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ENERGY EFFICIENCY IN AGRICULTURE: THE POULTRY SECTOR

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Introduction

In the past few years, the Economic and Social Commission for Western Asia (ESCWA) conducted a series of studies dealing with energy consumption and indicators, and ways to improve energy efficiency in various sectors (industry, construction, transport, electricity production and tourism). Further to these studies, ESCWA prepared this document to shed light on energy consumption in the poultry sector given that it is an important agricultural sector. The poultry sector contributes to food development as a primary source of protein, and to the creation of job opportunities in ESCWA member countries. Although energy cost accounts for a limited percentage of the total production cost, the energy factor is of utmost importance. For example, the disruption of heating for baby chicks, even if for a short period, or the interruption of cooling from poultry after slaughter may cause heavy losses. Furthermore, the energy sector has an indirect role in poultry projects as a main element in the production of poultry feed and the infrastructure of those projects.

This document focuses on energy consumption and ways to support sustainability and improve efficiency of energy use in the poultry sector. It gives an overview of the poultry production cycle and outlines the main energy consumption indicators in the poultry sector, mainly specific energy consumption and the ratio of energy cost to the total production cost. The document sheds light on energy audits in the poultry sector as a preliminary step to the implementation of energy efficiency improvement measures in this sector. It discusses the phases of energy audits, the measuring devices used and their importance in the rationalization of energy consumption. The document proposes three key issues to improve energy efficiency and support sustainability in the poultry sector in ESCWA member countries: (1) improving thermal and electrical energy efficiency, including heating, cooling, ventilation, lighting and combustion at all phases of the production cycle, from breeding to skinning, cleaning, manufacturing and transportation; (2) converting poultry litter into energy; this section also provides estimates of the potential amount of energy production from poultry litter in member countries, key indicators and considerations in this regard and a number of international experiences in this field; (3) using solar energy in poultry projects. The document concludes with a set of proposals and guidelines on the development of national programmes to improve energy efficiency in the poultry sector, especially with regard to awareness and training, choosing economically and environmentally feasible measures, and legislation and implementation mechanisms.

I. THE LIFE CYCLE OF POULTRY PRODUCTION AND RELATION TO ENERGY USE

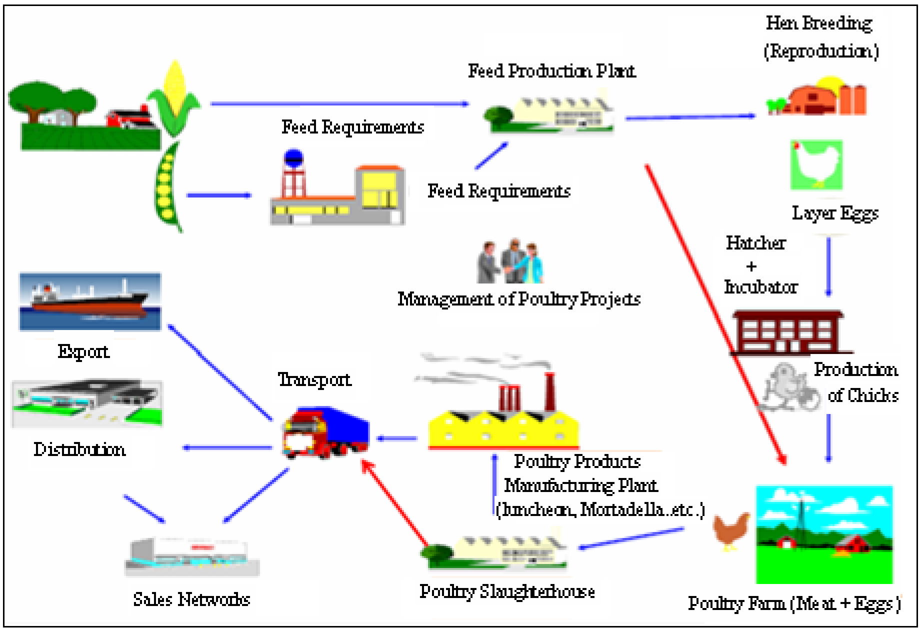
Poultry projects have various developmental dimensions: economic, social and environmental. These projects start with the preparation of poultry farms and related activities; poultry feed production and waste disposal; and product preparation for delivery to the consumer, which involves slaughtering, skinning, cleaning, transporting and distribution. The poultry production cycle consists of basic phases, operations and activities, such as feed manufacturing, transportation, distribution and export (figure I). Each of these phases has a particular way of using energy and energy-consuming equipment as shown in table 1.[1]

TABLE 1. MAIN PHASES OF POULTRY PRODUCTION AND USE OF ENERGY

Phases	**Energy type and area of use**
(1) *Breeding in poultry farms*: The breeding process in the Arab region usually starts with the import of chicks aged one day from abroad. In some cases, the breeding process starts at an advanced phase by importing second generation chicks. These chicks are reared in farms equipped with appropriate systems that provide food and water, ensure waste removal and create suitable air conditions, such as ventilation, heating, and humidity inside the poultry houses according to the poultry age groups. When the hens lay their eggs, the eggs are moved to hatcheries or incubators for 21 days to produce chicks. These chicks are reared in poultry farms for 40 to 45 days in order to produce chicken meat with an average weight of about 2 kg per chicken. In addition to broilers, there are the layers which lay eggs, and whose life cycle lasts for approximately 1.5 years.	Fuel for heating; and electricity for lighting, ventilation and water pumps
(2) *Slaughter and skinning*: After reaching the required weight, boilers are transferred from farms to slaughterhouses. There, they undergo veterinary medical examination and sick chickens are dispensed of. The process of slaughter and skinning begins by suspending or tying chickens by the legs. The chickens are then transported via conveyers to the slaughterhouse, where they are slaughtered and the blood is disposed of. Chickens are later exposed to steam or hot water to remove the feathers. This is done inside a device specifically designed for this purpose. The carcass is washed with water, and its head, legs, and viscera are removed. This is followed by washing, rinsing and disinfection. The packing process begins with chilling by air, air mixed with spray water, or with water only. Chickens are later sorted by weight. Visual inspection is performed before packaging and delivery to the consumer, or manufacturing.	Fuel for steam production and water heating; and electricity for cooling, running conveyers, lighting, ventilation and water pumps
(3) *Manufacturing*: During manufacturing, chicken meat is converted to multiple products based on market needs. These products include mortadella, escalope [chicken], roasters and nuggets. The stages of manufacturing are largely similar. In the case of mortadella and luncheon meat, for example, the manufacturing process begins with chopping the meat over two phases, then mixing it with spices and water. This gives a paste-like product, which is later packed in packs of different weights. These packs are combined in large cubic blocks, which undergo cooking in steam-heated autoclaves. This is followed by freezing the product, storing it, then delivering it to the final consumer.	Fuel to run autoclaves in order to cook the product; and electricity to operate production lines and lighting lines and water pumps
(4) *Transport*: Trucks and passenger cars are used for transportation between poultry farms, slaughterhouses and manufacturing facilities, and to the final consumer.	Fuel, such as diesel or gasoline, to operate trucks and passenger cars

[1] Philippe Lescoat, Thierry Bonaudo, Jean Lossouarn, René Poccard-Chapuis and Luis Carlos Mior, 2010, *Questioning poultry industry about sustainability and bonds to territories: a case study in France and* Brazil, in Innovation and Sustainable Development in Agriculture and Food (ISDA 2010), June 28-30, Montpellier, France.

Figure I. Poultry production life cycle



II. ENERGY CONSUMPTION INDICATORS AND AUDITS IN THE POULTRY SECTOR

A. PATTERN OF ENERGY CONSUMPTION AND COST INDICATORS

The pattern of energy consumption in poultry projects varies according to the size and season of production, the technology and type of energy used in these projects, and the level of energy efficiency at the facility. Specific energy consumption, i.e. the amount of energy consumed per unit of production, is a key indicator of the rate of energy consumption and the level of efficiency of use at any facility. Specific energy consumption in poultry meat production is measured by the amount of energy per chicken or kilogram (kg) of chicken, while in table egg production it is measured by the amount of energy consumption per chicken or egg. Table 2 includes the standard and actual value indicators for specific energy consumption in the production of chicken meat and eggs in the United Kingdom. It is noted that specific energy consumption per layer largely exceeds the specific energy consumption per broiler. The reason is the life cycle of layers, which is about a year and a half, while the life cycle of boilers does not exceed 40-45 days. Box 1 shows the energy consumption indicators in a poultry producing company in Lebanon.

TABLE 2. INDICATORS OF SPECIFIC ENERGY CONSUMPTION IN BROILER AND LAYER FARMS IN THE UNITED KINGDOM (ENGLAND/WALES)

Project Size	Standard value of energy consumption	Actual value of energy consumption
200,000 chickens for meat production	0.39 kWh per chicken	0.71 kWh per chicken
75,000 chickens for egg production	3.9 kWh per chicken	4.12 kWh per chicken

Source: Agriculture and Food Development Authority, United Kingdom, *Energy Use in Agriculture*, 20 September 2011.

An examination of the costs of poultry productions shows that feed costs are the highest exceeding 50 per cent, while the costs of chicks is 13-20 per cent and that of energy is below 8 per cent (table 3). The share of energy costs in the production of poultry in Lebanon is the highest compared to that in other countries, ranging between 6 and 8 per cent. The reason is that the farms rely primarily on privately-owned diesel-powered generators to compensate for the continuous outages of electricity produced by Electricité du Liban (EDL), which raises the cost of energy. The share of energy costs in the cost of production depends on the price and efficient use of energy, in addition to the price of other production inputs, such as feed, chicks, water and labour. The energy component is key in cooling and heating processes. Feed production also consumes energy, but the cost of this energy is not taken into account because feed manufacturing is done outside poultry farms. Box 2 shows the distribution of energy cost in the life cycle of poultry in a poultry company in Lebanon, from the breeding of hens to consumer.

Box 1. Energy consumption indicators in a poultry producing company in Lebanon

The table included in this box shows the consumption of energy per unit of production, from the phase of breeding layer hens to delivery to the consumer in a poultry production company in Lebanon. Energy consumption indicators vary from one farm to another according to size of project, management, applied technology and form of energy used. Specific energy consumption (fuel and electricity) in skinning exceeds threefold that of breeding. This indicates the necessity of rationalizing energy consumption and improving its efficiency in poultry slaughterhouses. Given the specific energy consumption in the company, estimated at about 0.4375 kWh per kg of chicken (bottom of box), and considering that the weight of a living chicken is 2 kg, the specific energy consumption is estimated at 0.875 kWh per chicken while the standard value of specific energy consumption is estimated at about 0.39 kWh per chicken (table 2).

Compared to the specific energy consumption in chicken farms in the United Kingdom, which is 0.71 kWh per chicken (table 2), the specific energy consumption in the Lebanese farm is 23 per cent higher. This underlines the necessity of improving energy efficiency in poultry farms in the region.

Box 1 (*continued*)

Energy consumption per unit of production from parent breeding to consumer in a poultry producing company in Lebanon, 2011

Activity	Energy consumption per unit of production			Total energy consumption[c/] (Fuel oil + gas + electricity)
	Fuel Oil/Diesel[a/]	Gas[b/]	Electricity	
Parent Breeding	0.027 liter per egg	0.00056 liters per egg	0.0086 kWh per egg	0.1445 kWh per egg
Production of chicks in hatcheries and incubators	0.0155 liter per chick	zero	0.062 kWh per chick	0.1378 kWH per chick
Breeding in poultry farms	0.071 liter per kg of living chicken	0.0128 liter per kg of living chicken		0.4375 kWh per kg of living chicken
Transport from farms to slaughterhouses	0.0109 liter per kg of living chicken	zero	zero	0.1122 kWh per kg of living chicken
Slaughterhouses	0.191 liter per kg of slaughtered chicken	0.089 liter of fuel per kg of slaughtered chicken	0.157 kWh per kg of slaughtered chicken	1.2772 kWh per kg of slaughtered chicken
Transport from slaughterhouses to consumer	0.054 liter per kg of slaughtered chicken	zero	zero	0.5557 kWh per kg of slaughtered chicken

Source: Tanmia, Agricultural Development Company, Zahle, Lebanon (data provided in response to a 2012 ESCWA questionnaire).

a/ Diesel is used at a rate of approximately 70 per cent in electricity production since electricity produced by EDL is not available most of the time, 30 per cent for heating in farms, and 100 per cent in electricity production in slaughterhouses;

b/ Gas is used for heating in case of the non-availability of diesel fuel;

c/ The total energy consumption was calculated according to the following criteria:

(1) Fuel oil, diesel and gas were converted to kWh based on the conversion factors contained in the energy report in Egypt;[2]

(2) The average gas density was set as 0.54 kg per liter,[3] and the average density of fuel oil and diesel at 0.83 kg per liter.

TABLE 3. PRODUCTION COST INDICATORS IN POULTRY FARMS IN SELECTED COUNTRIES

Country	Cost elements (percentage)			
	Feed	Baby chicks	Energy	Other expenses[a/]
Netherlands	56.7	17.1	5.3	20.9
United States	63.8	13.5	5.8	16.8
Thailand	68.0	16.6	4.5	10.9
Brazil	60.7	15.7	5.9	17.8
Lebanon	61	13-15	6-8	16-20
Syrian Arab Republic[b/]	55	20	5	20

Sources: For the Syrian Arab Republic, Miidad Qarqoot, *Poultry Production, Agriculture from a Goods Perspective*, Paper No. 2 (Arabic), December 2007, National Agricultural Policy Center of the Syrian Ministry of Agriculture and Agrarian Reform, napcsyr.net/dwnld.../02_co_poultry_mK_ar.pdf;

For Lebanon, Tanmia, Agricultural Development Company, Zahle, Lebanon (data provided in response to a 2012 ESCWA questionnaire).

For other countries: Piet Simons, *Global Production, Consumption and International Market of Poultry Meat and Eggs*, 2009, World's Poultry Science Association (WPSA), Poultry Seminar, Lonovala, India, 12 September, p. 19, http://www.clfmaofindia.org/Simons.pdf.

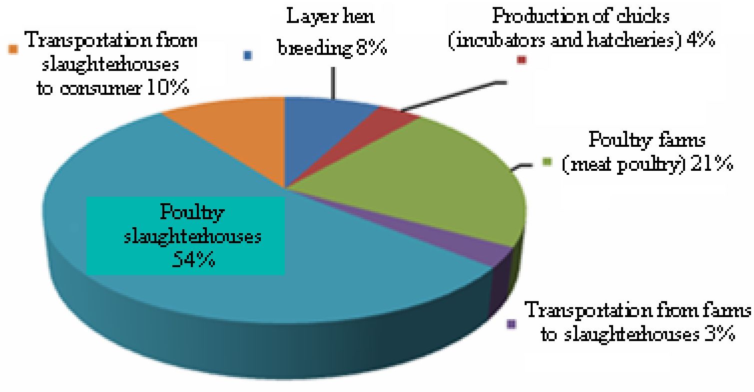
a/ Including labor.
b/ Energy cost includes cost of water.

[2] Organization of Energy Planning, Ministry of Energy in Egypt, *Energy in Egypt 2002-2003* (Arabic), p. 45.

[3] Online Conversion Forum, http://forum.onlineconversion.com/showthread.php?t=4858.

Box 2. Distribution of energy cost in the life cycle of poultry from hen breeding to consumer

Based on the data received from a poultry company in Lebanon, the cost of energy (fuel and electricity) in 2011 reached US$3,362,268 or about 8 per cent of the total cost of production. The share of slaughterhouses was 54 per cent, farm breeding 21 per cent, transportation 13 per cent, layer hen breeding 8 per cent, and production of chicks 4 per cent. It is obvious that there is a need to improve energy efficiency in slaughtering operations.



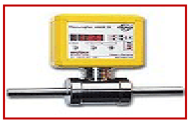
B. ENERGY CONSUMPTION AUDIT

Energy auditing is a first step towards improving energy efficiency and conservation, through which it is possible to determine the rates of energy consumption and efficiency within the different sections of the poultry facility. The implementation of measures to improve energy efficiency becomes possible after the conduction of a comprehensive survey of energy consumption within the facility. In general, energy consumption audit in the poultry sector aims to achieve the following: (1) Identify the types, flows and quantities of consumed energy; (2) Locate the sources of energy loss and excessive use; (3) Identify potential ways to improve energy efficiency and reduce loss; (4) Identify the feasibility of implementing energy efficiency measures. Energy consumption auditing and efficiency in the poultry sector allow the achievement of a number of benefits, most notably : (a) Reduce production costs to increase profitability since energy is a component of production cost; (b) Regulate the degree of air temperature and humidity and the level of ventilation inside poultry houses and slaughterhouses, and create appropriate health conditions for poultry, which leads to a reduced poultry death rate; (c) Adjust the performance of energy-consuming equipment, such as steam boilers, electric motors, heaters, coolers and fans, and ensure optimal operation, thus enabling the preservation and lifespan extension of this equipment. It is noteworthy that conserving and efficiently using energy is, in many cases, less expensive than buying it. Improving energy efficiency in general leads to reducing emissions, thereby protecting the environment, supporting sustainable development and transitioning to a green economy, in addition to creating new job opportunities in projects and activities related to improving energy efficiency.

Energy audits in poultry projects include the following four main steps: (1) Collecting data on energy consumption, and consumption patterns, flows and equipment; (2) Conducting field visits and measuring energy consumption and efficiency; (3) Analysing data and measurements, and identifying and evaluating the potential for energy efficiency measures; (4) Preparing an energy audit report focusing on the following aspects: (a) A comprehensive and concise look at the poultry facility, equipment and devices, as well as the energy-consuming sections, their specifications and methods of operation; (b) An analytical look at the pattern and flow of energy consumption; (c) A technical and economic characterization of opportunities to save energy and improve efficiency of use. Table 4 contains the main measurement devices used in the energy audit.

Energy management and conservation in the poultry facility is affected by the management of the facility as a whole. Energy management is part of the administrative system of the facility, which includes the management of the following elements and components: production and (primary) raw materials; individuals and workers; maintenance and operation; financial affairs; and quality control and assurance. It should be noted that the financial resources saved as a result of improved energy efficiency and conservation can be used to develop production systems, introduce advanced equipment to poultry farms and slaughterhouses and improve overall productivity in poultry projects.

TABLE 4. MAIN MEASUREMENT DEVICES USED TO AUDIT AND MEASURE ENERGY EFFICIENCY IN THE POULTRY SECTOR

	Electrical measurements, such as voltage, ampere and kilowatt; electrical power factors; and electric current frequency
	Combustion analyser, which measures oxygene (O2), carbon monoxide (CO), nitric oxides (NOx) and sulfur oxides (SOx) in combustion gases in boilers, furnaces and heaters
	Thermometer, which measures the temperature of gases and hot air through direct contact and from a distance, as well as the temperature of thermal insulation to verify its efficiency
	Manometer, which measures the speed of air and gases to determine the degree of ventilation and air flow in poultry houses
	Water flow meter, which measures the speed of water in pipes based on ultrasonic sound, and calculates the amount of water consumed in poultry farms and slaughterhouses
	Speed meter, which measures rotational speed in RPMs (revolutions per minute) to regulate rotation speed of fans and water pumps
	Leak detector, which measures the leaking of gas, including air and steam, to calculate the amount of energy lost
	Combustion efficiency reader, which measures exhaust gas temperature and oxygen concentration on the basis of the calorific value of fuel
	Lux meter, which measures the intensity of illumination in poultry houses to adjust the amount of lighting and save energy

III. WAYS TO IMPROVE ENERGY EFFICIENCY AND PROMOTE SUSTAINABILITY IN THE POULTRY SECTOR IN ESCWA MEMBER COUNTRIES

In order to improve energy efficiency and promote sustainability in the poultry sector in ESCWA member countries, efforts should be focused on three main areas.

A. IMPROVING ENERGY EFFICIENCY AND CONSERVATION MEASURES

Energy consumption in the poultry sector covers four main phases/activities: (1) poultry farms; (2) poultry slaughterhouses; (3) manufacturing processes; (4) transport operations linking farms, slaughterhouses, manufacturing operations and consumers. Energy is used in different processes, mainly heating, cooling, ventilation, water heating, lighting, operating electric motors and water pumps, manufacturing, as well as fuel used in motor vehicles for the transport of raw materials, feed and products. It should be noted that the processes of heating, cooling and ventilation are the most energy-consuming in poultry projects. Opportunities to improve energy efficiency in the poultry sector can be addressed in accordance with the four main phases mentioned above.

1. *In poultry farms*

A large proportion of the energy consumed in poultry farms is used to address climatic conditions, particularly temperature, humidity and ventilation, and to create an environment conducive to the survival of chicks and chickens. Patterns of energy consumption in poultry farms vary according to many factors, namely the weather, temperature and humidity degree, size and season of production, in addition to the technology used in the farms. In the United Kingdom, where the weather is cold, heating accounts for about 84 per cent of total energy consumption, ventilation 7 per cent, lighting 6 per cent and electric motors and water pumps 3 per cent.[4] In Jordan, the Syrian Arab Republic and Egypt, where the weather is milder, heating constitutes 55 to 60 per cent of the total energy consumed, ventilation 20 to 30 per cent, lighting 5 to 10 per cent, and electric motors and water pumps 5 to 7 per cent.[5] There are available ways and guidelines for reducing energy consumption in poultry farms. The following are the main ones:[6, 7]

(a) Improving thermal insulation and undergo periodical tests, fill the holes and cracks in poultry houses and reduce air leakage to maintain proper temperature inside. In some cases, filling the holes and using proper curtains in poultry houses would save heating energy by 30 to 50 per cent;

(b) Adjusting ventilation and humidity to meet the needs of chicken inside houses while paying attention to the following aspects: (1) Lowering humidity, even if it is slightly high, requires a considerable amount of energy; (2) Humidity increases when the temperature inside poultry houses rises; (3) Ventilation must be increased during summer days. It should be noted that ventilation in poultry farms provides the amount of oxygen needed by chicken for breathing and metabolism; reduces harmful gases such as ammonia, carbon dioxide and carbon monoxide; moderates the air, excess heat in the summer and excess humidity in the winter; and lessens dirt and dust inside poultry houses to decrease the susceptibility of chicken to respiratory diseases. A number of factors affect the amount of air inside poultry houses, namely the type and environmental design of the building, the degree of thermal insulation, the temperature and relative humidity inside and outside the poultry house, and the type, age, and density of chicken inside poultry houses;

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[4] Agriculture and Food Development Authority, United Kingdom, *Energy Use in Agriculture*, 20 September 2011.

[5] Poule d'or Company, Chweifat, Lebanon, visit on 4 April 2012.

[6] Tom W. Smith, Jr., *Reducing energy costs in poultry houses, 7 September 2009,* Mississippi State University, USA, http://www.thepoultrysite.com/articles/1509/reducing-energy-costs-in-poultry-houses.

[7] Mike Czarick and Gary Van Wicklen, *15 cost-saving ideas for poultry housing*, 7 April 2009, http://www.wattagnet.com/15_cost-saving_ideas_for_poultry_housing.html.

(c) Maintaining homogenous temperatures inside poultry houses, as the non-circulation of air causes temperature variations, where warm air accumulates at the top of the room near the ceiling, and cold air at the bottom of the room near the floor. Thus, it is necessary to use fans for air circulation inside poultry houses. Maintaining air circulation and homogenous temperatures may reduce energy consumption in some cases by 10 to 30 per cent, and improve the quality of air inside the houses. It is therefore recommended to adjust temperature, ventilation and humidity in poultry farms in accordance with the recommended values/standards included in table 5, given that the relative humidity ranges between 50 to 70 per cent;[8]

(d) Using evaporative cooling pads inside poultry houses, as is the case in a poultry company in Egypt, which uses strong cellulose evaporative cooling pads that are approximately 10 cm thick. These would lower the temperature inside poultry houses by almost 12 degrees Celsius compared to the outside temperature within half an hour. This technique entails continuously spraying the top of these pads with water sprinkles, which are absorbed into the openings of the pads. Heat is withdrawn from the air during this process and the temperature inside drops;

TABLE 5. TEMPERATURE AND MINIMUM VENTILATION INSIDE POULTRY HOUSES ACCORDING TO AGE

Age	**Optimum temperature (degree Celsius)**	**Minimum ventilation (cubic meters per bird per hour)**
First week	30	0.5
Second week	28	1.0
Third week	27	1.7
Fourth week	23	2.6
Fifth week	21	4.5
Sixth week	21	5.5

Source: Mohammad Ata, *Ventilation in Poultry Houses* (Arabic). http://kenanaonline.com/users/lopez/posts/64816.

(e) Using energy-saving lighting systems, cleaning the lamps and using light reflectors to increase the amount of light directed at the chicken, reducing electricity consumption. It should be noted that modern high-efficiency compact bulbs can reduce the cost of lighting in poultry houses by up to 75 per cent. Adjusting light intensity and duration (table 6) reduces power consumption and achieves other advantages, most notably allowing the rapid growth of poultry and activating their immune system;

TABLE 6. INTENSITY AND NUMBER OF HOURS OF LIGHTING ACCORDING TO THE AGE OF POULTRY

Age	**Lighting number of hours**	**Lighting intensity**
First week	22 hours	20 (lux) or more
Second week	16 to 18 hours	10 lux
Third week	16 to 18 hours	10 lux
From 4th to 7th week	22 hours	10 lux

Source: Modern Office Poultry, *Important Recommendations* (Arabic), Egypt, http://www.officepoultry.com/ar/7-2.

(f) Managing poultry litter and maintaining cleanliness at poultry houses to reduce the emission of ammonia gas and reduce the rates of ventilation required. This minimizes the cost of electrical energy needed for ventilation by up to 30 per cent in some cases, and may be employed, for example, to cover the cost of treating poultry litter;

(g) Using radiant heating systems instead of hot air heaters, which save energy by 10 to 30 per cent in many cases;

[8] Mohammad Ata, *Ventilation in poultry Houses* (Arabic). http://kenanaonline.com/users/lopez/posts/64816.

(h) Using variable speed electric motors and adjusting the speed of ventilation fans to reduce energy consumption. Reducing fan speed by 10 per cent causes an approximate corresponding decrease in the amount of air but reduces energy consumption at a higher rate of up to 30 per cent. In principle, it is possible to run more fans at a lower speed instead of running a smaller number of fans at a maximum speed, thereby saving power;

(i) Improving combustion processes inside hot air furnaces used for heating, and adjusting the air to fuel ratio inside these furnaces and performing regular maintenance;

(j) Inspecting and performing maintenance on the control devices of electrical equipment in order to adjust the temperature inside poultry houses; performing maintenance on electrical equipment, especially fans and preserving them; and using high-efficiency engines, fans and water pumps;

(k) Preventing water leakage and performing maintenance on water filters and water pressure control systems to reduce the consumption of water and energy;

(l) Conducting periodic energy audits; monitoring the energy consumption of electricity and fuel and recording it monthly; monitoring the fluctuation of consumption during the year to track errors and identify cases of excessive energy consumption.

2. *In poultry slaughterhouses*

Poultry are transported from farms to slaughterhouses for slaughter, skinning, and cleaning. Energy consumption in slaughterhouses is distributed over water heating; cooling; operating electric motors, fans, and water pumps; and lighting. Given the multiple phases of poultry production, slaughterhouses have the highest rate of energy consumption (table 2). The following are the main opportunities and guidelines that may contribute to the reduction of energy consumption rates in poultry slaughterhouses:

(a) *Improving efficiency of energy use in cooling systems*

Compressors used in cooling processes are the largest electricity-consuming equipment in poultry slaughterhouses. In some cases, the energy consumption by compressors constitutes more than 50 per cent of the total electricity consumption in poultry slaughterhouses. The following are some guidelines to reduce energy consumption in cooling systems:

(i) Improving thermal insulation through the cooling system, including pipes and fittings, and through the walls, floors, and ceilings of cooling rooms;

(ii) Preventing the infiltration of air from and to cooling rooms, filling holes, and ensuring the absence of leakages in the doors and windows;

(iii) Cleaning the surfaces of heat exchangers to enhance heat transfer efficiency and reduce the consumption of electrical power;

(iv) Controlling and adjusting the cooling temperature according to required standards;

(v) Programming the compressors at optimal load to achieve the highest degree of efficiency, whenever possible avoiding operation at less than the rated load, and using automatic operation based on the required cooling temperature;

(vi) Performing maintenance and periodic checks on cooling systems, especially compressors;

(vii) Cooling poultry rooms by pumping air into chillers to save between 60 and 70 per cent of the energy needed for cooling in some cases.

(b) *Improving energy efficiency in combustion, steam, and hot water systems*

(i) Using heat exchangers to recover the heat of exhaust gases emitted from boilers, furnaces and diesel generators. This heat can be used for many purposes, namely for heating the water needed in poultry skinning. The heat recovery of exhaust gases of diesel generators (figure II), for example, can save between 12 and 15 per cent of the energy used to heat water;

(ii) Adjusting the air fuel ratio in steam boilers (figure II) and heating furnaces, and performing regular maintenance on burners. Estimates indicate that each 5 per cent drop in excess air increases boiler efficiency by 1 per cent, and each 1 per cent drop of oxygen in the gas inside vents increases boiler efficiency by 1 per cent;[9]

(iii) Performing maintenance on the steam and hot water networks used in skinning operations, and preventing leaks in these networks.

Figure II. Heat recovery and adjustment of boiler burners in poultry projects

Heat exchanger to recover heat of exhaust gases of diesel generators at Tanmia, poultry company, Lebanon

Boiler used in the slaughterhouse at Tanmia

(c) *Maintenance of electric motors*

Energy conservation requires the use of high-efficiency variable-speed motors, and operation of engines at full load whenever possible to improve the electrical power factor and reduce electric power consumption (table 7). The electrical power factor is defined as the ratio of the real/active power to the apparent/total power. It can be improved by installing electrical capacitors that reduce reactive power.

TABLE 7. RELATIONSHIP BETWEEN ELECTRICAL LOAD AND POWER FACTOR IN ELECTRIC MOTORS

Electrical load	**Power factor**
Zero	17%
25%	55%
50%	73%
75%	80%
100%	84%
125%	86%

Source: ESCWA, *Energy Efficiency Opportunities and Indicators in the Industrial Sector*, by Salah Kandil, Training Workshop on The Role of Productivity Improvement in Enhancing Competitiveness of Manufacturing Firms in Jordan, Amman, 6-9 June 2011.

[9] Pawan Kumar, *Training Manual on Energy Efficiency for Small and Medium Enterprises*, 2010, Asian Productivity Organization, India, http://www.apo-tokyo.org/publications/files/gp-12-tmee.pdf.

3. *In manufacturing poultry meat*

(a) Improving energy efficiency in the autoclaves used for cooking, controlling temperature and pressure during cooking, and preventing steam leaks from these autoclaves;

(b) Improving the electrical power factor in chopping, mixing, and minced meat pumping machines;

(c) Improving energy efficiency in boilers that produce steam for cooking operations;

(d) Running production lines in poultry meat manufacturing plants to achieve an optimal level in the reduction and management of energy consumption.

4. *In the transport of poultry and poultry products*

(a) Improving the management of trucks that transport poultry and poultry products, running them at full load, and avoiding running these trucks at partial load whenever possible. The reason is that the energy consumed per kilometre-ton by a vehicle at full load is less than in the case of partial load;

(b) Implementing maintenance programmes and periodic inspections and examinations of vehicles. The periodic regulation of motors can save fuel by up to 15 per cent in some cases. Also, adjusting the pressure of truck tires leads to significant saving in fuel (table 8);

(c) Using transportation trucks with engines that consume less fuel;

(d) Performing periodic maintenance on poultry transportation trucks, checking cooling systems and applying periodic thermal isolation, and performing maintenance on refrigerators

TABLE 8. EFFECT OF LOW TIRE PRESSURE ON FUEL CONSUMPTION OF VEHICLES

Low tire pressure to standard value	**Increase in fuel consumption**
Less by 0.3 bar	1.2 per cent
Less by 0.5 bar	2.4 per cent
Less by 1 bar	6.0 per cent

Source: ESCWA, *Policies and Measures to Promote Sustainable Use of Energy in the Transport Sector in the ESCWA Region* (Arabic), E/ESCWA/SDPD/2011/2.

B. CONVERT POULTRY LITTER TO ENERGY[10, 11]

1. *Characteristics of poultry litter and challenges of poultry litter-to-energy conversion*

Poultry litter is a mixture of poultry waste and manure, and materials used as bedding to protect the poultry during breeding, such as sawdust, peanut hulls, shredded sugar cane, and straw. Generating power from this waste is an important option to mitigate the negative effects of poultry waste, whose components and thermal value vary according to the components of poultry feed.

The heat value of these wastes varies according to moisture content and ash in poultry waste. The conversion of biomass into energy faces significant challenges, especially in the case of poultry waste, where the amount of sulfur and nitrogen is 7 to 10 times higher than it is in wood. This high content of sulfur and nitrogen increases the emission of sulfur and nitrogen oxides, and requires special measures to reduce these emissions.

[10] Vitalia Baranyai, Sally Bradley, Chesapeake Research Consortium, Chesapeake Bay Program Office, *Turning Chesapeake Bay Watershed Poultry Manure and Litter into Energy: An Analysis of the Impediments and the Feasibility of Implementing Energy Technologies in the Chesapeake Bay Watershed in Order to Improve Water Quality*, pp. 61, 63, January 2008, http://www.chesapeakebay.net/documents/cbp_17018.pdf.

[11] Rangika Perera, Priyan Perera, Richard P. Vlosky and Paul Darby, *Potential of Using Poultry Litter as a Feedstock for Energy Production*, Working Paper No. 88, 15 July 2010, Louisiana State University Agricultural Center, USA.

Chlorine levels in poultry waste are higher than in wood. When merged with high levels of alkali, chlorine causes an increase in particulate emissions which leads to the erosion of combustion systems and emission of acid gases. Also, the high levels of ash in poultry waste require the use of special equipment to eliminate slag and combustion deposits.

Therefore, the combustion of poultry waste to produce steam or electricity requires the use of special equipment and supplies to address these problems, in addition to the collection of waste from farms scattered across the country and transporting them to the energy production plant. All these requirements increase the investment cost of electricity production (table 9), where the production cost of 1 MW of electricity from poultry litter is two or three times higher than the production cost through thermal power plants.

ESCWA member countries can provide these investments through the adoption of the clean development mechanism (CDM), which requires knowledge of the procedures and steps involved in the implementation of environmental projects through this mechanism, and identifying the conditions that should be met to benefit from CDM. It should be noted that Bangladesh has expertise in financing solid waste treatment projects resulting from poultry projects through CDM.[12] It should also be noted that the results of detailed feasibility studies, which take into account economic, environmental and social dimensions, determine the possibility of converting poultry waste into energy, or using it in another area while taking into account the particularities of each individual case.

TABLE 9. EXAMPLES OF ELECTRICITY PRODUCTION PLANTS USING POULTRY WASTE AND THEIR INVESTMENT COST

Plant description	**Amount of fuel used in the plant**	**Plant capacity (MW)**	**Investment cost (US$million)**	**Cost per MW (US$million)**
First plant in USA (initial operation in 2007)	500,000 tons of poultry waste per year (2-2.5 tons per day)	55	150	2.7
Plant operating on poultry litter and forest wood (study proposal)	300,000 tons of poultry waste + 50,000 tons of forest wood per year	38.5	125	3.2
Rehabilitation of Conectiv power plant (Vienna, Maryland-USA) adding two new boilers	1,920 tons of poultry waste per day (400,000 tons per year)	35	52.2	1.5

Source: Vitalia Baranyai, Sally Bradley, Chesapeake Research Consortium, Chesapeake Bay Program Office, *Turning Chesapeake Bay Watershed Poultry Manure and Litter into Energy: An Analysis of the Impediments and the Feasibility of Implementing Energy Technologies in the Chesapeake Bay Watershed in Order to Improve Water Quality*, pp. 61, 63, January 2008, http://www.chesapeakebay.net/documents/cbp_17018.pdf.

2. *Applications of poultry litter conversion into biogas and electricity*

Poultry waste can be converted into biogas, through a process known as gasification, during which poultry manure is subjected to anaerobic decomposition through the use of “bacteria”, or the conversion of organic acids into biogas. Biogas is used in many applications, including cooking and lighting, heating and cooling, and the operation of internal combustion engines, such as irrigation machines, poultry farm and crop production machinery. One cubic meter of biogas can cover one of the following requirements:[13] (a) Operating a 60 cm long poultry farm heater for two hours; (b) Running a medium heat stove for a period ranging between two and three hours; (c) Running an internal combustion machine with 1 HP (horse power) capacity for two hours; (d) Operating a tractor weighing 3 tons for a distance of 2.8 km; (e) Running

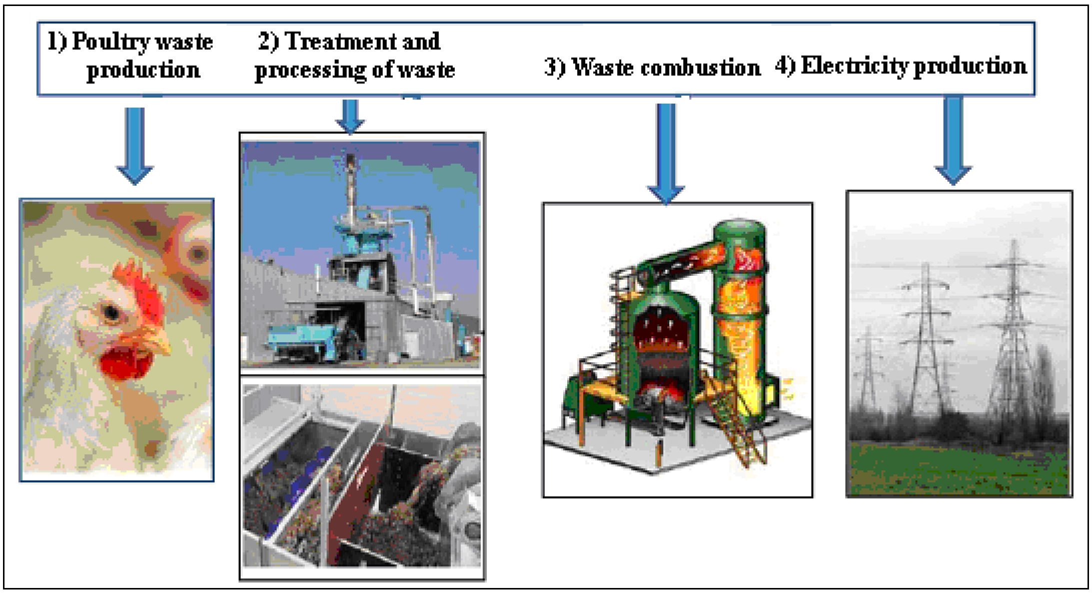
[12] Waste Concern, *CDM Project Potential in the Poultry Waste Management Sector in Bangladesh Final Report*, December 2005, Bangladesh, http://www.wasteconcern.org/Publication/Poultry%20Final.pdf.

[13] Samir Al-Chimi, *Transforming Animal Waste into Energy and Fertilizers (Biogas)* (Arabic), Soils, Water and Environment Research Institute, Agricultural and Rural Development Network, Ministry of Agriculture and Land Reclamation, Egypt.

a refrigerator sizing 10 feet for a period ranging between one and two hours; (f) Generating electric power with a capacity of 1.3 to 1.5 kWh. (g) Operating a medium-sized oven for two hours. It should be noted that the conversion of poultry waste into biogas has three positive dimensions: (i) power generation; (ii) environmental protection; (3) use of leftover waste as fertilizer.

Poultry waste can also be used as fuel to operate high-capacity, central power plants. This requires the development of national plans to collect poultry waste from the farms located in cities and villages across the country. Poultry waste is collected and processed before combustion to produce electricity (figure3). The first plant for generating electricity from poultry waste was built in the United Kingdom in 1993 with a capacity of 12.7 MW, and an annual consumption of about 140,000 tons of poultry waste. This was followed by the construction of central poultry-litter power plants with capacities up to 55 MW. They were operated by Energy Power Resources Ltd, which is the first company in the world that was successful in converting poultry waste into energy. There are other power plants in the United Kingdom and the United States which use poultry waste as essential fuel, including Thetford which produces 38.5 MW, Eye which produces 12.7 MW, Westfield which produces 9.8 MW, and Benson which produces 55 MW. The cost of electricity production plants operating on poultry waste depends on many factors, most notably plant capacity. Table 9 contains examples of the use of poultry waste in electricity production plants and the cost of installation.[14] It should be noted that the mechanisms of transition to green economies and environmental protection may support the conversion of poultry waste into energy.

Figure III. Use of poultry waste in electricity production



On a smaller scale, poultry waste in Ireland is used as fuel for steam boilers instead of liquefied petroleum gas (LPG) in heating operations needed in poultry breeding. In this context, some companies working on the development of gasification technology seek to benefit from poultry waste as fuel for electric applications and heating, and the production of other products such as activated carbons and fertilizers. The first advanced biogas production plant running on poultry waste operated in eastern Germany at a cost of 10 million euros.[15] This plant operates on poultry waste (70 per cent) and a mixture of corn and grass (30

[14] Vitalia Baranyai, Sally Bradley, Chesapeake Research Consortium, Chesapeake Bay Program Office, *Turning Chesapeake Bay Watershed Poultry Manure and Litter into Energy: An Analysis of the Impediments and the Feasibility of Implementing Energy Technologies in the Chesapeake Bay Watershed in Order to Improve Water Quality*, January 2008, pp. 22-61, http://www.chesapeakebay.net/documents/cbp_17018.pdf.

[15] Forums on Electrical power and Transport Network Systems, *Generating Electricity from Poultry Waste in Germany* (Arabic), http://www.sayedsaad.com/montada/showthread.php?t=25146.

per cent) for the production of electrical energy and thermal energy used for heating. The company executing the project aims to cover the yearly electricity need of 4,600 homes, and produce thermal energy with a 1.23 MW capacity annually needed for heating poultry farms and government buildings near the plant. This can be a model project for the optimal use of poultry waste, since it provides electric and thermal energy for multiple uses in the project itself and the surrounding facilities, in addition to the production of agricultural fertilizers.

3. *The potential energy produced from poultry waste in ESCWA member countries*

It is estimated that the world produces more than 22 million tons of poultry waste.[16] If the percentage of poultry waste in ESCWA member countries is equivalent to the percentage of poultry consumption (3.8 per cent),[17] the estimated annual poultry waste produced in member countries would be about 836,000 tons (3.8 per cent x 22 million tons). If each 1,000 kg of poultry waste produces about 500 cubic meters (m^3) of biogas,[18] the estimated total amount of biogas which can be produced from poultry waste in member countries would be about 418 million m^3 annually. In fact, although the conversion of poultry waste into energy leads to the creation of green jobs, energy production and environmental protection, it is expensive and must be subjected to economic, technical, environmental and social feasibility studies.

C. THE USE OF SOLAR ENERGY IN POULTRY PROJECTS

Solar energy can be used in multiple applications in poultry projects, including solar cells, as is the case in the Wadi poultry production company in Egypt, where solar cells are used to provide about one-third of the energy required for residential buildings allocated to company workers.[19] In Palestine, solar energy has been used in poultry farms in the village of Khirbet Atuf, eastern Tubas Governorate[20] within the framework of a project that was implemented in April 2007 through funding from Spanish company SIBA for electricity production via solar cells. The project consists of 90 solar panels, each of which includes 130 solar cells with a 12 kW capacity. The project provides poultry farms, homes and some agricultural projects with electrical energy. The provision of poultry projects with electrical energy has helped improve the living conditions of the population in Khirbet Atuf, reduce migration from the village and encourage investment in various agricultural projects. The success of the experience in Khirbet Atuf led to the implementation of similar projects in other villages, such as the village of Amnizel, where a solar system with a 13 kW capacity was built in December 2009. In October 2011, other projects were established in Khirbet Al-Makhal and Khirbet Al-Saeed.

In addition to the production of electrical energy using solar cells, solar energy can be used for water heating needed in the slaughter of poultry, where the solar system is used in conjunction with the thermal system operating on a steam boiler running on fuel. The thermal system is activated when the solar energy cannot meet the needs of the poultry slaughterhouse. This is done through the control circuit (figure IV).

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[16] Food and Agriculture Organization (FAO), *Agribusiness handbook: Poultry, Meat & Eggs*, 2010, page 22, Rome, http://www.fao.org/docrep/012/al175e/al175e.pdf.

[17] Musa Freiji, *The Poultry Industry in the Arab World - Present & Future* (Arabic), April 2008, table-2, page 45, Lohmann Information, vol. 43(1), Lebanon, http://www.lohmann-information.com/doc_l_i_43_artikel5.pdf.html.

[18] Maysoon Ghanem, *A Power Generation Plant from Cattle Waste: A Leading Project by Students of the Technical Engineering College in Tartous* (Arabic), Syrian Arab Republic, http://wehda.alwehda.gov.sy/_print_veiw.asp?FileName=65859952820120306164342.

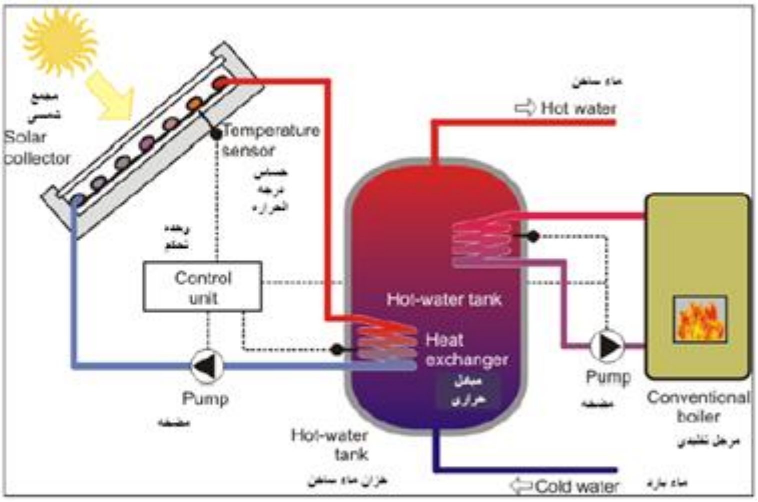
[19] Al-Wadi Poultry Company, Egypt, data provided in response to a 2012 ESCWA questionnaire.

[20] Raed Jamal Mouwaqadi, *Project for lighting through solar cells in the village of Khirbet Atuf in Palestine: A transition to renewable energy* (Arabic), Electronic Magazine Environment and Development Prospects (Arabic), Maan Development Action Center, June 2012, Issue No. 45, http://www.maan-ctr.org/magazine/Archive/Issue45/topic11.php.

Solar energy can also be used for heating in poultry farms, as is the case in the south-eastern areas of the United States, where solar energy is used for heating in about 90 per cent of poultry farms.[21] This experience has shown that the heating energy required for each thousand chickens requires a total flat-plate collector area of about 6.7 square meters, and the hot water needed for night use requires a tank with a capacity of 833 litres per 1,000 chickens.

It should be noted that the use of solar energy in poultry projects in Arab countries has significant economic and technical advantages due to the high intensity of solar radiation and the number of hours of sunlight in these countries. However, each country is a special case and requires a separate economic and technical feasibility study. The use of solar energy in poultry projects in Arab countries can be supported through the following actions: (1) Providing financial support to owners of poultry projects, and facilitating financial loans for the use of solar energy in these projects; (2) Capacity building and training in the area of solar energy in poultry projects (manufacturing, installation and maintenance of solar energy equipment); (3) Promoting cooperation and coordination between the parties concerned, including owners of poultry projects, manufacturers and suppliers of solar equipment, donors and providers of funds, the government and the private sector; (4) Eliminating administrative impediments and passing legislation that would push towards the use of solar energy in poultry projects.

Figure IV. Solar heating system in conjunction with the thermal system in poultry slaughterhouses



[21] F. N. REECE, *Use of Solar Energy in Poultry Production*, May 1981, Poultry Science Association Inc., USA, http://ps.fass.org/content/60/5/911.abstract.

IV. GUIDELINES FOR DEVELOPING NATIONAL PROGRAMMES TO IMPROVE ENERGY EFFICIENCY IN THE POULTRY SECTOR

Here are some proposals and guidelines aimed at promoting and improving efficient energy use, and supporting sustainability in the poultry sector in the Arab region.

A. PROMOTION, TRAINING AND CAPACITY-BUILDING

1. Implementing public campaigns to raise awareness of the economic, environmental and social significance of energy efficiency programmes in the poultry sector and their impact on the sustainability of this sector; and choosing the appropriate channels for these campaigns, such as media outlets, the Internet or advertisements among others.

2. Implementing training programmes, workshops and scientific activities to build technical capacity in the field of energy efficiency improvement at all levels, including technicians, engineers and managers, and at all stages of production, including poultry farms, slaughterhouses and manufacturing processes, with a focus on the following aspects:

(a) Improving energy efficiency in combustion, steam, hot water and heating systems;

(b) Improving electrical energy efficiency – including lighting in poultry houses, ventilation systems, cooling systems and electric motors – and the electric power factor;

(c) Improving energy efficiency in poultry meat manufacturing plants;

(d) Using solar energy in poultry projects, particularly in heating, lighting and water heating processes;

(e) Using poultry waste in the production of energy, such as biogas and electricity;

(f) Conducting energy audits and identifying energy consumption indicators in poultry projects.

B. GIVING PRIORITY TO ENERGY EFFICIENCY IMPROVEMENT MEASURES THAT ARE ECONOMICALLY AND ENVIRONMENTALLY FEASIBLE

Efforts should be focused on economic, technical, environmental and social standards through the following actions:

1. Developing measures that yield rapid economic results and at a reasonable cost.

2. Taking into account the health of chicken, particularly the degree of ventilation, humidity and lighting.

3. Taking into account the overall production and management system in the poultry facility so as to avoid any adverse effect the production system.

4. Applying mature technology on a large scale.

5. Developing measures that can be supported by locally available technologies.

6. Adopting measures that have an economically, environmentally and socially sustainable dimension, such as the use of renewable energy.

7. Implementing measures that can be easily replicated on a national level.

C. Issuing and developing legislation and laws to support energy efficiency improvement

Legislation and laws aimed at supporting energy efficiency improvement in the poultry sector should be focused on the following main points:

1. Energy pricing legislation pushing towards energy conservation and improved efficiency.

2. Environmental legislation supporting the reduction of energy consumption at all stages of production and in all facilities, i.e. poultry farms, slaughterhouses, and during the processing of poultry meat and poultry transport.

3. Legislation supporting the use of renewable energy in poultry projects.

4. Legislation supporting the adoption of energy-saving technologies in poultry projects, such as energy-saving bulbs, high-efficiency motors, high efficiency cooling/refrigeration systems and high efficiency thermal insulation systems.

5. Legislation supporting the provision of funds and loans for activities aimed at improving energy efficiency and supporting sustainability in the poultry sector.

6. Legislation supporting the work of energy service companies (ESCOs) in poultry projects, and the provision of financial and administrative support for these companies.

D. Supporting cooperation and coordination between the parties concerned with energy efficiency improvement

Following is a list of the main parties concerned with improving energy efficiency in the poultry sector:

1. Owners of poultry projects.
2. Manufacturers and suppliers of energy-consuming equipment in the poultry sector.
3. Energy service companies (ESCOs).
4. Banks and bodies that finance energy efficiency projects.
5. Governments and relevant ministries.
6. The private sector and civil society organizations.

E. Providing the requirements for energy efficiency improvement

It is necessary to consider the provision of the following requirements for the implementation of energy efficiency procedures:

1. The necessary financial needs.
2. Human resources such as engineers and technicians.
3. Technological requirements, such as devices and equipment, and related technical specifications.

F. Identifying impediments

It is necessary to determine the financial, institutional, technical, environmental and social impediments hindering the implementation of energy efficiency improvement programmes in the poultry sector, and propose solutions that can remove these barriers.

G. DEVELOPING AN IMPLEMENTATION MECHANISM

All the parties concerned must take part in the implementation mechanism. The general framework of implementation includes stakeholders concerned with the implementation and the role of each of them; the time frame for implementation; financial, human and technological requirements; requirements related to awareness-raising, training, capacity-building and incentive mechanisms; legislation and policies in support of the programme implementation; and follow-up, monitoring and adjustment of the implementation process.

The mechanism for implementing measures to improve energy efficiency is based on the following three pillars:

1. Urging owners of poultry projects to ensure implementation through binding legislation and laws, such as the imposition of fines if the electric power factor drops below a certain level.

2. Encouraging owners of poultry projects to implement improvement measures, such as providing incentives for increasing the electrical power factor above a certain level, and providing financial and technical facilities.

3. Providing facilities and activities that support implementation, such as capacity-building, knowledge dissemination, training and awareness-raising.

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