year.

Energy cost of milk production at the examined dairy farms varied between 2.5 – 7.5 HUF/litre. The difference between the best and worst values is 5 HUF/litre which is small proportion of the prime cost of milk. This means that there is much more potential for the improvement of efficiency and successfulness in other areas (for example on the field of labour utilisation and foraging).

Assessment of the spread of technological elements indicates that farms with higher cow number have more modern technology. For smaller dairy farms modern technologies are relatively more expensive and their level of utilisation is lower which further increases expenditures and slows their spread.

As for cattle-related IT solutions, every dairy farm has at least one type of cattle management software. Individual milk yield recording and activity measurement are being spread more; in the case of the latter 4 farms are planning related investments.

The examined dairy farms are aware of the different renewable energy options and they try to use them. Ten farms utilise renewable energy, primarily solar collector and biomass heating. Multiple farms are planning solar collector investments and some of them are interested in installing solar cells, since the return period of solar cells seems to be decreasing in recent years.

Project funding schemes improve the technological level and competitiveness of dairy farms and due to the requirements of the 5 year follow-up period they constitute long term stability for employees and the related enterprises. It is assumable that there will be no new project possibilities for cattle farms in the scope of the 2014-2020 project period. Where there are ongoing *VP Modernisation of cattle farms* projects, evaluation results are expected for autumn and their implementation is the task of the next 2 years for the farms. CAP directions after 2020 are not known yet, but it is expectable that the sector will receive considerably less funding in terms of both income subsidies and investment funding – the latter will probably exist in the form of interest subsidies in the future. Therefore, cattle farms will have to try improving their competitiveness until 2020 I and carry out the most important investment until then.

As for energetic modernisation, the following suggestions have been made for dairy farms (these are considered the most efficient and achievable ones):

Purchase of modern biomass boilers is recommended for the reduction of heating costs of buildings, primarily for dairy farms where natural gas is not available, therefore heating is carried out via PB-gas.

For the reduction of energy consumption in the milking parlour, heat recovery milk refrigeration system is recommended where it is not yet available; additionally the completion of such systems with solar collectors is also recommended.

Purchase of efficient LED lighting units and reflectors are recommended in the scope of lighting modernisation, primarily for places where daily lit periods are the longest in the farm.

Obviously, there are considerable justified technological development possibilities at the farms, but no suggestions are made to these. The implementation of these requires significant financial resources, and these investments could be realised only in the scope of complex developments.

5. NOVEL SCIENTIFIC RESULTS

The general objective of present doctoral (Ph.D.) thesis has been the complex technological and energetic analysis of the dairy cattle sector. In the course of the research, the following new results have been found:

1. An own method has been elaborated for the data collection amongst dairy farms in Hajdú-Bihar County in terms of sampling, determination of representativeness, and farm ranking, on the basis of publicly available and own data.
2. In relation with the analysis of milk production by energy type it has been found that 50% of the total energy consumption is diesel oil, 32% is electricity, while PB-gas, natural gas and biomass amount to 18% combined.
3. For the determination of the technical, technological modernity of the farms a system of parameters consisting of 30 technical/technological elements and 3 factors (on the basis of their effects on milk production, work efficiency and energy saving) has been elaborated.
4. It has been found that there is a statistically justifiable correlation ($P<0.05$) between cow number and the cumulated modernity indexes created by myself.
5. Examining the spread of renewable energy and energy saving solutions it has been found, that energy saving solutions are more widely used than renewable energy sources.

6. PRACTICAL USEFULNESS OF THE RESULTS

1. The method defining the modernity can be used for other dairy farms in practice. With the help of this method the technological level can be determined in terms of milk production, labour productivity and energy efficiency, as well as the combined modernity score. Among the elements of the methodology there were novel, spreading technical solutions therefore it can be used in the near future as well.
2. The weights given to the technological elements can be an aid for the farms in the decision of their intended development, to understand the possible effect for the development in milk production, labour productivity and energy efficiency.
3. According to the survey, the most applicable renewable energy solutions for dairy farms were biomass for heating and solar thermal collectors.

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