Direct energy use in the livestock-breeding sector of Cyprus

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Abstract: Energy consumption for most sectors in Cyprus is not well monitored and therefore their impact on greenhouse gases emissions has never been estimated. Thus, the aim of this study was to estimate the energy consumption in livestock breeding activities in Cyprus, and estimate the respective emissions of greenhouse gases. The energy consumption considered is related to all direct energy uses on a farm except transport. All data available from national sources have been taken into account and the consumption of energy per animal was estimated to be 401 k Wh/cow, 624 k Wh/sow and 0.618 kWh/chicken. The direct energy consumption in livestock breeding was estimated to be 53 G Wh for 2008. The greenhouse gas emissions from this were estimated to be 15.6 kt CO_2 equivalent of which 91% is CO_2. The contribution of livestock breeding to the total agricultural energy consumption has been found to be 10-15%. Comparing the energy consumption per animal to other countries in a sample for which data was available, the consumption for Cyprus has been found for all animal species to be lower, mainly due to the warmer climatic conditions.

Keywords: *Direct energy consumption, Livestock breeding, Cyprus, Greenhouse gases emissions*

1. Introduction

Sustainability, energy and climate change during the recent years are increasingly gaining political attention. The European Union has already set legally regulated targets on climate and energy in June 2009 [1] and has just recently agreed to the new sustainability and financial strategy of the Union, the EU2020 [2] which also includes climate and energy targets. Currently, there are several legal obligations in the European Union at country level and installation level that require baseline data on sectoral energy consumption to be available. Decision 406/2009/EC [3] is among those obligations that requires Member States of the European Union to reduce greenhouse gases emissions from sectors not included in the European emissions trading system, i.e. waste, agriculture, transport, energy use in household and services and agriculture. Cyprus is facing a large deficiency in statistics for several sectors, among which the energy sector. One source of greenhouse gases emissions for which a target has been set by Decision 406/2009/EC [3] is energy use by livestock breeding.

The uses of energy in a farm can be classified into direct and indirect [4]. Direct energy use is associated with the consumption of energy (fuels and electricity) in a farm. Indirect energy use is the energy consumed for the production and transport of materials used in a farm (e.g. feed and machinery). 70% of total energy use on dairy cattle and pig farms is for indirect uses [5].

Traditionally, animal farming in Cyprus was characterized by small; family ran units, spread throughout the island, but the increasing demand in meat and other products, the production of genetic material and the automation introduced in the production, have caused an increase in animal farming, which have caused certain areas of the island to have high animal density. A typical animal farm in Cyprus, as in the rest of the world, consists of one or more buildings distinguished in three types: animal breeding areas, support buildings and waste treatment and storage areas. In most areas in Cyprus, electricity is supplied by the central network of the

solely electricity provider, the Electricity Authority of Cyprus (EAC). Electricity in Cyprus is produced predominately by heavy fuel oil (HFO), with only a small amount produced by diesel [6]. It is expected that by 2014, natural gas will also be available for use. The most commonly used fuel in farms in Cyprus is diesel, which is mainly used for heating of the housing areas. During the last years the consumption of Liquid Petroleum Gas (LPG) for heating is rapidly increasing.

Not much data is readily available on energy consumption for livestock breeding in Cyprus. This paper brings together all the available data for stationary uses of energy for cattle, pig and poultry farming in Cyprus. Based on this data, the total energy consumption is estimated for the total population of the three animal species in Cyprus for 2005-2008. For 2008 the greenhouse gases emissions are also estimated and compared to other sources of emissions. Finally, results for both energy consumption and greenhouse gases emissions are compared to international literature.

2. Methodology

The main stages of the methodology applied are presented in Figure 1: (a) estimation of total energy consumption, (b) estimation of energy consumption according to source of energy and (c) estimation of the greenhouse gases emissions.

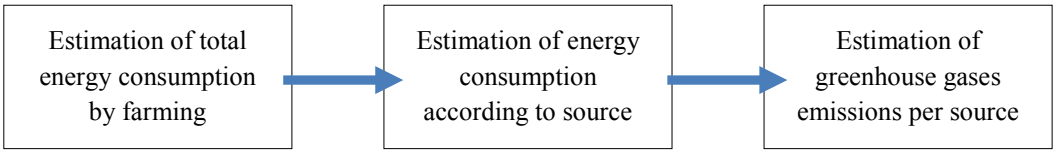

Fig. 1. Methodology implemented for the estimation of greenhouse gases emissions from energy consumption in livestock breeding in Cyprus.

2.1. Estimation of direct energy use from livestock breeding of Cyprus

The main sources of available data in Cyprus is limited to environmental impact assessment reports for animal farms submitted to the Department of Environment according to the Cyprus Law No. 140(I)/2005 on the assessment of environmental impacts from works [7] and annual reports submitted by installations that are above the benchmarks of the Integrated Pollution Prevention (IPPC) Directive [8]. Table 1 summarises the weighted energy consumption per animal in Cyprus as these were reported by the sources presented above; i.e. total amount of energy divided by total number of animals.

Table 1. Annual energy consumption per animal in Cyprus.

	Dairy cattle farms (kWh/cow)	Pig farms (kWh/sow)		Chicken farms (kWh/chicken)	
	178*	763+	1015+	0.741+	0.500+
	908*	1282+	244+	0.498+	0.292+
	610*	918+	1742*	0.578+	0.344+
		892+	64*	0.592+	0.760*
		181+	328*	layer chicken	0.864 [10,11]
		1087+	111*	broiler chicken	0.644 [10,11]
		225+	227*		
Weighted Average	401	624		0.618	

+ data submitted by installations that are above the IPPC levels for 2008 [9]
* data submitted for new installations according to the Environmental Impact Assessment report prepared [10]

Using the average annual energy consumption per animal in Cyprus of 401 kWh/cow, 624 kWh/sow and 0.618 kWh/chicken and using the animal population for 2005 - 2008, the total energy consumption for animal breeding of cattle, pigs and chicken in Cyprus for the same period was estimated by multiplying the animal population by the per animal consumption (Table 2). The animal population data used was according to the latest published annual animal population census of the Department of Agriculture [12]. The results of Table 2 were also based on the following assumptions:

(a) Layer chicken and broiler chicken have the same, average energy consumption because not sufficient data was available for the population of each type.
(b) Dairy cows and other cattle were assumed to have the same energy consumption per animal because in Cyprus the animals are in the same farms.
(c) Goats and sheep are not taken into account for the estimation of the total energy consumption by livestock breeding in Cyprus because no data is available yet.
(d) No distinction is made into breeding methods and waste management technologies used.
(e) Energy consumption of waste management technologies is also included in the energy consumption of the farm.
(f) Both gestating and farrowing sows have been considered for the population of sows because the difference in energy consumption is small to be taken into consideration.

Table 2. Animal population and total energy consumption from livestock breeding in Cyprus for 2005 - 2008.

	Animal population (x1000)				Annual energy consumption (GWh)			
	2005	2006	2007	2008	2005	2006	2007	2008
Cattle	57.6	56.1	54.9	55.9	23.1	22.5	22.0	22.4
Sows	61.4	64.7	64.3	46.6	38.3	40.4	40.2	29.1
Chicken	3007	2763	2800	2820	1.9	1.7	1.7	1.7
Total					63.3	64.6	63.9	53.3

2.2. Estimation of greenhouse gas emissions from direct energy use in livestock breeding of Cyprus

The distribution of energy consumption according to source (Table 3) was estimated using the average energy breakdown according to the IPPC annual reports for pig and chicken farming [9].

Table 3. Average energy breakdown of energy consumption in Cyprus for chicken and pig farms according to IPPC annual reports [9]

	Electricity	Diesel	LPG
Cattle*	28.5%	44.8%	26.7%
Pigs	28.7%	48.3%	23.0%
Chicken	28.3%	41.3%	30.4%

* cattle farms energy consumption = average of pigs and chicken due to lack of data

Using the emission factors of the greenhouse gases and the fuel densities proposed as default by the IPCC 2006 guidelines [13], the CO_2 emission factors from electricity production based on the weighted average specific emissions of the electricity producing units of Cyprus [6], and the global warming potentials proposed by the 1996 IPCC guidelines [14], the emissions of a specific greenhouse gas by an animal species (GHG_{animal}) were estimated by equation 1 in t CO_2 equiv.

$$GHG_{animal} = (EF_{GHG})_{fuel} \times EC_{fuel} \times GWP_{GHG} \quad (1)$$

where $(EF_{GHG})_{fuel}$= emission factor for a specific gas for a specific energy source (or fuel), t/TJ and GWP_{GHG}= is the global warming potential of a specific gas. The energy consumption of a specific energy source (or fuel), in (EC_{fuel}) was estimated by Eq.2:

$$EC_{fuel} = (\%_{fuel})_{animal} \text{ x } EC_{animal} \quad (2)$$

where $(\%_{fuel})_{animal}$ = percent contribution of a specific energy source (or fuel) to the total energy (or fuel) consumption of an animal species, % and EC_{animal} is the total energy (or fuel) consumption of an animal species, TJ. All the data used is presented in Table 4.

Table 4. Parameters used for the estimation of GHG emissions

Parameter in Eq.1	Description	Value
$(EF_{CO2})_{electricity}$	Electricity CO_2 EF*	78.94 t/ TJ [6]
$(EF_{CH4})_{electricity}$	Electricity CH_4 EF	3 kg/ TJ [13]
$(EF_{N2O})_{electricity}$	Electricity N_2O EF	0.6 kg/TJ [13]
$(EF_{CO2})_{diesel}$	Diesel CO_2 EF	74.1 t/ TJ [13]
$(EF_{CH4})_{diesel}$	Diesel CH_4 EF	10 kg/ TJ [13]
$(EF_{N2O})_{diesel}$	Diesel N_2O EF	0.6 kg/TJ [13]
$(EF_{CO2})_{LPG}$	LPG** CO_2 EF	63.1 t/ TJ [13]
$(EF_{CH4})_{LPG}$	LPG CH_4 EF	5 kg/ TJ [13]
$(EF_{N2O})_{LPG}$	LPG N_2O EF	0.1 kg/TJ [13]
GWP_{CO2}	GWP*** of CO_2	1 [14]
GWP_{CH4}	GWP of CH_4	1 t CH_4 = 21 t CO_2 eq. [14]
GWP_{N2O}	GWP of N_2O	1 t N_2O = 296 t CO_2 eq. [14]
	Energy conversion	3600 kJ/kWh [13]
	Diesel Energy content	43 TJ/ Gg [13]
	Diesel Density	0.85 kg/l [13]
	LPG Energy content	47.3 TJ/ Gg [13]
	Butane liquid density	0.57-0.58 kg/l [13]
	Propane liquid density	0.50-0.51 kg/l [13]

* EF = emission factor, ** LPG = liquid petroleum gas, *** GWP = global warming potential

3. Results and Discussion

Data collected from the available studies and reports in Cyprus, have shown that energy consumption per animal varies considerably among farms. The available data has a very large range for all animal species, i.e. 178 - 908 kWh/cow, 64 - 1742 kWh/sow, 0.292 – 0.760 kWh/chicken. Nevertheless, the average of the results are reasonable when compared to other countries and the total contribution of the sector to energy consumption by agriculture.

3.1. Contribution of livestock breeding to agricultural energy uses

Comparing the results obtained for livestock breeding energy consumption (Table 2) to the total energy consumption by agriculture [15], the contribution of direct energy use in livestock breeding to the total energy consumption by agriculture has been found to decrease from 14% in 2005 to 11% in 2008. The energy consumption by livestock breeding has reduced considerably from 63 GWh in 2005 to 53 GWh in 2008, due to a decrease in the animal population, which is probably due to the increase in imports of meat. The total energy consumption of the sector has increased from 439 GWh in 2005 to 504 GWh in 2008, probably due to the change in climate conditions. The years of 2006 to 2008 were years with extensive droughts in Cyprus. This has caused the cultivations to require more artificial irrigation since natural precipitation was very limited. Consequently, the energy demand for

the irrigation systems was larger. Additionally, the number of small desalination plants installed for agricultural use in coastal areas where saline intrusion takes place has been increasing during the last few years. This has been again caused by the reduction in precipitation and the need for farmers to use their already exhausted water extracting boreholes.

3.2. Comparison of direct energy consumption in livestock breeding in Cyprus to other countries

Cattle in most farms throughout the world are field-grazing most of the time of the year. When the cows are collected indoors due to weather conditions, the housing areas are closed. Therefore energy for ventilation and lighting is needed. In the case of Cyprus cattle is kept in the open but restricted areas instead of fields. With no lighting and ventilation used, energy per animal is considerably less. The comparison is presented in Fig. 2(a).

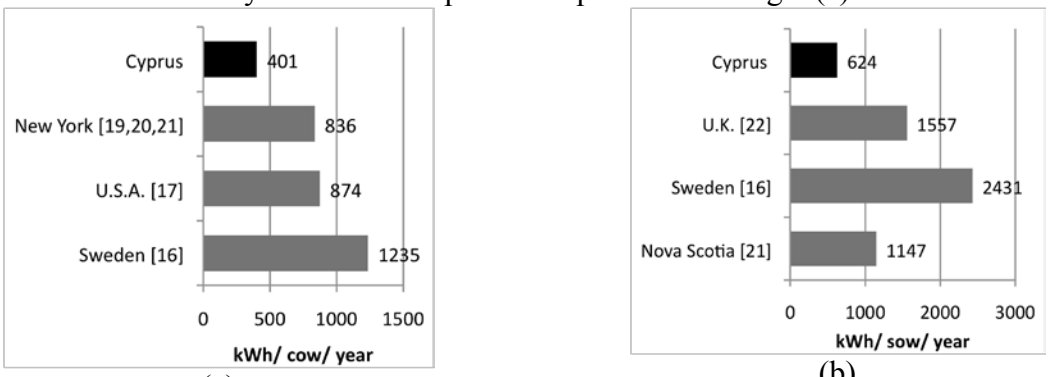

Fig. 2. Annual energy consumption for various countries compared to energy consumption in Cyprus (a) per dairy cow found and (b) per sow for farrow to finish.

Figure 2(b) presents the Nova Scotia [18], U.K. [19] and Sweden [16] consumption per sow compared to Cyprus. Cyprus has the smallest consumption among the four areas. This is due to the reason that in pig farming most of the energy demands is for heating. Therefore, in Cyprus, where heating days are significantly less than Nova Scotia [18], U.K. [19] and Sweden [16], the energy demand is also significantly less compared to the same countries.

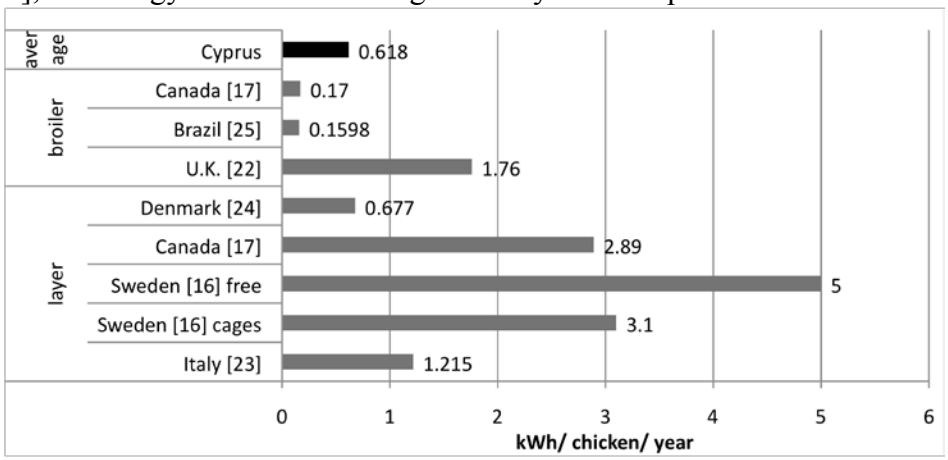

Fig. 3. Annual energy consumption per chicken for various countries compared to energy consumption in Cyprus for layer and broiler chicken.

The energy consumption estimated for chicken farming (Fig. 3) appears not very dissimilar to other countries. Most of the energy consumption is expected to be during summer for ventilation purposes as in Italy [20]. The per-chicken consumption of Denmark [21], Brazil

[22] and Canada [17] is smaller than Cyprus. A probable reason for this is that Denmark has well-developed technologies and therefore higher efficiency in energy consumption than Cyprus. For Brazil and Canada the smaller energy consumption could be due to differences in the methods of breeding.

3.3. Greenhouse gas emissions from energy consumption in livestock breeding

The total GHG emissions from energy consumption in livestock breeding have been estimated to be 15.26 kt CO_2e for 2008 of which 91% is CO_2. For the same year other agricultural greenhouse gas emissions according to the Greenhouse Gas Inventory of the country were 348 kt CO_2e [24]. The emissions according to gas and energy sources are presented in Table 5. The larger emissions are CO_2 emissions from diesel consumption in cattle and pig farming, which correspond to 21% and 29% of the total emissions respectively. Energy related emissions contribute approximately 3% to the total for cattle, 2% for pigs and 1.4% for poultry. Comparing the results to emissions from total agricultural use of energy, energy use in livestock breeding contributes 4% to the total agricultural emissions and 13% to the total agricultural energy emissions. This result is supported by the estimations of "Compassion in world farming" [23] where energy contributes 2% to the total livestock emissions.

Table 5. GHG emissions from direct energy consumption in livestock breeding in Cyprus according to gas and energy source, 2008.

	Cattle	Pigs	Poultry	TOTAL
CO_2 from Electricity, t	1,816	2,375	140	4,331
CO_2 from Diesel, t	2,679	3,752	192	6,624
CO_2 from LPG, t	1,360	1,521	120	3,002
Total CO2, t	5,855	7,649	453	13,956
CH_4 from Electricity, kg	69	90	5	165
CH_4 from Diesel, kg	362	506	26	894
CH_4 from LPG, kg	108	121	10	238
Total CH_4, kg	538	717	41	1,296
N_2O from Electricity, kg	14	18	1	33
N_2O from Diesel, kg	1,608	2,251	115	3,974
N_2O from LPG, kg	136	152	12	300
Total N_2O, kg	1,757	2,421	128	4,307
Total GHG from Electricity, kt CO_2 equiv.	1.82	2.38	0.14	4.34
Total GHG from Diesel, kt CO_2 equiv.	3.16	4.43	0.23	7.82
Total GHG from LPG, kt CO_2 equiv.	1.40	1.57	0.12	3.10
TOTAL GHG, kt CO_2 equiv.	6.39	8.38	0.49	15.26

4. Conclusions

In Cyprus, the annual consumption per animal was estimated to be 401 kWh/cow, 624 kWh/sow and 0.618 kWh/chicken. The estimates were based on available data for Cyprus. According to these figure, the direct energy consumption in livestock breeding of cattle, pigs and poultry is estimated at 53 GWh for 2008, which corresponds to 10-15% of the total agricultural energy consumption. Comparing the energy consumption per animal to other countries in the sample used in the study it was found that energy consumption per animal for Cyprus was, on average, lower. Energy consumption for cows was much lower than the countries for which data was available (Canada, Nova Scotia, U.K., Sweden) mainly because the majority of energy consumption in these countries is for heating which is not needed in Cyprus due to the relatively warm weather conditions. For chicken farming, the results are

comparable to Italy, since a large portion of the country has similar climatic conditions to Cyprus (hot and dry).

Using the emission factor of each greenhouse gas according to fuel type proposed by the IPCC 2006 guidelines [13] and for electricity as proposed by national specific data by the Electricity Authority of Cyprus [6], the greenhouse gas emissions for each animal species and energy source were estimated. Comparing these to emissions from total agricultural use of energy, the results show that the emissions from energy use in livestock breeding contribute approximately 4% to the total agricultural emissions and 13% to the total agricultural energy emissions.

These results can be used by relevant Cyprus authorities for the assessment of the impact of measures for the reduction of energy consumption and greenhouse gases emissions.

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