SUPPLY CHAINS IN THE CONTEXT OF LIFE CYCLE ASSESSMENT AND SUSTAINABILITY

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Abstract

Production and consumption of many products are subjected to a thorough study of their evident impact on local ecosystems and global warming, with the purpose of reduction their emissions, finding product and process alternatives and/or their total suspension or penalization. The procedure for assessing these impacts through a different length of the supply chains is known as product life cycle assessment (PLCA). PLCA is the basis for the study of environmental damage and the costs of their prevention and compensation. Putting priority on the issue of environmental protection, PLCA and Environment life cycle costs assessment (ELCCA) concepts leave aside problem of development, especially for the less developed areas. Given the fact that the production and consumption of products in a single life cycle must contribute at least declarative social equality of participants in the PLCA, the concept of social life cycle assessment was offered. Starting from the fact that sustainable development involves both generating and maintaining a certain level of material well-being, environmental protection and adequate supplies of natural resources and social equity, the concept of life cycle sustainability assessment (LCSA) was proposed.

The formal supply chains that are created in the product life cycles are still looking for total and partial optimality, mainly through the analysis of economic criteria which may be in conflict with the concept of LCSA.

The paper analyzes LCSA of pork meat in Croatia based on cradle-to-grave approach. Based on data of production, import, export and consumption of pork meat in a given period, and also findings in previous research about emission and functional unit (kg CO2 equivalent/kg pork consumed), a simple PLCA, ELCCA and LCSA were conducted. The imbalance in the supply chain was confirmed showing questionable sustainability of pork meat life cycle in Croatia. The results can be the basis for future comprehensive LCSA and research of entire meat sector as well as to create a framework for development policy of meat sector in Croatia.

Key words: product life cycle, environmental costs and sustainability assessment, supply chain, pork meat, Croatia

1. INTRODUCTION

A number of research on ecological systems have shown that those systems are degraded due to human activities in production and consumption of various products and services. Such degradation necessitates thorough analyses of products' functionalities as well as processes in which they are produced, the ways of resource usage, and a more detailed investigation of all relevant flows of materials, energy and values created. Based on those requirements, the concept of product life cycle assessment (PLCA) appeared as a system of total assessment of material, energetic and value flows, which includes the whole supply chain – producers, distributors, users, and their indirect and direct effects on ecological systems.

The first and most frequent research in that area was related to energy flows in supply chain of specific categories of energy sources and consumers. It enabled an insight into summarized and/or multiplicative effects on the environment that the production of an individual product can have regarding the waste (primarily greenhouse gases). When the effects of the whole production on the environment were considered, starting from natural resource exploitation to waste disposal into the soil, water and air, it became clear that the product life cycle (so-called „from cradle-to-grave“) needs a different approach.

Based on such cognitions, numerous researches have started focused on individual processes and (alternative) products on local levels. During time the research has extended to national and regional, as well as international and cross-sectional relations. It resulted in systematic analyses of partial (cradle-to-gate, gate-to-gate or gate-to-grave) and/or integrated (cradle-to-grave) supply chains of specific categories of products, as well as in large data collection and development of models for estimating whole life cycles of products. Such researches had various purposes and aims and were frequently arbitral regarding assessments of real impacts of production on environment.

That was the reason to propose, improve and update recommendations and rules, as well as methodological framework for conducting such analyses. Based on the experience of a number of previous cases, the SETAC-Society of Environmental Toxicology and Chemistry (1993) has suggested Life-Cycle Assessment Code of Practice.

In the same time, because of inconsistencies in approach, in data and in interpretation of data across different cases, the whole set of standards has been developed (todays ISO 14040 standards and their derivations 14043, 14044), as well as specifications such as GHG Protocol Life Cycle Accounting and Reporting standard and PAS 2050, based on which LCA for an individual product (or a group of product) or process is conducted.

Physical, material and energetic flows recorded in LCA represented a basis for cost merging and assessment which appears in the environment. Based on that the Life Cycle Costs Assessment (LCCA) or Environment Life Cycle Costs Cssessment (ELCC) concept appeared. This concept raised the question who will, in what amount and on what basis pay the costs incurred in the environment. "An assessment of all costs associated with the life cycle of a product need to be directly covered by any one or more of the actors in the product life cycle (e.g., supplier, manufacturer, user or consumer, or End of Life actor) with complementary inclusion of externalities that are anticipated to be internalized in the decision-relevant future" (Swarr et al., 2011).

Further efforts have been focused on mapping those two concepts and data consolidation with methodologies. How and in what way the production of certain products and services affect the individual parts of the ecosystem (air, water and soil), manifested in the loss of natural resources, reduction of biodiversity, human health and other biocenoza or of man-produced material goods.

Due to the threat of pollution growth and increase global warming, specialized national, regional, transnational and international organizations began (based on the conclusions of several world conferences - Rio, Tokyo, Montreal, Paris) to deal with the LCA. Key results of their efforts in recent decade are systematization of methodologies for environmental impact assessment and construction of the LCA databases of many different products.

Due to some remarks on principles, those two concepts do not reveal the development potentials and social equity (especially in low-income regions). Therefore, the concept of Social Life Cycle Assessment (SLCA) was proposed (UNEP, 2011).

Starting from the request of sustainable development, which integrates the former three concepts, accordingly life cycle sustainability assessment (LCSA) concept was proposed (Swarr et al., 2011). LCSA recognizes all these three concepts (procedures) what can be put as:

$$LCSA = LCA + LCCA + SLCA \qquad (1)$$

"The code of practice is grounded in a conceptual framework for life cycle sustainability assessment (LCSA) of products that uses distinct analyses for each of the three pillars of sustainability, environment, economy, and social equity" (Swarr et al, 2011). This concept is based on the fact that the consumption of common natural resources (air, water and soil) are mostly exploited by economically most developed systems at the expense of less developed due to which the economic development gap between developed and developing is becoming deeper.

Formal supply chains, which are formed among the participants for various products and services (primary and secondary producers, manufactures, producers of final goods, distributors, logistics systems, wholesalers, retailers and end-consumers) are based primarily on the criteria of economic efficiency and profitability of individual participants as well as the whole supply chain.

It is obvious that environmental requirements or requirements for sustainable growth (and development) set new limits to the participants in the chain which must be fairly distributed. In such a manner, optimal supply chains should be sought in more complex objectives and constraints.

The purpose of this study is to provide a preliminary research of meat production sector in Croatia and assess the acceptable level of development of the domestic supply chain of meat from an environmental (LCA) and sustainability (LCSA) point of view. This objective is part of the overall objectives of project proposal planned for the calls (national and European) which support research for reduce greenhouse gas emissions, provide balanced growth of countries and regions and shorten the life cycle of products.

2. PLCA, LCCA, SLCA, LCSA AND SUPPLY CHAINS

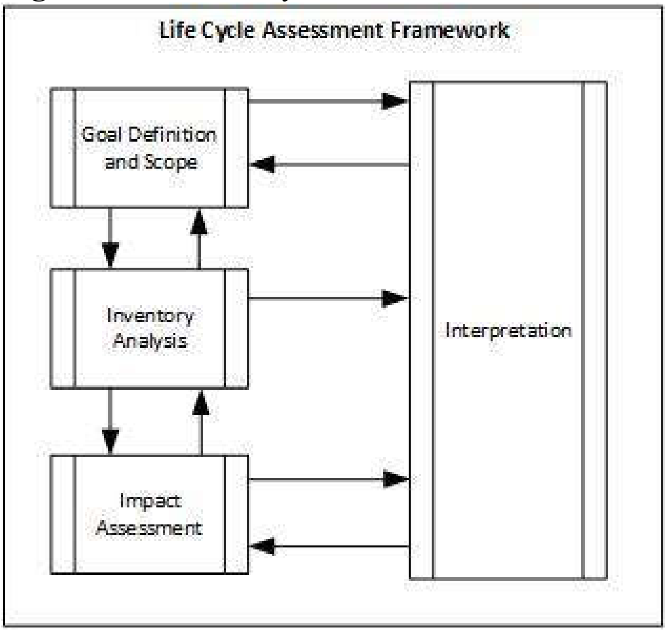
PLCA, LCCA, SLCA and LCSA are timely and data demanding tasks. When it became evident that some industries, i.e. production and consumption of certain types of products irreversibly degrade local and global environment, intensive research on emissions and pollutants upstream and downstream in the supply chain of products began. Research on "environmental footprint" for many processes and products are carried out in different environment and findings that are acquired and publicly available, will be used in this preliminary study.

Key sources of data for this analysis are publicly available database of the Croatian Environment Agency, European Environment Agency (EC-JRC-LCA), Environmental Working Group and US lifecycle inventory database, researches carried out by specialized institutions and faculties.

2.1. Product Life Cycle Assessment

PLCA is the procedure for the collection, analysis, impact assessment and interpretation of results about impact of the production and consumption of different products on the environment. PLCA analysis is a multi-phase process that is carried out with various modifications (WRI, 2011) of the methodological framework established by the ISO 14000 standard. The framework for the implementation of the analysis is shown in Figure 1.

Figure 1. ISO Life Cycle Assessment Framework



Source: ISO (2006)

Objectives of life cycle assessment can be varied and manifold. "The primary goal is to choose the best product, process, or service with the least effect on human health and the environment" (SAIC, 2006). Other objectives include improvement of existing processes and products in terms of environmental impact, comparison of alternative products and processes, cost analysis, penalization of process (product) pollutants, product certification as an environmentally friendly, facility planning on a local and national level, preparation for inter-sectorial analysis and training. Before each analysis it is necessary to determine the scope of the analysis and the participants whose impact on the environment is estimated.

A life cycle inventory analysis (LCI) is „a process of quantifying energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases for the entire life cycle of a product, process, or activity" (SAIC, 2006). The data are collected from measurements and processing plants documentation and loaded into the specific databases.

Data collected „can assist an organization in comparing products or processes and considering environmental factors in material selection. In addition, inventory analyses can be used in policy-making, by helping the government develop regulations regarding resource use and environmental emissions" (SAIC, 2006).

Life cycle interpretation is a „systematic technique to identify, quantify, check, and evaluate information from the results of the LCI and the LCIA, and communicate them effectively. Life cycle interpretation is the last phase of the LCA process" (SAIC, 2006).

2.2. Life Cycle Cost Assessment

In the product life cycle assessment, the cost assessment that are related to the life cycle of the explored product or group of products can be carried out. Thereby it is important to separate the costs in the categorization of costs, the costs that are internalized because of environmental requirements and those that are externalized and have to be compensated to external users of environmental resources (through taxes, fees or ad-hoc estimated costs of the incident) when processes are environmentally inadequate. The cost analysis is used to assess the investments required for the elimination of environmental inefficiencies of processes, to explore alternative processes and / or pollutants penalization. Legislation of these costs, whose distribution can vary among participants along with other costs, can significantly affect the competitiveness of certain participants in the supply chain. The key question that must be addressed is a fair distribution of these costs among the participants in the product (service) life cycle.

The assessment of these costs can be performed on the basis of data that must be collected in the field, either on a representative sample or the whole set.

2.3. Social Life Cycle Assessment

Through SLCA one seeks to observe the attitude of participants in the (cradle-to-grave) life cycle to social equality (exploitation, rewards, working conditions, education and training, health care), social engagement and social responsibility of participants in the environment in which they operate (UNEP/SETAC, 2011). Costs related to the requirements for environment protection (preventive costs, environmental taxes, additional disposal costs) that were transferred to the pollutants often resulted in the devaluation of man-made work and requirements to reduce its unit costs. Product life cycle assessment and the assessment of life cycle costs at a given moment represents the state of the production and use of a product in a given area. If it includes all the relevant participants in the life cycle, then it represents the state of the sector and at a given moment, it represents a certain negotiating position in relation to the exploitation (pollution) of the common natural resources. As the production of a product at the local or national level can have a significant impact on the socio-economic growth and development, local (national) systems will try to keep the achieved or planned level of economic development, trying to reduce the real value of the damage caused to the environment. Environmental protection requirements are generally competing demands for economic welfare and it is obvious that a compromise should be sought in the sustainable level of economic growth and development and environmental protection as well. Neglecting development is stated as a criticism of the concept of environmental life cycle assessment, particularly by the less developed regions (UNEP/SETAC, 2011). This is because the problem of depletion of natural resources, the production of greenhouse gases and pollution of soil and water is actualized globally, taking into consideration the current situation in which some local systems reached a maximum depletion of natural resources and environmental pollution, raising their economic welfare at the expense of the less developed systems. Compensations through trading emission rights represent an important but insufficient source of funds for economic growth and development of less developed areas.

2.4. Life Cycle Sustainability Assessment

LCSA is based on the same approach and on the principles of integrated life cycle assessment, life cycle costs, and social life cycle assessment as is symbolically indicated by the expression (1). Sustainable development of an ecosystem (in this case the system is identified with the national environmental system), in which operates a certain socio-economic system, implies such a depletion of resources that future generations can provide at least the same or greater level of welfare in relation to that of a previous generation. Measuring the level of welfare obviously is no longer possible only through the classic (economic) indicators such as GDP per capita. Several models are proposed for sustainability measuring. The most comprehensive is System of Integrated Environmental and Economic Accounting (SEEA) proposed by United Nations, the European Commission, the International Monetary Fund, the Organization for Economic Co-operation and Development and the World Bank (SEEA, 2014).

The second is the modification (correction) of GDP over the Index of Sustainable Economic Welfare (ISEW) (Endres & Radke, 2012):

- private consumption is divided by index of social preference for an equivalent distribution of income,
- value of household production is added,
- values of usefulness of durable goods purchased in previous periods are added and values of newly purchased durable goods are deducted,
- the public (government) expenditure for roads, health, education are added,
- so-called defensive costs of removing the damage and the cost of private treatment are deducted,
- costs of environmental damage in the accounting period are deducted,
- values of decrease in inventories of natural resources are deducted,
- values of the cost of reparations damage from the environment are deducted,
- values of changes of the technical (of man-made) capital are added,
- the difference (positive or negative) of external investment and investment carried out abroad is added.

Eurostat recorded about 140 indicators in 10 fields: Socio-economic development; Climate change and energy; Sustainable transport; Sustainable production and consumption; Conservation and management of natural resources; Public health; Social inclusion; Demographic changes; Global partnership; Good governance.

2.5. Supply chains - requirements for shortening

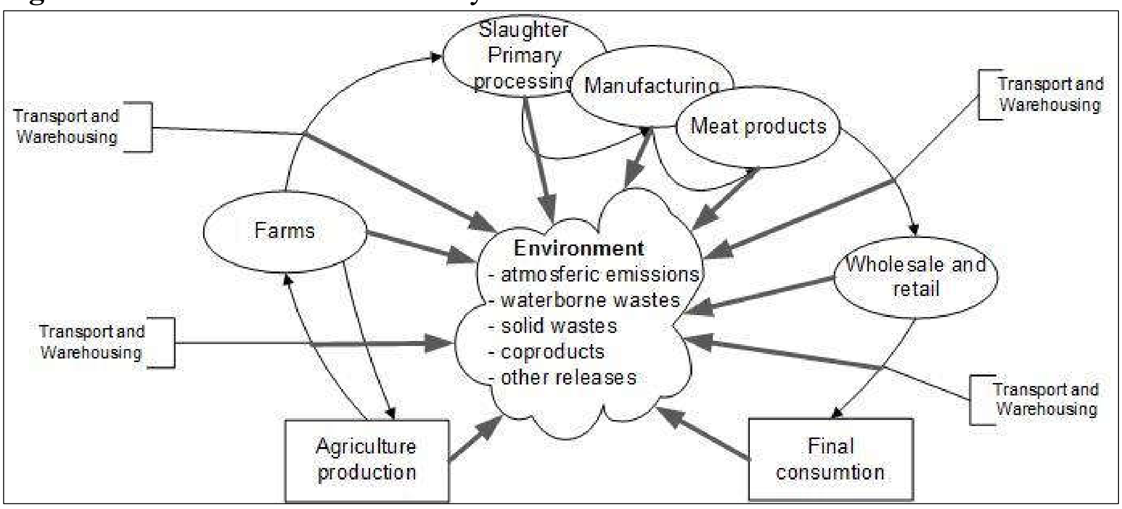
In the classical approach to the study of supply chains the starting point is the end-customer who's qualitative and quantitative needs are satisfied by some kind of products (goods) and / or services. The term goods indicates the price of good that customer is willing to pay. The functioning of the supply chain in which product or service is made will be based on the criteria of optimality, which generally start from the optimal level of product availability (Chopra & Meindl, 2016). But supply chain management means to achieve the objectives of economic efficiency, growth, flexibility and stability alongside the whole chain.

Any imbalance in the established supply chain will reflect upstream and downstream in the chain. Maintaining optimal functioning in the contemporary requirements for meeting the needs, new restrictions in the form of external costs that must be internalized are being imposed. PLCAs that are made in the last decade revealed and documented many emissions which resulted in claims for their reduction and / or complete elimination (Milar, 2015; Oliver et al, 2015; Hwang & Rau, 2006). For many products, especially those that do not tolerate high transportation costs, the demand for shortening the life cycle is imposed, both in terms of time of delivery of the product and length of transportation route. In "long" supply chains besides to the direct transportation costs there are a number of warehouses and handling of goods in which different emissions appear. Shortening of supply chain is justified also by the requirements of preserving the quality of the product (as e.g. in many food products often required (SCW, 2013)) and the requirements for sustainable growth and development of local areas (Kebir, 2013). On the other hand, the globalization of business and the requirements for free trade within a formally structured trade agreements, impose the creation of different supply chains (CSCMP, 2015). In the given circumstances, frames for the supply chains design are often determined by socio-political decisions.

3. MEAT LIFE CYCLE ASSESSMENT AND SUPPLY CHAIN IN CROATIA

Contextual framework for meat LCA is shown in Figure 2. It represents the so-called "cradle-to-grave" approach and takes into account all key emissions that occur in the process preceding the production of meat in its processing and consumption. Cradle-to-grave approach is taken because in Croatia there are all of the participants listed in the model.

Figure 2. Contextual for meat life cycle assessment



Source: authors

The intention of this paper is to make a preliminary life cycle assessment as well as LCSA of pork meat production in the Republic of Croatia based on the available data on production, import, export and consumption of pork meat.

Source for emission data for the estimation of total emissions in our case will be taken from Environmental Working Group: Meat Eater's Guide (2011). The data of the production, import, export and consumption of pork in Croatia is taken from Grgić et al. (2015) and Croatian Bureau of Statistics (CBS).

Life cycle costs assessment will be carried out on the basis of CO2 equivalent calculated in PLCA and prices of CO2 equivalent in the European market of emission allowances at eeX (2016) and from Investing.com (2016).

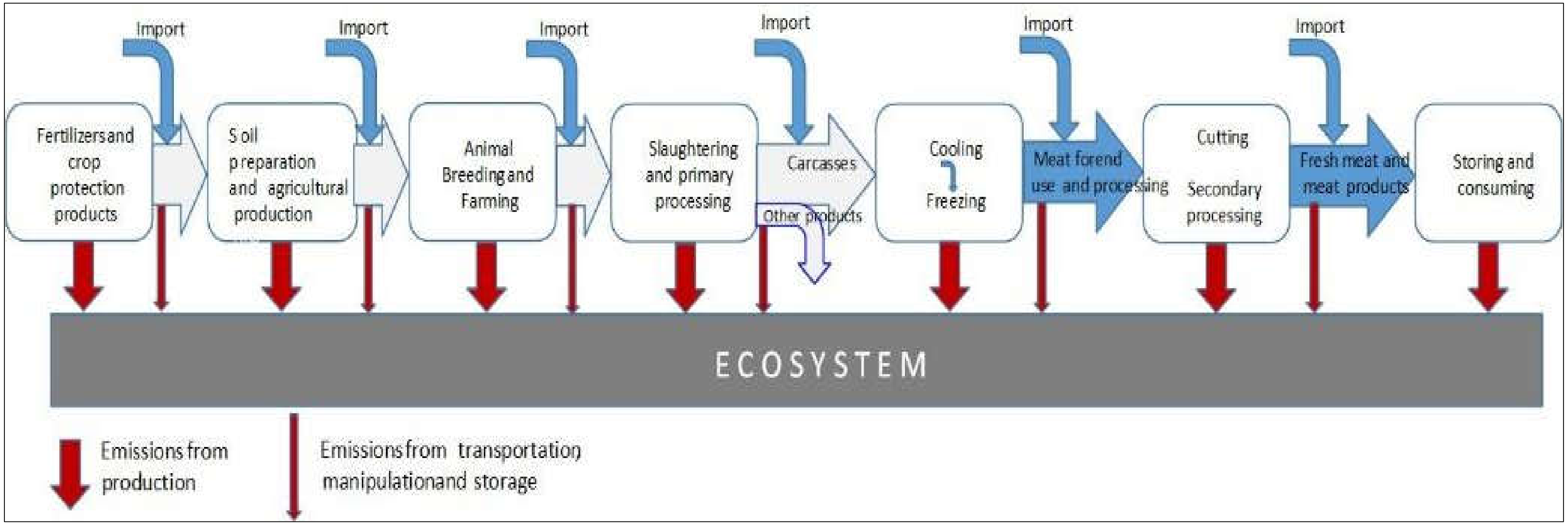
Given the importance that meat production has, particularly for rural areas of Croatia, imbalances in the domestic meat supply chain will be examined. These imbalances caused underutilization of natural resources and production capacities and consequently underdevelopment of rural areas.

The share of pork meat in total meat consumption in Croatia is 35-42%. This consumption is close to the consumption of poultry meat 38-46% (chicken dominantly). The rest of 18 - 23% is beef and about 3% is lamb (CBS, 2015).

The paper did not explored all individual production capacities in the chain (cycle). Emissions are estimated based on data of production, import, export and consumption of pork meat. The starting point for the analysis is shown in Figure 3.

The US pork life cycle with all typical participant shown in Figure 3 according to EWG (2011), gives emission of cca. 12.1 kg of CO2 equivalent per kg of pork. These estimates are made for the conditions and capacities of typical LC participants in the USA (typical practices in agricultural production, the typical diet of pigs to the weight of the usual meat processing, the typical length of transportation routes, and the typical technology solutions of individual participants and modes of consumption). For an accurate assessment of emissions for participants in the chain of Croatia values have to be corrected after a comprehensive analysis of the collected data.

Figure 3. Extended meat supply chain



Source: authors

The pork LCA will be based on data of pork production, export, import and consumption in period from 2007 to 2012 and forecasts for the year 2016. Production of meat in the complete life cycle shown in Figure 1, gives different forms and amounts of outputs that have environmental impact and of which the most important are the so-called greenhouse gases that affect global warming:

- Carbon dioxide (CO2),
- Nitrogen oxides (N2O and NxOy),
- Methane (CH4),
- Fluorinated hydrocarbons (HCFx used as a coolant in refrigerating systems).

Other emissions include waste water from the slurries, slaughterhouses and the meat processing as well as solid wastes that both end up in water streams or in the soil. The emissions that occur in the production of meat come from:

- energy, water, fertilizers, pesticides and other additives in the production of plants for animal feed;
- breeding and raising cattle on farms (heating, cooling, lighting, fermentation digestive processes, irrigation of the slurry);
- fuel consumption in the transport of livestock and crops;
- consumption of electricity, fuel and water in slaughterhouses;
- energy consumption for cooling and freezing of meat;
- use HCFx liquid in stationary and mobile refrigeration systems;
- energy consumption and additional materials for the meat packing and processing in multiple stages including processing and preservation;
- the fuel consumption related to transportation to wholesalers and retailers;
- cooling and manipulation in stores;
- energy use for transportation of meat to the consumer and the consumer’s cooling;
- use of energy for the preparation of meat, discarding unused meat before and after cooking and serving.

All emissions of gaseous substances (greenhouse gases) are calculated to the functional unit - amount of emissions per unit weight of product (one kg of meat produced). For comparability impact of certain emissions they are converted to CO2 equivalent, which represents the ratio of the potential for warming (Global Warming Potential) of certain emissions compared to CO2 over a period of 100 years.

Thus, the GWP of certain greenhouse gases are:

- carbon dioxide (CO_2) = 1
- methane (CH_4) = 25 – I.e. Releasing 1 kg of CH_4 into the atmosphere is about equivalent to releasing 25 kg of CO_2
- nitrous oxide (N_2O) = 298 – I.e. Releasing 1 kg of N_2O into the atmosphere is about equivalent to releasing 298 kg of CO2
- Hydrofluorocarbon-23 = 14.800 - Releasing 1 kg of CHF3 into the atmosphere is about equivalent to releasing 14800 kg of CO2 (CCC, 2015).

Based on Meat Eaters Guide (2011) production and consumption of 1 kg of pork meat releases 12.1 kg CO2 eq. This finding will serve in GHG calculation in pork meat consumption in Croatia[1]. Table 1 presents data of meat production, import, export and consumption of pork meat in Croatia in period 2007-2012 and projection for 2016 (Grgić et al. 2015).

Table 1. Meat Production and Balance in Croatia 2007-2012 and 2016 forecast

	2007	2008	2009	2010	2011	2012	2016
Production							
Slaughtered (000 pigs)	2374	2492	2289	2159	1775	1684	1913
Carcases average weight (kg)	58,48	59,4	69,8	68,35	82,5	75,33	58,02
Net weight of slaughterd (000 t)	138,84	148,04	159,75	147,54	146,46	126,85	111,00
Balance (000 t)							
Domestic meat production (GIP)	133,23	137,12	146,63	136,39	137,70	121,98	104,10
Livestock import	5,64	11,97	14,28	13,05	12,41	10,85	18,42
Livestock export	0,02	1,05	1,16	1,90	3,65	5,98	11,52
Net meat production (000 t)	138,84	148,04	159,75	147,54	146,46	126,85	111,00
Pork import	37,87	54,19	64,50	60,91	63,34	68,82	85,38
Consumption potential	176,71	202,23	224,24	208,45	209,79	195,67	196,38
Pork meat export	2,24	4,79	5,58	5,72	5,65	7,20	8,66
Initial stock	5,63	7,92	6,53	0,87	7,62	4,87	5,11
Final stock	5,83	6,53	0,87	7,62	4,87	5,35	4,88
Domestic consumption	174,27	198,84	224,32	195,98	206,88	188,00	187,95
Per capita consumption	39,33	44,84	50,65	44,36	48,28	43,87	44,01

[1] Emissions of products and processes partly included in meat life cycle are presented in National Inventory Report 2011, Croatian greenhouse gas inventory for period 1990-2009, Ministry of Environmental Protection, Physical Planning and Construction; Croatian Environment Agency, Zagreb, 2011.

Level of self-sufficiency	76,82	68,96	65,37	69,60	66,56	64,88	55,39

Source: Grgić et al. (2015)

3.1. Meat life cycle assessment, costs assessments and sustainability calculation

CO2 emissions in the pork life cycle are calculated based on the data in Table 1. and the assumed amount of CO2 emitted from production of one kg of pork produced in the cradle-to-grave cycle and multiply by coefficient of 12,1 which is calculated in USA pork life cycle. Results are shown in Table 2.

Table 2. CO2 eq. emissions in Croatian pork life cycle

	2007	2008	2009	2010	2011	2012	2016
CO2 Eq emitted in domestic production (000t) (DP)	1.655,70	1.742,05	1.869,21	1.746,46	1.778,93	1.607,78	1.474,55
CO2 Eq emitted for domestic consumption (000t) (DC)	2.108,67	2.405,96	2.714,27	2.371,36	2.503,25	2.274,80	2.274,20
CO2 Eq for DC - CO2 Eq emitted (000 t) in DP	452,96	663,92	845,06	624,90	724,32	667,02	799,64
CO2 emission in full self-sufficiency (000 t)(FSS)	2.744,95	3.488,93	4.152,17	3.407,12	3.760,89	3.506,17	4.105,79
CO2eq price (Eur/t)*	22,50	25,00	16,50	17,00	12,50	7,50	4,50
Savings in CO2 eq not emitted (mil Eur) (SNE)	10,19	16,60	13,94	10,62	9,05	5,00	3,60
CO2 eq costs for full self-sufficiency (mil Eur)	61,76	87,22	68,51	57,92	47,01	26,30	18,48
Average import meat price (000 Eur/kg)	2,10	2,10	2,10	2,11	2,39	2,34	2,56
Average export meat price (Eur/kg)	2,05	2,05	2,05	2,00	2,17	2,37	1,84
Value of meat (import -	74,94	103,98	124,01	117,00	139,01	143,91	202,99

export) (mil Eur)							

Source: calculated by authors

$$CO2\ (eq)\ DP = (domestic\ production + livestock\_import*0{,}25 + livestock\_export*0{,}75 + meat\_import*0{,}05 + average\_stock*0{,}05)*12{,}1$$

The coefficients have the following meanings:

- Coefficient of 0.25 means that 25% of the total CO2eq is generated in the production cycle from slaughter to consumption in Croatia; previously created 75% of CO2eq was emitted abroad;
- The coefficient of 0.75 means that the domestic breeding created 75% of total emissions and rest of 25% will be produced abroad;
- The coefficient of 0.05 is derived from estimates of total emissions from the transport and storage of meat.

CO2eq prices are the prices achieved in the EU CO2 market. Meat prices are average annual prices on imports and exports of meat.

Table 2 shows that emissions from the production of pork are continuously falling since 2009 due to reduced farm breeding and decrease in meat production.

Production and consumption of meat in the cradle-to-grave approach is not a major polluter of the environment (Ekoenerg, 2015) and is not subject to direct penalizing at the national level. Indirect penalization takes place through the price of energy and water consumption at all stages of the life cycle. However, all stages in the life cycle are subjected to regulations based on the specific requirements of the environment (especially for soil and water) and special measures imposed by the conditions of production, processing and consumption.

The value of environmental damage can be seen as a tentative value of the rights (allowances) that can be sold if the right to consume the environment is not consumed. For the purpose of this paper a value of the right for CO2 eq emission is calculated based on differences of possible CO2 eq emission in case of complete domestic production and real production. This difference is multiply with a price of CO2 eq obtained for each year on European CO2 market.

It is obvious that the price continuously decline since 2008 to 2016. This means that in the last eight years, European countries are both, leaving the production which is a major source of emissions and have invested significantly in to the environmental efficiency of the systems used in the different product life cycle. According to Luckow et al. (2016) and Sandbag (2015) it is expected rising prices in the future of emission allowances in USA and EU respectively.

Due to the increasing dependence on imports in the pork life cycle, domestic emissions decreased. However, due to falling prices of emissions rights, "optional income" from the sale of those rights fell too.

Meat supply chain is important (even strategic) sector in the economy of the Republic of Croatia. Although it does not employ a large number of workers, in actual conditions it is important for development of Croatian rural areas as well as adequate use of natural resources. In Croatia, where there is untapped potential in agricultural land and relatively stable consumption of meat, it is socially necessary to have and maintain a meat supply chain, at least at the level of self-sufficiency.

Production and consumption of meat in the cradle-to-grave approach is minor polluter (in relation to the energy sector, chemical production, transport, thermal energy processes in the industry ...). Sustainable development of the sector is possible in the balanced development of all participants in a way to exploit their capacities and ensure stability of supply and demand. In the analyzed example continuous, slight decrease in meat consumption from 2009 to 2016 is evident, as well as drastic (almost 50%) decline in domestic production of meat. On the other hand, in the same period, there is a continuous increase in pork imports.

The value of the difference between imports and exports, conditionally can be seen as a loss of new value added. The unused own resources on the one hand and low fees that due to environmental protection can be achieved, indicating a disturbed sustainability of the observed supply chain. Imbalances in the meat life cycle, which is a sector of interest to the national economy, can be (must be) dealt with clear measures of economic or agricultural policy (including technology policy and supply chain management policy) and should not be exposed only to the law of supply and demand.

Supply chains created in the meat sector obviously have functioned at the sub optimal level, which means that the balance in the chain is disordered by internal relationships or changes of external conditions that have an impact on the chains. In our case it happened to be on the European market due to the embargo on food exports to Russia what caused a surplus of meat and consequently a drop of pork price.

Meat supply chain began to breakdown at the farm - slaughterhouse relations. The farms are pressed with lower price of output (livestock) on one side and relatively constant or rising input prices on the other side. This makes farms financially inefficient and uncompetitive. This resulted in significantly reduced production, poorly utilized capacities and abandoning of breeding especially on small and medium size farms. In other words, the sustainability of the sector in terms of cradle-to-grave is questionable.

4. CONCLUSION

Life-cycle analysis and collection of data on the production of various products in the cradle-to-grave approach allows detection of important environmental impacts of all participants. Requirements for reducing emissions have become the obligations of human kind. This rise the need for collection of numerous data on polluters - the types and quantities and their impacts on human health, the health of all biocenoza, biodiversity and man-made assets.

Fulfilling environmental requirements is becoming an important criterion of use and applicability of different products. At a time of intense degradation of private and common environmental resources, demand for their preservation becomes prioritized.

Environmental requirements are becoming external costs that must be internalized. In a particular case it results in raising costs of preventing emissions or, in many cases, direct or indirect penalization of polluters. This requirement is justified in the context of sustainable development and must be complied with.

Preliminary analysis of the pork life cycle in Croatia shows that in this cycle for a given level of production and consumption relatively small amount of emissions are generated. Consequently, penalization (or savings on emissions that can be traded) are also small in relation to the newly created economic value.

In the context of sustainable development it is justified expectation of such systems that production, at least within the limits of self-sufficiency consumption, is favored in relation to environmental requirements.

Supply chain which is created in the conditions of analyzed consumption, production and capacity utilization of individual participants shows its economic misbalance that hurts primarily pigs' breeder i.e. farms. As they are generally located in rural areas of eastern Croatia, it is evident that it will be most reflected in the development of these regions.

Decision-makers in national sectorial policies have budgetary resources, even those derived from emission allowances to direct the equilibrium growth of the sector. They are obliged to intervene in the disturbed relationship in formal supply chains to ensure its' lasting viability.

This research has preliminary character. In future studies a complete meat life cycle assessment as well as life cycle of sustainability assessment should be conducted. Future studies should be based on thorough data analysis and existing sound methodologies for all meat categories that make up the bulk of meat consumption in Croatia. There are numerous studies concerning the state of ecosystems; their use and renewal of natural resources in Croatia (Ekoenerg, 2015; CEA, 2015). In this context, data collected through LCA and SLCA will be useful for creating development and environmental policy related to the interconnected complex production systems.

A particular problem that has to be explored is what benefits for the participants in the chain brings the demand for meat life cycle shortening.

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