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Environmental assessment of the main Northern Italy beef production systems using an LCA methodology

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- Gac A. and **Boselli L.**, 2014. Empreinte carbone du jeune bovin Franco-Italien. 15ème Journées Sciences du Muscle et Technologies des Viandes, 4-5 novembre 2014, Clermont-Ferrand.

- **Boselli L.**, Gac A., Bava L., Migliorati L., Tamburini A., 2015. Environmental performances of the main Italian beef production systems. Ital. J. Anim.Sci., 14:s1 p. 130, XXI Congresso ASPA, **A**ssociazione per la **S**cienza e le **P**roduzioni **A**nimali Milano 9-12 giugno 2015.

- **Boselli L.**, 2014. Système viande bovine en Italie: dynamique de la production, caractéristiques techniques et performances environnementales. Reunion du Service Bâtiment et Environnement Institut de l'Elevage, Paris Maison des eleveurs, 22 Avril 2014.

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- Migliorati, L. and **Boselli, L.**, 2013. Reduction of nitrogen excreted in dairy farms through the application of high N efficiency ration. Book of Abstracts of the 64th Annual Meeting of the European Federation of Animal Science no 19, p.585 (2013) Nantes, France 26 – 30 August 2013.
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Abstract

Italian agriculture, included animal breeding, contributes for 7.0% to national greenhouse gases (GHG) emissions and also accounts for 95% of national ammonia emissions. Beef and dairy cattle production systems are considered the first contributors to the environmental impact of livestock sector mainly due to enteric fermentation emissions but also because of the lowest feed conversion rates compared to monogastric species. The Italian beef sector main outputs, young bulls, heifers, cull cows and veal calves were highlighted. This study aims to estimate, using an LCA approach, the environmental impact of the main Italian beef production systems that are: white veal calves, cattle for fattening and cow-calf system. White veal calves system includes a dairy cow-calf producer and stockers where dairy calves are fattened. The fattening system includes the French – Italian and Piedmontese chains. The cow-calf system consists of suckler-calf and calf-to-beef farms. A sample of thirty representative beef specialized farms, were identified thanks to breeders associations and beef chain actors. Each beef production system is analyzed from cradle to the farm exit gate, including both calf-to-weanlings and fattening stage, farm inputs, animal transport. Kilogram of live weight (LW) has been adopted as functional unit (FU). Biophysical allocation has been applied to split impacts among the co-products of the targeted systems. Environmental performances are summarized in the following categories: global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), cumulative energy demand (CED), ecological footprint (EFP). Calf-to-weanlings stage represents the major source of emissions apart from beef production system. Global warming potential values range from 14.28 kgCO_2-eq to 23.60 kg CO_2-eq per kg LW of French – Italian young bulls and young bulls reared in calf-to-beef farms respectively. Global warming potential values of Piedmontese fattening young bulls range from 17.46 kgCO_2-eq to 19.57 kgCO_2-eq per kg LW according to the methodology applied. French-Italian young bulls resulted to be the

best environmentally-friendly together with the other intensive system, the Piedmontese one, due to the higher birth percentage per suckler cow and cattle for replacement rate collected respectively in the French case study (91%, 21%) and in the Piedmontese one producing 5-months weaners (89%, 6%). An high variability is observed among production systems because of animal category, farm management, feeding system and land use. Results are in the range of those proposed by literature referring to the same animal category. A beef production system based on specialized calf-to-weanlings plus finishing farm seems to be more sustainable than a cow-calf one.

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Chapter 1

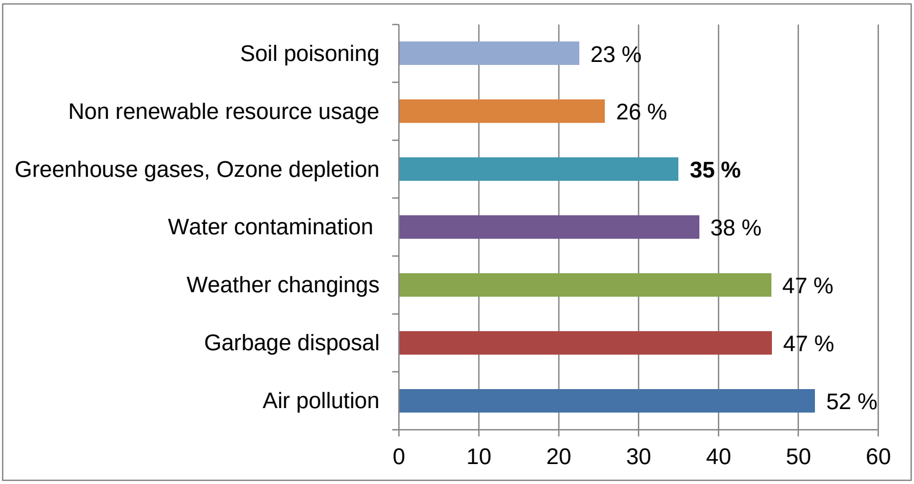
General introduction

1.1 The context

Recently Food and Agriculture Organization of the United Nations pointed out the importance of livestock sector contribution to the environmental pollution (Steinfeld et al., 2006). Agriculture and livestock activities play an important role in the environment maintenance and resource supply, but at the same time they are a key source of harmful substances both for the environment and human health and use large amounts of non – renewable resources. For example greenhouse gases are emitted from rumen fermentation and livestock waste, CO_2 is released both from fossil fuel consumption for feed production and as a consequence of deforestation practices with an increase of grazing and arable land areas. Water as well as fossil fuels are becoming a restricted resource because of the opportunities that they represent for other sectors and activities. An increase of global demand for food of animal origin – meat, milk and eggs – will promote the intensification of agriculture and animal husbandry. For example in 2002, a total of 670 million tonnes of cereals were fed to livestock, representing approximately one – third of the global cereal harvest. A 2012 FAOSTAT report still pointed out that 293 million tonnes of meat and over 720 million tonnes of milk in 2010 were produced. Traditionally livestock production is based on locally available feed resources such as crop wastes and byproducts that had no value as food. Nowadays it depends less and less on locally available feed resources, and increasingly on commercial feed concentrates. Beef and dairy cattle production systems are considered the first contributors to the environmental impact of livestock sector mainly due to enteric fermentation emissions but also because of the lowest feed conversion rates compared to monogastric species (pigs, poultry). Specifically the Italian agriculture, included animal breeding, contributes for 7.0 % to national GHG emissions (Condor, 2011). These two productive systems pollute much less than energy sector which includes every fuel combustion process (80 %), at the same time they release into the air a part of CO_2 equivalents comparable to other manufacturing areas such as waste and industrial processes. They also account for 95 % of national ammonia (NH_3) emissions, 21 % of hexachlorobenzene (HCB) emissions, 12 % of PM_{10} and 5 % of $PM_{2.5}$ emitted at national scale respectively (Romano et al., 2013).

Main concerns as regard environmental impact on Italian population's point of view turned out to be air pollution (52 %), garbage disposal and weather changings (47 %) as summed up in Figure 1.1 (ISTAT, 2014). All these polluting issues are taken into account by national researchers trying to find out efficient mitigation strategies, available to farmers, in order to make systems sustainable (AA.VV., 2011).

Figure 1.1. Questionnaire's percentage results about the environmental issues more relevant for Italian people (ISTAT, 2014)



1.2 Beef production and gaseous emissions: an overview

A beef production system is essentially characterized by three environmental hot spots: greenhouse gases emissions contributing to global warming potential and ozone depletion increase, ammonia emissions contributing to air acidification and then N and P losses negatively affecting water quality status. Potential sources of these gaseous emissions are referred to animal rumen activity but also to breeding method (confinement, pasture), manure management system and land application, soil cultivation, inputs manufacture and transport as specified in Figure 1.2.

1.2.1 Greenhouse gases

Methane (CH_4)

A study proposed by AEA Technology Environment in 1998 focused on mitigation strategies to reduce methane emissions revealed that inside GHG, CH_4 is certainly the most important gas released by agriculture in EU countries especially in France, Germany, Italy and the Netherlands where cattle productions are most diffused. Enteric fermentation and manure management explain together 30-to-75 percent of CH_4 total anthropogenic emissions in these countries. Detailed enteric CH_4 emissions have been estimated for each beef cattle category using a *Tier 2* approach as reported in Table 1.1. Figures are influenced by some aspects related to cattle morphology (live weight, energy requirements, dry matter intake), reproductive parameters (age at first calving) and dietary inputs (diet composition) that were used to estimate them. Values concerning CH_4 released from manure management are also reported for the Italian and Irish beef categories. In this case data are essentially restricted to animal housing. Some options to mitigate animal origin methane contribution to global warming were analyzed and discussed. On the one hand cattle herd reduction relying on highly productive heads, characterized by lower emission intensities, has been recognized as driven plan

(FAO, 2013). On the other side feeding strategies investigation was pointed out as the alternative approach. A significant reduction of enteric output was produced by decreasing forage : concentrate ratio in finishing diets with a positive effect of lipids supplementation (Martin et al., 2007). A meta-analysis performed by Archimède and colleagues (2011) underlines that forage type impacts on cattle enteric emissions too. In particular C_3 feed type (alfalfa, clover) is in charge of lower CH_4 production in comparison to C_4 feed one (maize).

Nitrous oxide (N_2O)

Nitrous oxide too was identified as a great contributor to the national GHG emissions from agricultural sector (56 % of the global sectorial emissions) as pointed out in the 2013 Italian Emission Inventory Report, because of animal breeding related activities such as pasture rather than animal manure handling and synthetic fertilizers utilization on agricultural soils. This gas is generated together with other N forms (NO_x, N_2), from a combined aerobic nitro – de-nitrification process supported by soil microorganisms. Data concerning N losses within cattle production practice revealed that N_2O formation occurs especially in deep litter while emissions within manure storage and application are redundant. They represent 5-to-2 % of N entering value respectively (Rotz, 2004).

Nitric oxide is mainly released after soil fertilization ranging from 0.003 to 11 % of N applied depending on crop variety and fertilizer class (Skiba et al., 1997). Measures that farmers may adopt to control this point are available at different levels. Crop nitrogen requirements as well as manure characteristics and fertilization timing information are key factors to increase the value of N farm inputs. Because urinary urea-N that is ready to volatilize as N_2O, has been confirmed to be mostly influenced by feed crude protein (CP) content, low CP diets supplementation has been applied to minimize potential nitrous emissions without negative effects on animal performances (Cutullic et al., 2013).

Carbon dioxide (CO_2)

Two types of emissions can be distinguished:

On-farm, consisting of fuel consumption for agricultural practices to grow feed crops and for cattle feeding related operations;

Off-farm, including all those emissions released within production cycle and transportation stage of farm inputs.

A survey performed by Dollé and Duyck (2007) conducted on direct energy costs of French specialized cow-calf farms, has proved that the animal feed accounts for 50 % of global energy expenditure with 0.48 liters burnt per week per livestock unit. On the other hand a Dutch database describing means of production required to crop cultivation, energy demand to process raw materials into feedstuffs rather than fertilizers production can be taken into account to estimate off-farms CO_2 emissions (Blonk Consultants, 2013).

1.2.2 Other pollutants

Nitrogen

Nitrogen is an essential element for dairy cows to produce milk and for beef cattle to reach daily weight gain but ruminants are not able to carry over all daily N – inputs into milk N or to fix N in body tissues (Tamminga, 2006). For this reason it is crucial 1) to meet N cattle requirements and 2) to maximize animal N utilization efficiency reducing N losses. N lost in air is mainly volatilized as ammonia while $N\text{-}NO_3^-$ is leached in water bodies. A great number of research studies aimed at investigating NH_3 fluxes from liquid and solid manure management systems for cattle because they represent together with synthetic N-fertilizers land application the major source of emission of this pollutant. A summary of these losses, expressed on N entering basis, has been proposed by Rotz (2004) showing a great variability of emissions inside each source: animal housing range from 8-to-50 %, manure storage range from 4-to-30 % with a higher contribution of dung than slurry. As regards organic manure land spreading the best practice resulted to be deep injection of slurry which just determines a 2 % ammonia loss. Because of NO_3^- ion is moving, it is considered a potential dangerous agent for human health, the European legislation in 1991 has fixed a limit concentration of 50 mg/L in water bodies. Monitoring studies were conducted to understand water bodies potential contamination by livestock defining a precise picture about N excretion rates for the representative beef categories reared in Italy (Crovetto and Sandrucci, 2010). Reference values in kg per head per year are 47, 54 and 11 for young bulls, suckling cows and white veal calves respectively. Results obtained in these fields were used to discipline animal effluents utilization (MIPAF, 2006). They were calculated using a methodology suggested by ERM (2001) which permits to estimate N excretion starting from productive characters such as milk yield, dry matter intake, feed crude protein content easily collected by farmers. Because this methodology has been also successfully applied on farm scale to the main Northern Italy maize-based forage systems, it was possible to perform N balance considering either animal breeding or agronomic phase (Grignani et al., 2007). Bassanino and his team (2007) with their work pointed out that, on the basis of N farm balance, specialized beef systems turned out more sustainable than dairy and pork production systems.

Phosphorus

Phosphorus soil total content is relatively low averaged 0.05 % on DM basis. It is present in the plant-animal-soil system for 90 quota of which only 10 % is available for the plant-animal subsystem as bonds with many other elements are formed resulting in unsolvable components (Barberis and Fusi, 2003). Phosphate represents the preponderate part of phosphorus observed into the soil of which mono and di-calcium particles are the exclusive usable by crops. For this reason Italian farmers tend to make use, sometimes in excess, of P fertilizers as emphasized by data collected at national scale (Condor, 2011). Animal excreta also contribute to the increased levels of phosphorus in water bodies through leaching, erosion and run-off processes. Diets are usually formulated according to NRC (2000) recommendations taking into account mature body weight, average daily gain and requirements at any stage of production. Some studies focusing on diets P levels often revealed that there are overfeeding status. Esterman and colleagues (2002) said that suckler cows during lactation assimilate on average a higher phosphorus quantity (44-75 g/day) in comparison to standard values reported on NRC beef requirements (13-23 g/day). These figures are confirmed by Dell'Orto and colleagues (2008) for lactating Limousine cows (42 g/day) and pregnant heifers (24 g/day vs 12-20 g/day reference values). The same circumstance has been remarked for French young bulls reared in Italy passing from 38 to 20 g/day suggested by NRC (2000).

1.3 Environmental impact and beef production

Entering in Google ® website one of these sentences "Carbon footprint", "Water footprint", "Environmental sustainability " rather than "LCA milk" or "LCA meat", thousands of items return to you demonstrating that, in these years and certainly in the future, food products will be produced taking into account environmental issues. Studying the environmental impact of a product or a production system means taking into account one or more systems with whom the product is linked and releases its emissions. Life Cycle Assessment is a powerful tool available to do that because it allows to estimate the environmental impact of beef production system in terms of air, water and soil emissions. The UNI EN ISO 14040 (2006) standard establishes that an LCA study has to be performed considering: goal and scope definition, system boundaries definition, functional unit definition, description of unit processes with input and output data, life cycle inventory collection, life cycle inventory assessment, life cycle assessment interpretation and review. First of all we have to define our system: beef production such as “every human activity aimed at animal growth until slaughtering” (Legge regionale 30 marzo 1988, n.19), then we have to define what environmental impact is. This impact can be simply explained by different impact categories such as global warming potential (GWP) on a 100 years basis, acidification potential (AP) eutrophication potential (EP) cumulative energy demand (CED), ecological footprint (EFP) biodiversity and water footprint.

Wiedmann and Minx, (2008) define GWP as a measure of the exclusive total amount of carbon dioxide emissions that is directly caused by an activity or is accumulated over the life stages of a product.

Acidification potential, which is measured in gSO_2-eq, shows the quantity of gases released into the air and partly put down in the soil or in the groundwater by the system.

Eutrophication potential, which is measured in gPO_4-eq, defines the quantity of nitrogen and phosphorus which the system can release into the groundwater.

Cumulative energy demand, which is measured in MJ-eq, shows the quantity of non-renewable resources consumed by the system.

Ecological footprint, which is measured in m^2-eq, indicates land area used by the system taken away from other human activities.

The presence of agro-ecological indicators such as meadows, hedges and woods, that are very important carbon sinks, favors the maintenance of biodiversity, which is measured in ha-eq.

The water footprint, which is measured in liters, is defined as the quantity of water consumed by the system.

Recently another indicator called Indicateur de Performance Nourricière (IPN) has been introduced in order to take into account farm contribution to the global food safety (Lapierre and Lapierre, 2013). This parameter measures the food potential of farms as the difference between feed inputs and cash crops designed to human beings on the basis of FAO nutritional guidelines.

Some of the various studies, aimed at investigating global warming potential of different beef production systems adopting an LCA approach, are summarized in Table 1.2.

The main differences are to be found in terms of functional unit. Williams (2006), Veysset (2011), Nguyen (2010) and Bonesmo (2013) took animal dead weight into consideration while Ogino (2004) considered, as the majority of studies, animal weight impact. Moreover different animal categories and feeding system affect the final result. Pelletier and her colleagues (2010), on the contrary, analyzed other important impact such as energy use, ecological footprint and eutrophication. It is relevant to outline her findings in cow – calf phase revealing the major source of pollution impact.

Italian LCA studies based on agricultural system such as Barilla (Bevilacqua et al., 2002), Granarolo (Falconi et al., 2006) and COOP Italia (2013) ones were performed and discovered different sources of impact on cereal, dairy produce and beef production. A special commission was entitled by Associazione Scientifica Produzioni Animali (ASPA) "Ecological Footprint e Produzioni Animali" in order to investigate and analyze the main pork, dairy produce, cows and buffalo systems. Their conclusion, out of their figure results, states as follow: among Italian animal origin products young bulls and veal calves turned out to have the highest impact (Figure 1.3).

Emilia Romagna is moving as well towards environmental issues through a project called “CLIMATE CHANGE-R” to estimate the environmental impact of agricultural systems.

The study proposed by Napolitano and colleagues (2009) provides an example of IPN indicator specifically applied to Podolian breeding system used to value its sustainability in terms of human edible protein and energy returns. On the other hand Bagliani and colleagues (2009) have concentrated their analysis on Ecological Footprint of Piedmontese cattle calculating, for two cow-calf case studies, the average land use of 91.5 m^2-eq per kg LW produced. Gac and Bechu (2014) measured the water footprint in four beef production systems and the result was between 20 and 50 liters of H_2O-eq per kg LW.

Figure 1.2. Potential sources of emissions in a beef production system (GES'TIM, 2010)

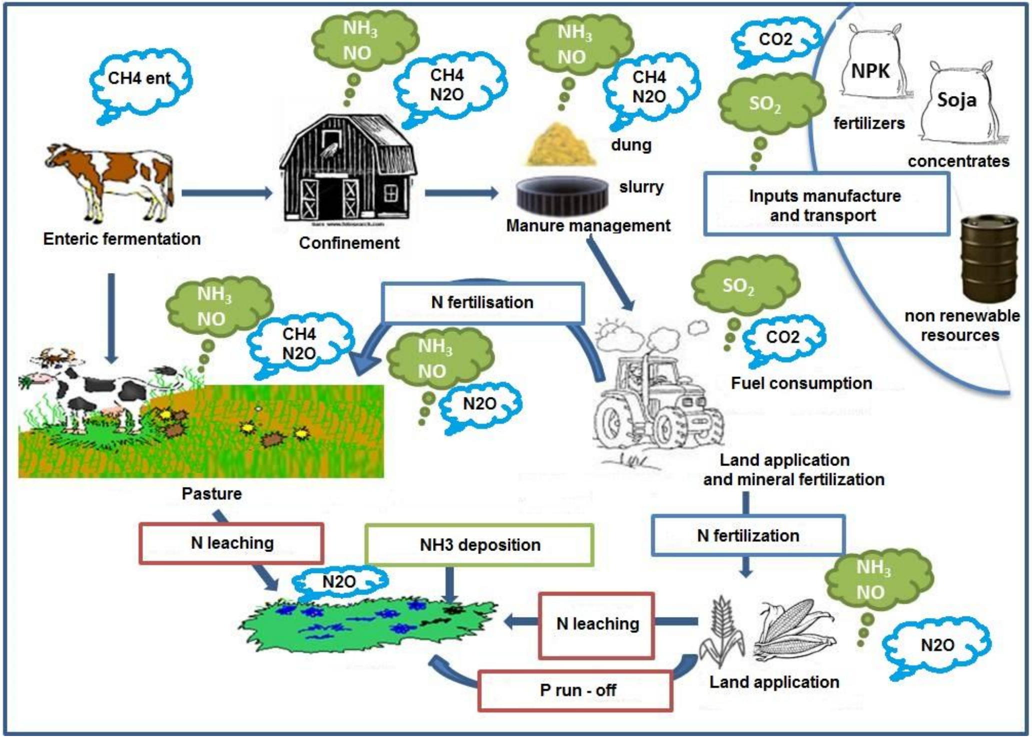


Table 1.1. Enteric CH_4 emission factor (kg head^{-1} year^{-1}) per animal category

Source	Condor, 2011	Vermorel et al., 2008	O'Mara, 2006	Smink et al., 2004
Year of reference	2009	2006	2003	2002
Methodology	*Tier 2*	*Tier 2*	*Tier 2*	*Tier 2*
Country	**IT**	**FR**	**IRE**	**NLS**
Animal category				
Cattle for breeding				
Heifers, 0-to-1 year	23.5	24.1	27.86	34.75
Heifers, 1-to-2 years	61.8	58.3	44.6	52.2
Heifers, 2-to-3 years	83.5	68.2	53.6	
Suckler cows	83.5	77.6	74.2	64.6
Bulls	124.0	76.7	81.5	62.6
Cattle for fattening				
Males 0-to-1 year	23.5	7.8	27.86	40.43
Males 1-to-2 years	56.3	52.4	60.37	60.08
Males over 2 years	not reported	52.3	34.27	
Females 0-to-2 years	44.9	47.9	22.46	49.2

Table 1.2. Global warming potential of the main worldwide beef production systems

Reference	Year	Country	System boundaries	Production system	FU[1]	GWP (100 years-time horizon) FU^{-1}
Subak	1999	Africa	Methane emissions + embodied fuels + carbon sink/loss	Pastoralist	kg beef	8.1
		USA		Feedlot		14.8
Cederberg	2002	Sweden	Cradle to gate	Conventional dairy calves	kg meat	17.0
Ogino	2004	Japan	Cradle to gate	Steers 28 months	Animal	5,959
Williams	2006	UK	Cradle to farm gate	Non organic	1 t dead weight	15,800
				Organic		18,200
				100 % sucker		25,300
				Lowland		15,600
				Hill and upland		16,400
Casey	2006	Ireland	Cradle to farm gate	Suckler beef production	kg LW	7.17 – 11.26
Hacala	2006	France	On-farm emissions + inputs	Extensive mixed system	kg LW	9.0

			+ carbon sink	Calf-to-beef		11.1
				Weaned calves		11.2
				Beef-Eastern		12.21
Vergé	2008	Canada	Farm gate	Beef-Western	kg LW	10.06
				Beef-Canada-wide		10.37
Peters	2010	Australia	Cradle to meat processing plant exit gate	Beef feedlot	kg HSCW	10.2
				Organic beef		11.5
				Feedlot		14.8
Pelletier	2010	USA	Cradle to farm gate	Background/feedlot	kg LW	16.2
				Pasture		19.2
				Sucker cow-calf		27.3
Nguyen	2010	EU	Cradle to farm gate	Young dairy bulls 12 months	kg CW	16.0
				Young dairy bulls 16 months		17.9
				Steers 24 months		19.9
Foley	2011	Ireland	Cradle-to-farm exit gate	National farm survey	kg CW	23.1

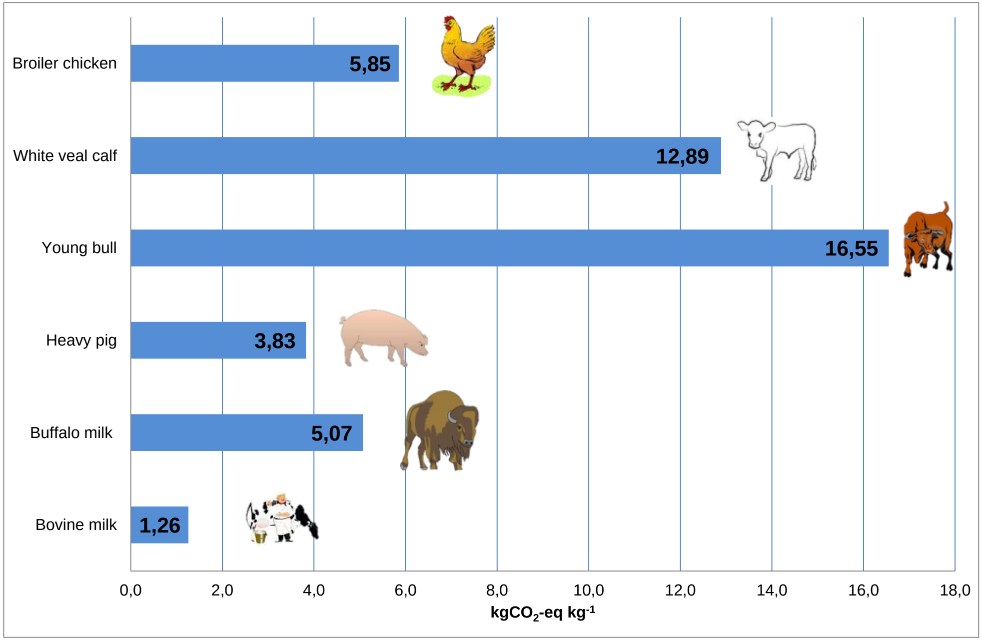
				Steer moderate		19.7
				Steer intensive		22.0
				Bull moderate		18.9
				Bull intensive		20.4
				Calf-to-beef Charolaise		11.5
				Calf-to-beef Limousine		9.0
Dollé	2011	France	Cradle to farm exit gate, carbon sink included	Young bulls	kg LW	10.9
				Calf-to-weanlings Charolais		14.6
				Calf-to-weanlings Limousine		14.6
Veysset	2011	France	Cradle-to-farm exit gate	Calf-to-weanling 100 % grassland	kg CW	17.2
				Calf-to-beef steers		16.9
				calf -to-beef baby beef		14.9
Lieffering	2012	NZ	Farm-to-meat consumption (consumer waste stages	Beef cow	kg LW	16.1
				Bull 22 months 574 kg		7.3

			included)	LW		
				Heifer 22 months 424 kg LW		8.5
Alig	2012	Switzerland	Cradle-to-farm gate (land use change included)	Conventional bull fattening	kg LW	8.8
				Conventional suckler cow		14.6
				Organic suckler cow		15.2
Lartategui-Arias	2012	Spain	Cradle to grave	Intensive	t meat ready to eat	5,060 – 6,184
				Extensive		8,015
				Semi-extensive		7,389
Nguyen	2012	France	Cradle to farm-gate	Standard bull fattening maize silage	kg CW	27.8
				Bull fattening maize silage + linseed		27.7
				Bull fattening fibre based diet		27.9

				Bull fattening concentrate + linseed		27.0
Bonesmo	2013	Norway	Cradle-to-farm gate (C soil changes included)	Young bulls	kg CW	17.25
				Culled cows and heifers		21.67

LW = live weight; CW =carcass weight; HSCW =hot standard carcass weight

Figure 1.3. Global warming potential of the main Italian cattle productions (Bava et al., 2014; Cesari et al., 2015; COOP ITALIA, 2013; Pirlo et al., 2013; Pirlo et al., 2014)



1.4 Worldwide beef production

The main beef producers in the world are the United States of America (19 % on the total) followed by Brazil (14 %), Europe (13 %) and China (9 %). The produced meat derives from beef specialized heads but also from both dairy and cull cows that are relevant in particular in Europe and Australia as shown on Table 1.3 (http://www.fas.usda.gov/). Another classification parameter is based on the average suckler cows attendance compared to the total cows number. Milk countries, mixed countries and beef countries can be distinguished. In Argentina, Australia, Canada, China and USA, there is the higher percentage of beef cows so these countries belong to the last typology; India does not breed beef but only dairy cows; Brazil and Europe are considered mixed countries. Beef specialized farms are typified also by different production systems. Deblitz and colleagues (2005) have identified some typical beef sample farms characterized by number of heads and by breeding method. Argentinian, Brazilian and American farms location permits to manage a large number of cattle in feedlot while small-scale European farms mostly use an intensive method based on maize silage plus purchased concentrates.

Table 1.3. Worldwide beef market trends in 2011 (source: http://www.fas.usda.gov/)

	AR	AU	BR	CA	CN	EU-27	IN	US
Meat production, 000 tonnes CW-eq	2,500	2,140	9,030	1,155	5,550	8,050	3,060	12,048
Total slaughter, 000 heads	11.600	8.580	40.205	3.391	40.680	28.230	35.000	34.222.000
Cow slaughter, 000 heads	2.900	3.300	11.170	535	-	11.850	1.225	6.800
Cow slaughter, %	25	38	28	16	-	42	4	0
Total cows, .000 heads	22.100	15.120	90.345	5.213	59.740	35.428	129.350	39.996
Beef cows, .000 heads	20.000	13.500	52.669	4.228	46.200	12.306	-	30.846
Beef cows, %	90	89	58	81	77	35	-	77

1.5 Beef production system in Italy

The Italian agriculture produced in 2011 a turnover of about 50 million euros, a third of which came from animal breeding almost exclusively from meat and dairy chain. The beef sector has provided 1 million tons meat deriving from the following beef categories: young bulls 604 kg average LW (50 %), heifers 500 kg average LW (18 %), cull cows 570 kg average LW (14 %), veal calves 250 kg average LW (12 %) (INEA, 2012). As pointed out in Figure 1.4 cattle breeding represents the 30 per cent of Italian animal productions; it has been subjected to a decline during the years, with the lowest pick registered in 2001 because of BSE effect (1st case in Italy as reported by Marabelli, 2003) and consequently to a change in food habits reducing red meat consumption which is considered responsible of cardiovascular diseases and cancers (MacAfee et al., 2010). A further decrease has been found out in the following years after the European Union imposition concerning environmental pollutants limits that cattle herds have to respect.

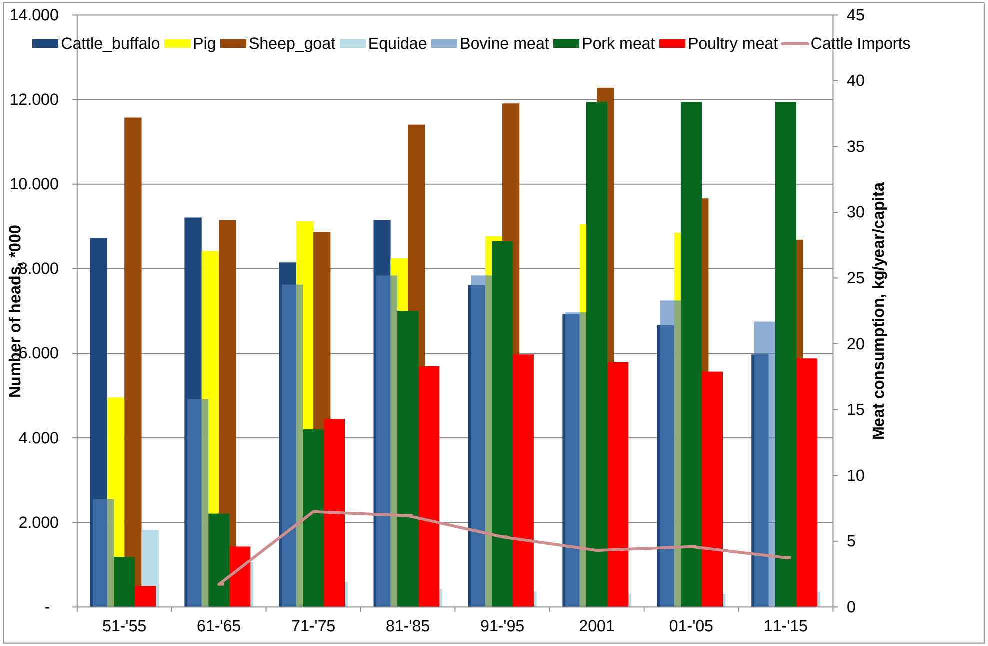


Figure 1.4. Trends of Italian livestock productions. (Amadei, 2003)

Table 1.4. Live cattle attendance per area in 2011

	Number of live animals
Piemonte	**782.006**
Valle d'Aosta	33.372
Lombardia	**1.461.758**
Trentino Alto Adige, BZ	132.209
Trentino Alto Adige, TN	45.010
Veneto	**742.549**
Friuli Venezia Giulia	85415
Liguria	13.862
Emilia Romagna	**559.162**
Toscana	84.209
Umbria	55.388
Marche	51.987
Lazio	209.653
Abruzzo	66.236
Molise	43.889
Campania	174.783
Puglia	163.803
Basilicata	87.872
Calabria	104.699
Sicilia	339.055
Sardegna	258.155
Italy	**5.494.603**

Data provided by BDN dell'Anagrafe Zootecnica istituita dal Ministero della Salute presso il CSN dell'Istituto "G. Caporale" di Teramo

Bovine herd is essentially concentrated in the Po Valley district (Table 1.4) that is characterized by two different production systems: milk and meat.

Italy counted in 2011 35.255 dairy farms of which 17.704 farms were located in the Po Valley area.

The main Northern Italy dairy production systems are:

a. Grana Padano cheese PDO (5.359 dairy farms, 24.842.491 quintals of milk processed equal to 4.658.957 cheese wheels) (Bocchi, 2015);

b. Parmigiano Reggiano cheese PDO (3.500 dairy farms, 17.423.000 quintals of milk processed equal to 3.231.000 cheese wheels) (Ufficio Piani Produttivi Parmigiano Reggiano, 2015);

Except for dairy cull cows the main Italian beef production systems are:

a. white veal calves;
b. fattened young bulls and heifers;
c. cow – calf system.

a. White veal calves production system

Veal production is mainly diffused in milk production area, particularly in Veneto and Lombardia that include about 60 % of males 0-to-1 year at national scale largely coming from dairy herd (Table 1.6). Dairy calves are usually sold to fattening units where they are fed a milk powder based diet until slaughtering. Dairy calves are fattened for a 160 - 190 d period and they are slaughtered at 260 – 320 kg LW. This category involves about 845.000 heads, the 24 percent of national slaughtered animals (INEA, 2012).

b. Fattened young bulls and heifers

Young bulls are the most relevant beef product with about 2 million heads slaughtered in 2011 of which 45 percent came from other countries and the remaining 55 percent of national origin (Rama, 2012). The fattening of weaners imported from France is certainly the main beef production system in the Northern Italy district as revealed by Italian BDN available data about live animals imports. French livestock represents 74 % of the national imports of which 94 % is concentrated in the Po Valley area (Figure 1.6 and 1.7). Massif Central is the main source of this input category with 4 of 5 weaners exported abroad of which 80 % for the Italian market (Sanne et al., 2013). This system consists of two stages, the French grass-based one that produce 11 months aged weaned calves followed by the Italian intensive one in which animals are generally finished with corn silage plus concentrate mix based diets.

On the contrary the fattening of Piedmontese young bulls and heifers is characterized by a short weanlings period in comparison to French – Italian beef production chain. The first step aimed to produce 180 – 220 kg LW weaners ranging from 4-to-6 months. In this period animals are fed breast milk and increasing amount of solid feeds while fattening specialized units provide protein and energy diets according to animal physiology and requirements where a key role is assumed by maize concentrate mix rather than forage source (http://www.anaborapi.it).

Figure 1.6. Live cattle imports in Italy (year 2011).

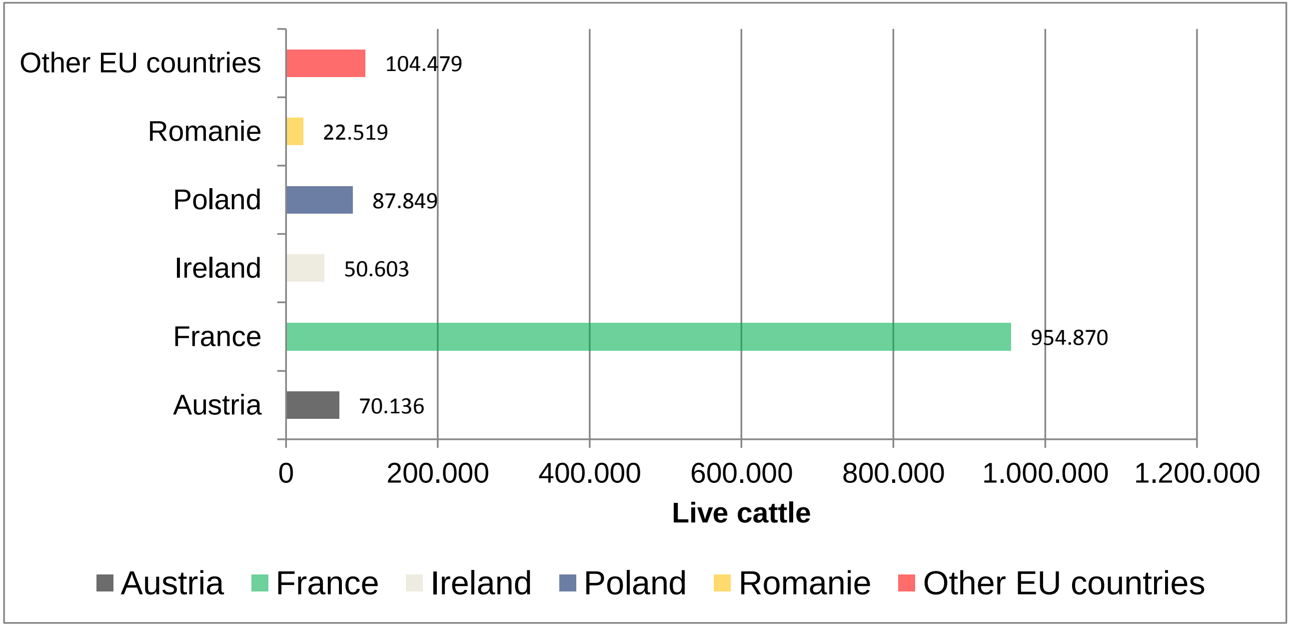
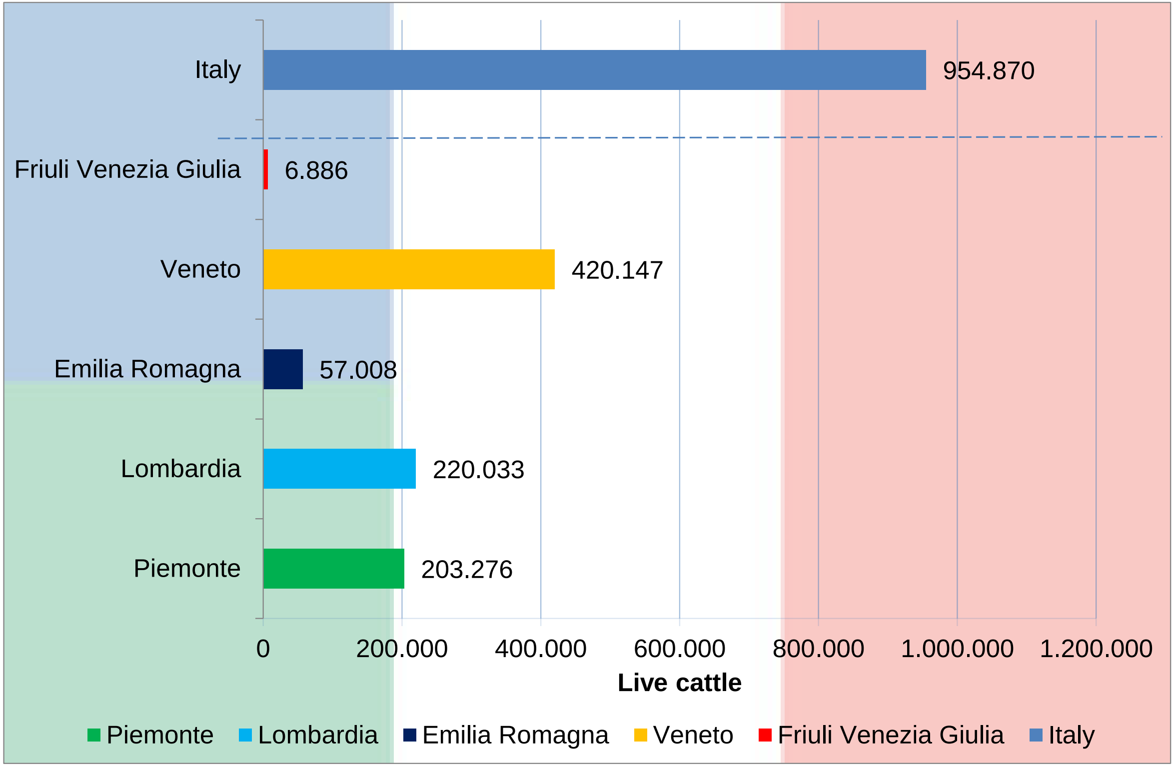


Figure 1.7. Live cattle imports from France per area (year 2011)



Cow calf system

Cow – calf production system, so called closed loop system, breeds the animal from cradle to slaughtering according to an extensive system based on pasture with addition of concentrates. Young bulls are fattened for a 650 d period and they are slaughtered at 650 kg LW. Amadei (2003) reported that this system prevailed in Central Italy. In Po Valley district cow – calf farms are mainly located in Piemonte, Lombardia and Emilia Romagna that account respectively for 21 %, 7 %, 2 % of national suckler cows as reported by BDN.

The Italian beef production system is typified by a great number of small farms in which, in addition to beef production, other animal categories are reared and cash crops are cultivated. The biggest fattening units with more than 500 heads per farm are located in Veneto, Piemonte and Lombardia while Emilia Romagna units are characterized by a little size, from 20 to 49 heads per farm (Table 1.5). Most of the cattle, about 70 % at national scale, is placed in the Po Valley district.. The males 0-to-1 year old, so called white veal calves, are reared in Lombardia (29 %) and Veneto (28 %) but this animal category is well represented also in Piemonte (18 %). As regard to males 1-to-2 years old and females 1-to-2 years old for slaughter Veneto is the cradle of fattening production system with respectively 41 % and 22 % of heads reared in specialized beef farms. Suckler cows are mainly located in Piemonte (Table 1.6).

Table 1.7 shows the distribution of male cattle per age and breed in the Po Valley district.

Piemontese breed is the most represented in Piemonte with about 55 thousands heads from 0-to-11 months and 30 thousands heads from 1-to-2 years. It is possible to suppose that the first are reared in cow-calf (weaner) units, the second ones in stockers units. French cross-breeds represent, after the Piedmontese one, the most representative breed. It is possible to suppose that the majority of heads is imported for fattening. Friesian dairy calves are fattened to become white veal calves.

In Emilia Romagna, Lombardia and Veneto, Friesian breed is the most representative. French cross-breeds, in particular Charolaise breed, from 1-to-2 years are in a higher number in comparison to 0-to-11 months heads. For this reason it is possible to suppose that many heads have been imported for fattening. In Emilia Romagna the Romagnola breed, typical of this area, is fairly widespread.

Table 1.8 shows the distribution of female cattle per age and breed in the Po Valley district.

The Friesian dairy cows prevail on the other breeds. In Piemonte the Piedmontese breed is reared in beef specialized units (cow-calf production). On the contrary French cross-breeds are reared in Lombardia and Veneto for fattening.

Figures reported in Table 1.9 show a significant reduction in specialized beef farms with a negative trend on French cattle imports too. This situation could be explained by the high production cost to produce young bulls, determined largely by feed inputs, in particular maize and soybean meal, and by fuel consumption. Montanari and colleagues (2012) have highlighted these issues investigating economical performances of Italian beef farms.

Table 1.5. Distribution of farms specialized in beef production per area and size.

	Farm size, n heads							
	1-to-2	3-to-5	6-to-9	10-to-19	20-to-49	50-to-99	100-to-499	+ 500
Piemonte	1.800	1.549	1.208	1.609	2.140	1.350	1.245	62
Emilia Romagna	866	622	360	447	433	180	108	25
Friuli Venezia Giulia	383	195	82	49	46	20	23	5
Veneto	3.641	1.612	712	593	565	414	834	200
Lombardia	3.080	1.597	775	684	608	349	477	157
Valle d'Aosta	7	3	2	1	1	1		
Trentino Alto Adige, BZ	14	6	7	7	6	2	1	
Trentino Alto Adige, TN	110	86	31	41	20	8	16	2
Liguria	273	154	89	78	80	35	12	1
Marche	1.322	481	274	374	397	139	51	
Umbria	1.033	430	278	331	338	103	52	
Toscana	1.216	568	349	382	493	194	98	6
Lazio	3.369	1.525	820	891	788	292	137	5
Abruzzo	1.429	623	420	449	373	100	31	1
Puglia	404	285	173	280	343	159	64	1
Molise	552	350	281	344	236	50	9	1
Basilicata	338	312	267	395	362	163	70	1
Campania	2.308	1.266	820	1.034	826	233	59	
Calabria	1.378	931	633	838	762	210	47	2
Sicilia	771	942	907	1.685	2.357	1.044	365	6
Sardegna	1.039	1.270	1.175	1.642	1.865	750	251	
Italy	25.335	14.808	9.664	12.153	13.041	5.795	3.950	471

Data provided by BDN dell'Anagrafe Zootecnica istituita dal Ministero della Salute presso il CSN dell'Istituto "G. Caporale" di Teramo

Table 1.6. Distribution of live animals in farms specialized in beef production (year 2011).

Livestock category	Piemonte	Emilia Romagna	Veneto	Lombardia	Italy
Males 0-to-1 year	112.713 18 %	18.820 3 %	171.978 28 %	176.607 29 %	617.180
Males 1-to-2 years	92.747 23 %	23.548 6 %	166.206 41 %	51.356 13 %	410.208
Males +2 years	5.918 13 %	1.543 3 %	2.681 6 %	2.829 6 %	46.217
Females 0-to-1 year	68.229 24 %	11.540 4 %	46.504 16 %	33.431 12 %	285.280
Females 1-to-2 years	49.876 18 %	14.361 5 %	61.107 22 %	51.748 19 %	278.263
Heifers	17.255 12 %	3.520 2 %	5.331 4 %	6.725 5 %	145.207
Suckler cows	167.020 21 %	18.138 2 %	14.348 2 %	57.529 7 %	796.838
Live cattle	786.375 14 %	559.470 10 %	751.059 14 %	1.470.301 27 %	5.534.754

Data provided by BDN dell’Anagrafe Zootecnica istituita dal Ministero della Salute presso il CSN dell’Istituto “G. Caporale” di Teramo

Table 1.7. Distribution of male cattle per age and breed in the Po Valley district

		Males	
	Breed	0-to-11 months	12-to-24 months
Piemonte	Friesian	23.897 (**17 %**)	2.665 (**3 %**)
	Blonde d'Aquitaine	21.343 (**16 %**)	21.440 (**20 %**)
	Piemontese	54.857 (**40 %**)	30.138 (**28 %**)
	Limousine	7.005 (**5 %**)	24.137 (**23 %**)
	Charolaise	3.178 (**2 %**)	15.039 (**14 %**)
Emilia Romagna	Friesian	14.035 (**44 %**)	3.178 (**11 %**)
	Charolaise	2.671 (**8 %**)	12.318 (**42 %**)
	Limousine	1.917 (**6 %**)	2.305 (**8 %**)
	Romagnola	1.930 (**6 %**)	1.672 (**6 %**)
Veneto	Aubrac	2.017 (**1 %**)	11.733 (**6 %**)
	Friesian	38.285 (**20 %**)	2.834 (**1 %**)
	Charolaise	22.396 (**11 %**)	80.385 (**43 %**)
	Limousine	17.193 (**9 %**)	27.023 (**14 %**)
Lombardia	Friesian	164.013 (**69 %**)	26.889 (**34 %**)
	Charolaise	4.759 (**2 %**)	19.092 (**24 %**)
	Limousine	8.545 (**4 %**)	17.179 (**22 %**)

Data provided by BDN dell'Anagrafe Zootecnica istituita dal Ministero della Salute presso il CSN dell'Istituto "G. Caporale" di Teramo

Table 1.8. Distribution of female cattle per age and breed in the Po Valley district

	Breed	Females 12-to-23 months	24-to-35 months	Over 36 months
Piemonte	Blonde d'Aquitaine	3.785 (4 %)	281 (0 %)	1.503 (1 %)
	Charolaise	1.001 (1 %)	117 (0 %)	174 (0 %)
	Friesian	33.321 (34 %)	32.119 (48 %)	72.632 (26 %)
	Limousine	4.999 (5 %)	388 (1 %)	2.424 (1 %)
	Piemontese	36.393 (37 %)	21.585 (32 %)	136.560 (49 %)
Emilia Romagna	Charolaise	3.338 (4 %)	152 (0 %)	445 (0 %)
	Friesian	64.294 (69 %)	64.767 (80 %)	173.933 (75 %)
	Limousine	2.991 (3 %)	668 (1 %)	4.554 (2 %)
	Romagnola	1.516 (2 %)	809 (1 %)	6.490 (3 %)
Lombardia	Charolaise	17.415 (7 %)	782 (0 %)	882 (0 %)
	Friesian	182.300 (71 %)	167.255 (87 %)	393.083 (82 %)
	Limousine	10.751 (4 %)	967 (1 %)	4.592 (1 %)
Veneto	Charolaise	22.153 (19 %)	1.005 (2 %)	599 (0 %)
	Friesian	38.265 (33 %)	36.219 (68 %)	93.854 (66 %)
	Limousine	12.146 (11 %)	567 (1 %)	2.363 (2 %)

Data provided by BDN dell'Anagrafe Zootecnica istituita dal Ministero della Salute presso il CSN dell'Istituto "G. Caporale" di Teramo

Table 1.9 Trends of farms specialized in beef production

	2006	2011	2013
Specialized beef farms, n	97.895	90.299	88.601
		- 8 %	**- 10 %**
Live cattle imports from France, n	1.078.972	954.870	845.766
		- 12 %	**- 22 %**

Data provided by BDN dell'Anagrafe Zootecnica istituita dal Ministero della Salute presso il CSN dell'Istituto "G. Caporale" di Teramo

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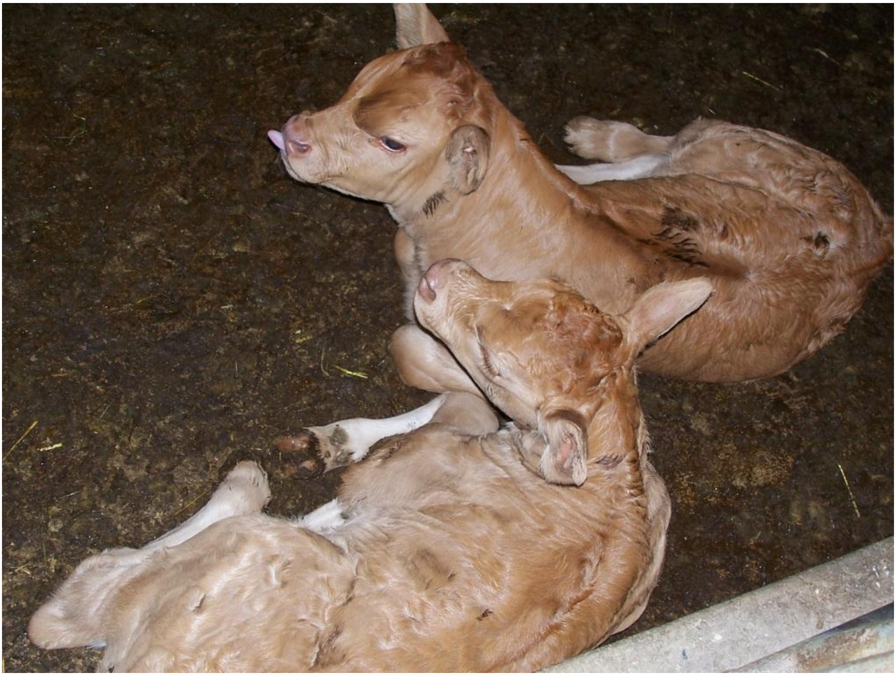
Chapter 2

Aim



2.1 General purpose

Objective of this study was to estimate the environmental impact of the main Italian beef production systems with a Life Cycle Assessment (LCA) approach.

2.2 Specific purposes

- Identify a French cow-calf (weaner) case study to estimate the environmental impact of the French – Italian beef cattle production system;
- Define a target to estimate the global warming potential and other impacts of beef cattle;
- Identify, through sensitive analysis, feeding practices for beef cattle GWP mitigation.

Chapter 3

Materials and methods

3.1 Materials

A sample of 30 farms was identified to define the main Northern Italy district beef production systems. According to the data of the National livestock register for Teramo representative case studies were found out thanks to some Breeders Associations rather than beef chain actors. The analyzed sample farms can be firstly divided in three main systems: fattening, cow-calf and dairy production. The first aims to fatten purchased weaners as soon as possible, the second aims to produce the largest possible number of weaners who will be partially used for replacement and partially for fattening, the third contains a dairy cow – calf producer who maintains a herd for milk production but also calves for sale who will become white veal calves in a stocker unit.

The fattening system includes French – Italian (F-I) and Piedmontese (P) chains. Suckler calf (SC) and calf-to-beef (CB) groups belong to cow – calf system while white calves (WC) are contained in dairy production system (Table 3.1).

All the groups referred to the first system are characterized by intensive farming. They show a high stocking rate, in particular French-Italian stockers. Maize silage represents the main forage source even if feed self – sufficiency is low due to the great amount of purchased inputs. Production cycle depends by the consumers' needs, for this reason there is a difference between F-I and P chains: French weaners are sold to F - I stockers older than Piedmontese ones.

As regard to cow-calf system calf-to-beef farms are characterized by a higher usable agricultural area in comparison to stockers as a part of this land is used for animal pasture. Fattened heads number is considerably lower while final LW is gained in a slightly longer period of time. The cow-calf (weaner) farms show a better birth rate in comparison to the extensive cow-calf sample farms.

Dairy cow – calf producer area is completely destined for animal feed of which a half as maize fodder. The white calves stockers fatten veals for a very shorter period with no land used for animal feed. The ration is based on milk powder and commercial grain mixture.

The Piedmontese (P) cow-calf (weaner) case study shows a better performance than French cow-calf (weaner) and suckler – calf ones in terms of weaned, sold heads.

Table 3.1. Main structural indicators of the Northern Italy beef production systems

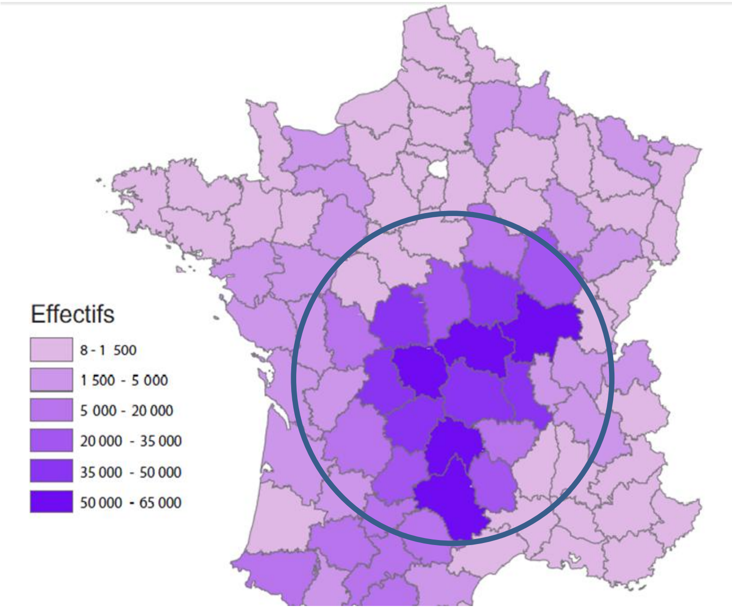
Production system	Fattening				Cow-calf		Dairy production	
Group	F-I		P		SC	CB	WC	
	Cow-calf (weaner)	Stockers	Cow-calf (weaner)	Stockers			Dairy cow-calf	Stockers
Farms, n.	1	10	1	3	3	9	1	4
UAA, ha	100	67 ± 26	752	30 ± 13	65 ± 26	74 ± 34	100	12±3
MFA, ha	90	37 ± 18	752	15 ±4	20 ± 8	47 ± 41	100	-
Maize MFA^{-1}, %	0	78.0 ± 26.0	1.0	31.0 ± 28.0	43.0 ± 9.0	23.0 ± 33.0	50.0	-
Feed self sufficiency, DM %	93.0	59.0 ± 21.0	81.0	69.0±8.0	96.0 ± 2.0	87.0 ± 21.0	64.0	-
Stocking rate, LU ha^{-1}	1.16	4.87 ± 6.30	0.3	3.20 ±1.50	1.08 ± 0.53	1.37 ± 1.08	2.20	25.1 ± 18.8
Birth rate, n cow^{-1} $year^{-1}$	0.91	-	0.89	-	0.77 ± 0.14	0.77 ± 0.16	0.78	-
Finished animals sold, n $year^{-1}$	51	626 ± 487	149	82 ±33	33 ± 6	21 ± 15	72	715 ± 378
Finished animals LW production, kg $head^{-1}$	362	317 ± 52	161	444 ±40	228 ± 43	609 ± 83	50	219 ± 18
Production cycle, d	335	221 ± 18	180	415 ± 15	222 ± 56	512 ± 64	-	205 ± 10

F-I French- Italian chain; **P** Piedmontese chain; **SC** Suckler - calf farms; **CB** Calf-to-beef farms; **WC** White veal calves
UAA Usable Agricultural Area; MFA Main Forage Area; LU Livestock Unit; LW Live weight

3.1.1 The French – Italian beef production chain

The study involves 10 stockers units located in Veneto and on the boundary between Lombardia and Emilia Romagna specialized in young bulls production. A French case study was used to get information about the main cow – calf system, based on grass, exporting weaners to Italy (Figure 3.1 and 3.2). To emphasize production system main features a questionnaire was prepared in detail according to Associazione Italiana Allevatori guidelines (AIA, 2008). Thanks to breeders' answers, a 2011 reference year dataset collection has been produced. It contained information about farm size, machinery tractors and operators, land use, animal feeding system and productivity, animal manure management system including land application.

Figure 3.1. French cow - calf case study location (Institut de l'Elevage, 2013)



Cow-calf (weaner) case study based on grass with production of Charolaise weaners located in Bourgogne district

Figure 3.2. French – Italian stockers location

Herd size and performances

Young bulls of 680 kg of live weight slaughtered at 18 months represent the output of the goal system. The calf spends two-thirds of its life cycle into the French cow-calf farm reaching 410 kg of live weight and it's later sold for an income of about 700 € per head to Italian sample farms to gain the slaughter weight. French cow – calf case study is characterized by a high usable agricultural area of which the majority is represented by grassland while Italian intensive farms are identified by a high stocking rate in terms of livestock units (Table 3.1).

Table 3.1. Profile of the French Italian beef specialized sampled farms

Item	F-I Cow-calf (weaner)	F-I Stockers
Farms, n.	1	10
UAA, ha	100	67±26
MFA, ha	90	37±18
MFA UAA^{-1}, %	90	62±30
Maize MFA^{-1}, %	0	78±26
LU, n	116	223±156
Stocking rate, LU ha^{-1}	1.16	4.87±6.30
Herd replacement, %	21	-
Finished animals sold, n year^{-1}	51	626±487
Finishing animals LW, kg head^{-1}	410	679±52
LW production, kg head^{-1}	362	317±52
Production cycle, d	335	221±18
Purchase price,€ head^{-1}	-	1.071±104
Sale price, € finishing animal^{-1}	667	1.817±238

F-I French Italian beef production chain
UAA Usable Agricultural Area; MFA Main Forage Area; LU Livestock Unit

Land use

Maize silage is the main forage source in Po Valley stockers sample farms while wheat prevails among crops to produce grain usually sold and straw rolled bales used such as feedstuffs and bedding material. The remaining portion of crops (20 %) is destined for tomato production and other vegetable crops. The main forage area of the French case study consists of meadow and alfalfa. Crops are completely destined for sale, there is no maize production (Table 3.2).

Table 3.2. Main structural indicators of the French – Italian specialized beef farms

Item	**F-I**	
	Cow-calf (weaner)	Stockers
Farms, n	1	10
MFA, ha	90	37±18
Maize silage, %	-	62±25
Maize ear, %	-	50±88
Alfalfa, %	20	33±45
Meadow, %	80	3±8
Crops, ha	10	31±27
Maize grain, %	-	13±26
Wheat, %	50	41±37
Barley, %	25	2±5
Other, %	25	13±21
Cereal crops used in farm crops^{-1}, %	0	14±26
Cash crops crops^{-1}, %	100	46±40
Feed self-sufficiency, DM %	93	59±21

F-I French Italian beef production chain
MFA Main Forage Area
Where sd > mean it means that in some case studies fodder/crop area lack

Feeding system

In the first stage of life French calves are fed a pasture based diet (Table 3.3) with introduction of hay at the end of cycle (8-to-11 months) to prepare animals to the intensive diet provided by Italian stockers.

The 2-months-old calves for replacement consume minute amounts of hay and wheat grain in addition to mother’s milk. In the following 7 months the mother’s milk quantity decreases in favor of the solid feed increase. Then heifers, until they become mature cows, begin to consume a diet consisting of meadow hay as forage source combined with rapeseed meal and wheat grain during winter season. A grass based diet is provided in the summertime.

Italian finishing diets are formulated on live weight basis. As a rule, feeding system is divided in two or more phases. Diets are usually fed as total mixed rations made of maize silage plus maize grain as energy input and soybean meal rather than a commercial concentrate mix as protein supplement (Table 3.4).

Table 3.3. Weaners diet composition (kg DM head^{-1})

Feedstuff	0-to-8 months	8-to-11 months
Hay	539	813
Grass	1609	-
Rapeseed meal	22	65
Wheat grain	68	199
Mineral - vitamin mix[1]	-	13
Milk, kg/head/d	7,2	-
Production cycle, d	243	92
Time spent in the barn, %	25	100

[1]$CaCO_3$ 61 %, $Ca(H_2PO_4)_2$ 11 %, $CaHPO_4$ 19 %, molasses 6 %, vitamines 1 %, Se 0.5 %, Zn 0.2 %

for Fodder and Pasture DM intake see *CAP2ER* methodology

Table 3.4. Ingredient proportions in finishing diets provided by stockers (kg DM $head^{-1}$)

Farms, n	10
Feedstuffs	
Hay	116±24
Maize silage	1217±323
Maize mash	92±182
Wheat straw	228±77
Maize grain	652±547
Maize distillers	42±77
Soybean meal 48 % CP	137±148
Soybean meal 44 %CP	22±66
Barley grain	16±52
Wheat bran	8±25
Sunflower seed	11±35
Concentrate mix 15% CP[1]	9±30
Concentrate mix 16% CP[2]	195±471
Concentrate mix 17% CP[3]	113±356
Concentrate mix 23% CP[4]	170±365
Concentrate mix 27% CP[5]	82±172
Production cycle	221±19

[1] wheat bran 28%, maize grain 24%, maize germ 17%, sunflower seed 12%, wheat middling 7%, soybean meal 3%, beet molasses, maize cob 3%, mineral salts 3%

[2] maize grain 40%, maize germ 10%, wheat bran 10%, sunflower seed 10%, soybean meal 8%, wheat middling 8%, barley 5%, beet pulps 3%, beet molasses 3%, mineral salts 3%

[3] maize grain 27%, corn gluten feed 20%, maize germ 15%, wheat bran 10%, soybean meal 10%, sunflower seed 10%, sugarcane molasses 5%, mineral salts 3%

[4] rice husks 40%, corn gluten feed 37%, sunflower seed 23%

[5] sunflower seed 30%, corn gluten feed 20%, cocoa hulls 20%, soybean meal 15%, wheat bran 5%, beet vinasse 5%, mineral salts 5%

for Fodder and Pasture DM intake see *CAP2ER* methodology

Where sd > mean it means that in some case studies fodder/crop area lack

Housing and manure management

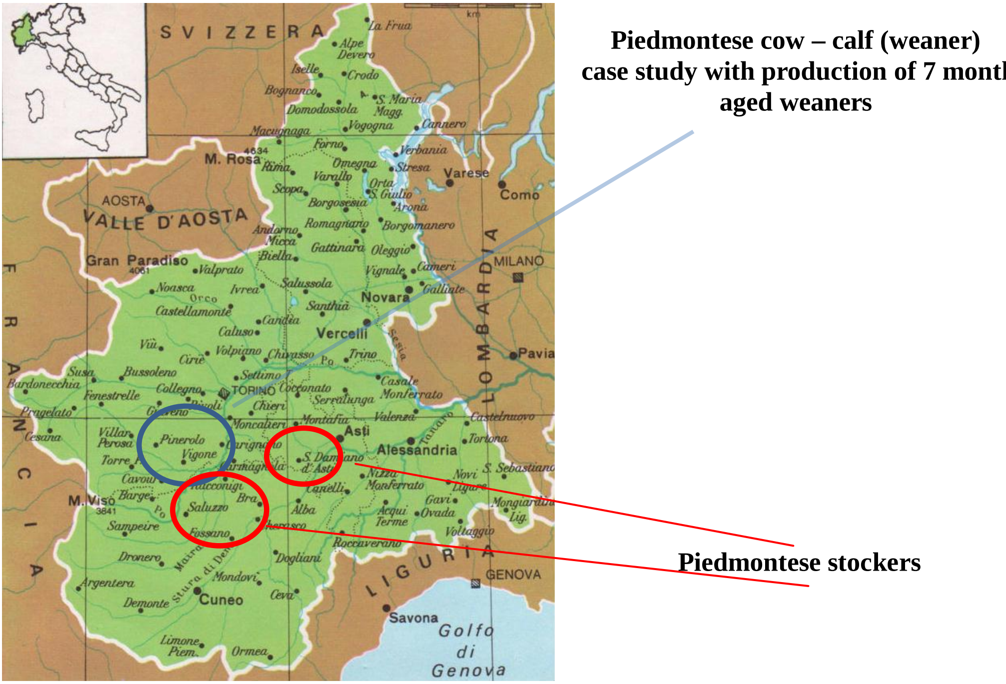
All the animals of the French cow-calf case study are reared on bedding material and solid manure is used to fertilize farm land area.

Stockers stables have concrete slatted floors or flat or sloping full floors. In the first situation slurry is produced, in the other case solid manure (bedding material in addition to manure) is produced and handled in piles.

3.1.2 The Piedmontese fattening production chain

Piedmontese fattening beef production chain is a typical beef production system concentrated in Piemonte district. This section is especially focused on life cycle of young bulls and heifers for fattening. They are born in a cow –calf system specialized in weaned calves production and then finished in Piedmontese stockers. The cow – calf case study is located in the blue coloured area while stockers are marked with red coloured circles (Figure 3.3). The three chief representative sampled finishing farms and the cow-calf (weaner) case study were highlighted thanks to the help supplied by ASsociazione PROduttori CARNE (ASPROCARNE) Piemonte and Associazione NAzionale BOvini di RAzza PIemontese (ANABORAPI)

Figure 3.3. Location of Piedmontese fattening production chain case studies



Herd size and performances

The cow – calf sample farm is characterized by a large area of which only a little portion was used to produce maize. Its aim is to produce weaned calves but also cattle for replacement. Each cow gives birth to 0.89 calves per year, with an age, at first calving, of 33 months (Table 3.5).

Table 3.5. Profile of Piedmontese fattening production chain

	P		
Item	**Cow-calf(weaner)**	**Stockers**	
Farms, n	1	3	
UAA, ha	752	30±13	
MFA, ha	752	15±4	
Maize MFA^{-1}, %	1.0	31±28	
Suckler cows, n	199	-	
Calves born, n year^{-1}	178	-	
LU, n	218	88±52	
Stocking rate, LU ha^{-1}	0.3	3.2±1.5	
Herd replacement, %	6	-	
First calving, months	33	-	
Finishing animals sold, n year^{-1}	149	82±33	37±24
Finishing animals LW, kg head^{-1}	200	639±40	456±21
LW production, kg head^{-1}	161	444±40	292±45
Production cycle, d	180	415±15	340±57
Sale price, € finishing animal^{-1}	1.065	2.087±338	1743±186

P Piedmontese fattening production chain
UAA Usable Agricultural Area; MFA Main Forage Area; LU Livestock Unit;
Stockers finished animal performances are referred to young bulls (left-column) and heifers (right-column)

Land use

Fattening units are typified by a low usable agricultural area, that is represented for a great portion by forage area. These units also show a higher stocking rate in comparison to the cow-calf (weaner) case study. Young bulls are slaughtered at 640 kg LW while heifers are fattened to reach an average final LW of 460 kg.

Meadows prevail in the cow – calf (weaner) farm where each animal category except for calves is subjected to pasture in summer. In fattening farms meadows are in association with maize silage and maize mash from grains and ears (Table 3.6). The main crops are maize and wheat grain, the former is used as the energy component of the ration, the latter as feedstuff and as bedding material in the form of straw.

Table 3.6. Main structural indicators of the Piedmontese specialized beef farms

Item	P	
	Cow-calf (weaner)	**Stockers**
Farms, n	1	3
MFA, ha	752	22±14
Maize silage, %	1	21±19
Maize mash, %	-	19±32
Meadows, %	99	54±8
Crops, ha	-	15±10
Maize grain, %	-	50±50
Wheat, %	-	26±25
Barley, %	-	-
Other, %	-	24±41
Cereal crops used in farm crops^{-1}, %	-	50±50
Cash crops crops^{-1}, %	-	83±29
Feed self-sufficiency, DM %	81	69±8

P Piedmontese fattening production chain
MFA Main Forage Area
Where sd > mean it means that in some case studies fodder/crop area lack

Feeding system

In table 3.7 are contained information about feeding system of Piedmontese cattle until weanlings. A 50:50 hay : concentrate based diet is supplied to calves that are kept in the barn for the 180-d entire cycle. Once arrived in the fattening units animals are fed maize silage based diet at the beginning and hay plus concentrate in the finishing period. As regards cattle for replacement from 8 months to the 1st birth (33 months) and suckler cows reared in the cow-calf unit, the feeding plan is based on a 50: 50 maize silage : hay diet with a maize grain supplement during winter season. During summertime the herd is subjected to pasture. In this period grass : maize silage ratio increases by degrees in order to gain a 100 % grass diet (Table 3.8).

Table 3.7. Analytical composition of diets provided to cattle for fattening

	P		
	Cow-calf(weaner)	Stockers	
Farms, n	1	3	
Feedstuff, kg DM head^{-1}		YB	H
Hay	392	-	-
Concentrate mix 13 % CP [1]	401	-	-
Milk, kg head^{-1} d^{-1}	7.2	-	-
Ryegrass	-	131±227	68±118
Meadow hay	-	1679±1379	1020±808
Maize silage	-	697±657	133±231
Maize mash	-	291±503	147±255
Straw	-	193±334	97±169
Maize grain	-	203±352	219±379
Concentrate mix 14% CP[2]	-	958±926	-
Concentrate mix 24% CP[3]	-	481±470	876±190
Production cycle, d	180	415±15	340±57

[1]Maize grain 20 %, barley grain 18 % corn flakes 10 %, sunflower seed extracted 8 %, soybean meal 8 %, faba bean 8 %, bran 8 %, sugar cane molasses 5 %, dehydrated beet pulp 5 %, rice husks 5 %

[2] maize grain 30%, barley 18%, broad bean 8%, soybean meal 8%, sunflower seed 6%, rice middling 6%, dehydrated beet pulps 6%, corn gluten feed 4%, sugarcane molasses 3%, mineral salts 3%

[3] wheat bran 42%, soybean meal 25%, beet pulps 8%, barley 8%, sunflower seed 8%, sugarcane molasses 3%, oil 3%, mineral salts 3%

for Fodder and Pasture DM intake see *CAP2ER* methodology

Where sd > mean it means that in some case studies fodder/crop area lack

Table 3.8. Analytical composition of diets provided to cattle for replacement (kg DM head^{-1})

	Cow-calf(weaner)	
Farms, n	1	
Animal category	Heifers 12-to-36 months	Suckler cows
Feedstuff,		
Grassland	721	1.350
Maize silage	777	1.141
Meadow hay	1.228	602
Alfalfa hay	272	-
Maize grain	229	269
Concentrate mix 13% CP	1.931	-

[1]Maize grain 20 %, barley grain 18 %, corn flakes 10 %, sunflower seed extracted 8 %, soybean meal 8 %, faba bean 8 %, bran 8 %, sugar cane molasses 5 %, dehydrated beet pulp 5 %, rice husks 5 %
for Fodder and Pasture DM intake see *CAP2ER* methodology

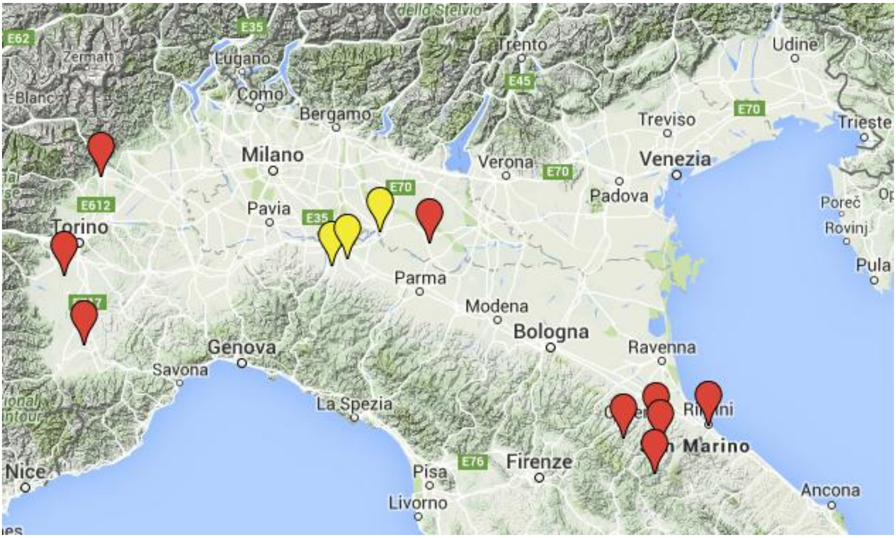
Housing and manure management

All Piedmontese sampled farms house their animals in a free stall barn on bedding material; solid manure is produced and used as fertilizer.

3.1.3 The cow-calf production system

The cow-calf production system, also called closed loop system, contains 3 suckler-calf (SC) farms and 9 calf-to-beef (CB) ones. The main products of the first units are 7-months years old weaners and cull cows; young bulls and heifers are produced by calf-to-beef units. The analyzed farms were identified thanks to some breeders Associations such as Associazione Provinciale Allevatori (APA) Forlì and Cremona section, Associazione Nazionale Bovini Italiani da Carne (ANABIC) located in San Martino in Colle (PG) and Associazione Produttori Carne Piemonte (ASPROCARNE). It is possible to recognize three production areas: the first one in Piemonte with Piedmontese breed, the second one on the boundary between Emilia Romagna and Lombardia characterised by French cross-breeds and the last one in Romagna district close to Apennines. (Figure 3.4).

Figure 3.4. Cow calf case study location (calf-to-weanlings yellow coloured spot, calf-to-beef red coloured spot)



Herd size and performances

The three analyzed SC farms are located in Cremona and Piacenza district as shown on Figure 3.4 and they have French cross-breeds. They are characterized by an extensive usable agricultural area of which about one third for fodder production, especially maize (43 %). They are also defined by a little number of heads and specialized in 7-months weaners production sold to fattening units at 270 LW kg (Table 3.9).

The nine calf-to-beef (CB) farms have a large usable agricultural area of which a good half is used to produce fodder. The number of heads and animals produced are definitely inferior respect to the F-I and P stockers. Suckler cows breed 0.92 calves per year; with an age of 30 months at first calving.

Table 3.9. Profile of specialized beef cow-calf farms

Item	Cow-calf SC	Cow-calf CB	
Farms, n	3	9	
UAA, ha	65±26	74±34	
MFA, ha	20±8	47±41	
MFA UAA^{-1}, %	34±19	47±26	
Maize MFA^{-1}, %	43±9	23±33	
LU, n	62±20	88±48	
Stocking rate, LU ha^{-1}	1.08±0.53	1.37±1.08	
Suckler cows, n	55±15	61±3	
Age at first calving, months	32.0±1.0	30.0±3.0	
Finished animals sold, n	33±6	20±15	12±9
Finished animals sold LW, kg head^{-1}	270±42	656±85	568±66
LW production, kg head^{-1}	228±43	609±83	521±67
Production cycle, d	222±56	512±64	510±70
Sale price, € finishing animal^{-1}	1.085±100	2.141±339	1.917±327

SC Suckler-calf farms; **CB** Calf-to-beef farms
UAA Usable Agricultural Area; MFA Main Forage Area; LU Livestock Unit;
Calf-to-beef finished animal performances are refered to young bulls (left-column) and heifers (right-column)
Where sd > mean it means that in some case studies fodder/crop area lack

Land use

The number of heads in exit by SC farms is relatively low so cash crops are cultivated to integrate the farm income (Table 3.10). Wheat is the first crop (51 %) for grain production with straw used as bedding material and feedstuff. Among other crops tomato for industry is relevant, in fact two of the three sample farms are in the tomato factory district based in Piacenza. Barley and maize grain are used in farm as concentrate mix provided to cattle.

The most important forage produced in CB units is not maize (20 %) but meadow hay (33 %) and alfalfa (44 %); maize is the first crop followed by wheat and barley of which grain and straw are both used as feedstuff and bedding material. Cereals crops used in farm are more relevant in comparison to F-I and P stockers farms but also cash crops (31 % on total crops) are important. Two of the examined farms breed not only beef cattle but also fattening pigs and ovines which have not been considered into the life cycle analysis.

Table 3.10. Main structural indicators of cow-calf specialized farms

Item	**SC**	**CB**
Farms, n	3	9
MFA, ha	20±8	47±41
Maize silage, %	43±9	20±33
Maize mash, %	-	3±8
Alfalfa, %	21±37	44±47
Meadows, %	35±31	33±33
Crops, ha	45±26	24±11
Maize grain, %	9±15	39±47
Wheat, %	51±19	11±19
Broad bean, %	-	5±12
Barley, %	13±22	25±31
Other, %	28±3	19±35
Cereal crops used in farm crops^{-1}, %	9±15	69±43
Cash crops crops^{-1}, %	91±15	31±43
Feed self-sufficiency, DM %	96±2	87±21

SC Suckler calf farms; **CB** Calf-to-beef farms
MFA Main Forage Area;
where sd > mean it means that some case studies lack in fodder/crop area

Feeding system

In addition to mother’s milk SC weaners are fed a 60 : 40 forage : concentrate diet. Concentrate mix is a 15 % CP commercial feed or a mixture composed by maize (52 %), barley (20 %) and soybean (18 %) grain. Heifers and mature cows are fed diets based on maize silage and hay integrated by a mixture of maize, barley and soy flakes (Table 3.11).

Table 3.11. Analytical composition of diets provided to SC cattle

	SC		
Farms, n	3		
Feedstuff, kg DM head^{-1}	Weaners	Heifers	Cows
Meadow hay	938±952	2127±2057	2093±965
Maize silage	385±667	1863±584	2115±884
Wheat straw	42±73	1318±1119	558±296
Concentrate mix[1]	279±103	110±156	73±126
Production cycle, d	222±56	593±21	365

[1] maize grain 55% barley 30% soy flakes 15%
Where sd > mean it means that in some case studies the feedstuff lacks
for Fodder and Pasture DM intake see *CAP2ER* methodology

The diets given to replacement heifers and suckler cows consist of on-farm forages, in particular alfalfa hay, and a mixture of cereals grain and pulses produced on-farm (Table 3.12). Both the animals furthermore are maintained during the summertime on pasture. The diets given to weaners are generally expressed in function, of the animal's age, weight and breed. The basic diet consists of grass hay or alfalfa joined to an energetic integration represented by maize and barley grain and a proteic one which include soybean meal and broad bean (Table 3.13). The CB units are located in a hilly Apennine area often not favored for maize silage production; for this reason the breeders try to optimize the available land growing directly crops designed to cattle nourishment and minimizing the purchase of concentrate feeds.

Table 3.12 Analytical composition of diets provided to cattle for replacement in CB farms

	Animal category	
Feedstuff	Heifers 12-to-36 months	Suckler cows
Meadow hay	2477±2306	1387±1539
Grass hay	-	1040±1355
Fescue hay	316±894	226±678
Alfalfa hay	1138±1981	1412±1994
Maize silage	840±1243	470±740
Maize mash	282±798	-
Straw	187±401	146±297
Concentrate mix 16 % CP[1]	144±407	-
Concentrate mix 19 % CP[2]	99±279	-
Barley grain	133±197	58±108
Maize grain	228±230	71±141
Wheat grain	60±170	7±22
Wheat bran	32±53	20±59
Triticale	7±21	3±8
Soybean meal	67±126	3±8
Protein pea	12±35	-
Broad bean	17±36	11±33

Where sd > mean it means that in some case studies fodder/crop area lack
for Fodder and Pasture DM intake see *CAP2ER* methodology

[1] maize grain 32 %, wheat middling 15 %, dehydrated beet pulpes 15 %, soybean meal 8 %, maize flakes 8 %, cottonseed 5%, barley grain 3%, broad bean 3%, barn 3 %, mineral salts 3%

[2] maize grain 40 %, sunflower seed 20 %, wheat barn 14%, corn gluten feed 8%, sugarcane molasses 6 %, maize germ 5 %, soy hulls 5 %, mineral salts 3%

Table 3.13. Analytical composition of diets provided to cattle for fattening in CB farms

	Young bulls	Heifers
Feedstuffs, kg DM head-1		
Meadow hay	2439±1745	1692±1336
Alfalfa hay	393±1038	529±1052
Fescue hay	233±700	278±833
Maize silage	185±310	216±356
Maize mash	293±879	113±340
Wheat straw	54±115	31±64
Concentrate mix 15.5 % CP[1]	59±176	36±108
Concentrate mix 16 % CP[2]	148±419	87±262
Concentrate mix 19 % CP[3]	164±464	56±168
Maize grain	440±402	297±250
Barley grain	171±180	111±112
Soybean meal	77±153	35±61
Wheat bran	97±162	50±121
Wheat grain	53±159	49±148
Broad bean	23±62	30±61
Production cycle, d	511±64	510±70

Where sd > mean it means that fodder/crop area lack
for Fodder and Pasture DM intake see *CAP2ER* methodology
[1] maize grain 33 %, wheat barn 22%, dehydrated beet pulps 8 %, sunflower seed 6%, , maize flakes 6%, barley flakes 4%, soy flakes 4%, oat flakes 4%, broad bean 4%, molasses 3%, wheat middling 3%, mineral salts 3%

[2] maize grain 32 %, wheat middling 15 %, dehydrated beet pulpes 15 %, soybean meal 8 %, maize flakes 8 %, cottonseed 5%, barley grain 3%, broad bean 3%, barn 3 %, mineral salts 3%
[3] maize grain 40 %, sunflower seed 20 %, wheat barn 14%, corn gluten feed 8%, sugarcane molasses 6 %, maize germ 5 %, soy hulls 5 %, mineral salts 3%

Housing and manure management

All the animal categories reared in SC farms (suckler cows, heifers for replacement and weaners) are housed in a free-stall barn characterized by full floors either in the resting or feeding area. They also have the possibility to move outside in a paddock. Solid manure is produced and handled in piles.

Cattle for fattening are kept in close barns for the entire fattening period except for the period spent under mom. Suckler cows housing system range from a tethering system (15 % of the sampled farms) to a free stall one (85 %). Manure is managed in the same way as previously described for the stockers.

Three CB units leave suckler cows and replacement heifers at pasture from 1st May to 31th October.

3.1.4 The White veal calves production system

The white veal calves (WC) production system includes a dairy cow-calf (weaner) unit and four stockers units in which beef calves, derived from dairy sector, are fattened. These units were highlighted thanks to the assistance of Cremona district breeder Association and thanks to the assistance of UNICARVE VENETO and beef chain actors (Figure 3.5).

Figure 3.5. Sample farms location (dairy farm blue coloured circled, veal calves red coloured circled)

Herd size and animal performances

The dairy cow-calf (weaner) case study breeds, on the average of the 2011 monitored year, 166 Freisian lactating cows which produce during lactation 10.000 kg of milk each. More details on the qualitative features of the milk produced are reported together with other benchmarks on the schedule below (Table 3.14). The farm not only produces milk but also meat, cull cows and calves that on one hand are used for replacement, on the other are sold.

Stockers units are organized according to the formality of agistment which is the drawing up of a contract by which, between the two parties one, gives the agrarian land and buildings, the other one gives the animals and is concerned with the costs of breeding.

Table 3.14. Dairy cow-calf farm profile

Item	
Farms, n	1
UAA, ha	100
MFA, ha	100
MFA UAA^{-1}, %	100
Maize MFA^{-1}, %	50
Dairy cows, n	166
Calves born, n year^{-1}	129
LU, n	22
Stocking rate, LU ha^{-1}	2.20
Herd replacement, %	29
First calving, months	28
Finishing animals sold, n year^{-1}	72
Finishing animals LW, kg head^{-1}	50
Milk protein content, %	3,40
Milk fat content, %	3,90
Milk production, kg cow^{-1} year^{-1}	10.270

UAA Usable Agricultural Area; MFA Main Forage Area LU Livestock Unit

Veal calves, partly imported from Austria, France and Czech Republic, are fattened for a period of about 7 months by stockers units reaching 273 LW kg (Table 3.15).

Table 3.15. White calves specialized sample farms profile

Item	
Farms, n	4
UAA, ha	11±3
LU, n	251±19
Stocking rate, LU ha^{-1}	25.1±18.1
Finishing animals sold, n year^{-1}	715±378
Finishing animals LW, kg head^{-1}	273±25
LW production, kg head^{-1}	219±18
Production cycle, d	205±10
Purchase price, € kg LW^{-1}	2,43
Sale price, € kg LW^{-1}	2,82

UAA Usable Agricultural Area; LU Livestock Unit
Where sd > mean it means that in some case studies fodder/crop area lack

Land use

In the bovine milk farm the whole area is used for the production of ensiled or hayed fodders assigned to the nourishment of dairy cows while the stockers produce exclusively maize seeds to be sold (Table 3.16).

Table 3.16. Main structural indicators of the white calves production system

Item	**Dairy cow calf**	**Stockers**
Farms, n	1	4
MFA, ha	100	-
Maize silage, %	50	-
Wheat silage, %	8	-
Meadows, %	20	-
Alfalfa, %	22	-
Crops, ha	-	11±3
Maize grain, %	-	100
Wheat, %	-	-
Barley, %	-	-
Other, %	-	-
Cereal crops used in farm crops^{-1}, %	-	0
Cash crops crops^{-1}, %	-	100
Feed self-sufficiency, DM %	64	0

MFA Main Forage Area

Where sd > mean it means that in some case studies fodder/crop area lack

Feeding system

To females just born it is given colostrum, replaced after 3-4 days for a three months period, by artificial milk with a protein content of 19 % expressed on the dry substance. Artificial milk powder is distributed by an automatic feeder from 4-to-8 liters per head per day. At the end of this weaning period dairy calves are fed with the same total mixed ration provided to dairy cows with increasing quantities from 5-to-10 kilos per head per day. One year heifers receive a maize silage based diet substituted during the summer season (15th July – 15th November) by wheat silage until the first birth. Dairy cows diet, on DM basis, consists of maize silage

(36 %) and alfalfa hay (17 %) as forage basis integrated by a proteic commercial feed (21 %). During the summer period maize silage is partially replaced by wheat silage adding soybean meal (8 %) in order to guarantee a balanced protein count (Table 3.17). During the dry period cows are fed a low protein diet made of maize silage (34 %) and meadow hay (36 %). Diet is enriched by a proteic commercial feed (8 %) and corn meal (9 %).

Table 3.17. Dairy cattle for replacement diet composition (kg DM head^{-1})

Animal category	Heifers 0-to-12 months	Heifers 12-to-36 months	Dairy cows
Feedstuff			
Maize silage	800	1354	3023
Wheat silage	83	365	263
Alfalfa hay	-	-	1311
Meadow hay	392	1869	370
Barley straw	-	717	128
Soybean meal	-	-	221
Maize grain	170	549	1338
Concentrate mix, 24% CP[1]	170	789	-
Concentrate mix, 40% CP[2]	-	-	1187

[1]Soybean meal 39 %, sunflower seed meal 26 %, soy flakes 10 %, wheat barn 10 %, maize germ 10 %, mineral salts 5 %;
[2]Sunflower seed meal 26 %, soybean meal 20 %, beet pulpes 20 %, sugarcane 15 % wheat barn 15 %, mineral salts 5 %
for Fodder DM intake see *CAP2ER* methodology

Table 3.18. White calves diet composition (kg DM head^{-1})

Farms, n	4
Feedstuff	
Milk powder	542±33
Maize silage balls	27±26
Cereals grain[1]	161±66
Milk yield, kg LW kg milk^{-1}	0.65±0.04

[1] maize grain 64 % maize flakes 25 % barley grain 11 %
for Fodder intake see *CAP2ER* methodology

The diet given by stockers is always based on powdered milk or assimilable (77 %) combined with a mixture of cereals given in growing quantities during the following days (Table 3.18).

Housing and manure management system

Veal calves are kept in close barns (multiple pens) for the entire fattening period as fixed by the European Council 97/2/EC Directive. From questionnaire rather than interviews, concrete or azobé wood slatted floors are mainly used in the sampled farms. Animal manures are collected in outdoor and opened tanks. Two different manure management systems are used in the dairy farm case study: dairy cows are kept in a free-stall barn with bunks and an outdoor paddock while cattle for replacement are reared on bedding litter with an outdoor paddock.

3.2 Methods

A common *Tier 2* approach is used to evaluate French – Italian and Piedmontese fattening chains global warming potential while *CAP2ER* tool is applied to assess all environmental impacts produced by the three analyzed systems.

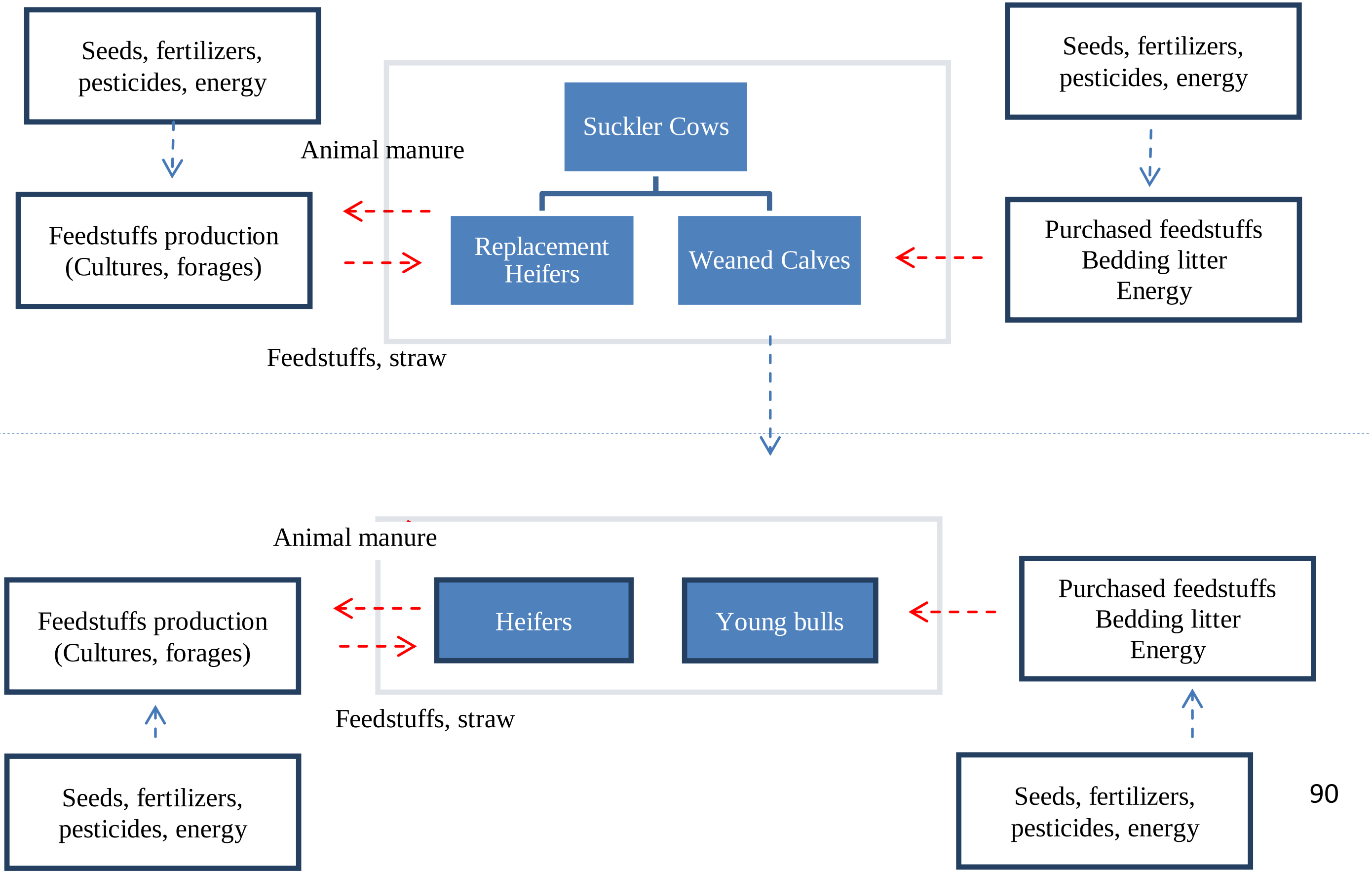
System boundaries

Beef production cycle was analyzed from cradle to farm exit gate, considering each stage (inputs, calf-to-weanlings and fattening phase) and taking into account greenhouse gases emissions at animal scale and those related to feed production (Figure 3.6). Suckler – calf case studies are treated such as cow-calf (weaner) units while calf-to-beef sampled farms are analyzed in a simplified way considering calf-to-weanlings and fattening phase as two separate units. The first included beef cows and calves, partly intended to replacement partly designed for fattening, the latter produces both young bulls and heifers.

The dairy production system includes either the farm where veals are born (dairy cow-calf) or farms where veals are bred in order to be slaughtered (stockers). It also includes the emissions released from animals, the emissions produced in the farm for the production of nourishment and the ones released outside the farm for the production of outputs like fertilizers, seedling, pesticides and transport from the birth breeding farm to that one specialized for fattening. Co-products of the dairy cow-calf farm are milk and meat, the first in this particular case is processed to make Grana Padano PDO cheese while for meat it is possible to distinguish two types: cull cow and calf

.

Figure 3.6. System boundaries of beef production cycle including cow-calf (weaner) and stocker units



Functional unit

Kilogram of live weight sold (LW) has been chosen as functional unit (FU). Live weight marketed (kg $farm^{-1}$ $year^{-1}$) was calculated as the sum of the weight of different animal categories marketed – cull cows and weaned calves in the case of cow-calf (weaner) farms, young bulls for F-I stockers and young bulls plus heifers for P stockers. Suckler – calf units live weight was calculated as the cow-calf (weaner) one while all animal categories, before described, were included into calf-to-beef farms.

As regard to dairy production, kilogram of fat and protein corrected milk (FPCM) sold and kilogram of LW sold were respectively chosen as functional units. FPCM has been calculated on the basis of the equation suggested by Gerber et al., 2010 here reported below:

$$\text{FPCM (kg)} = 0.337 + 0.116 \times \text{fat content (\%)} + 0.060 \times \text{protein content (\%)}$$

Table 3.19 shows the contribution of each phase, in percent, to the global LW production per each cattle category.

The French cow-calf (weaner) weight derives by the number of heads purchased by Italian stockers, the Italian weight is based on the fattening cycle of purchased animals.

The Piedmontese cow-calf (weaner) weight derives by the number of heads purchased by Piedmontese stockers, the P-stockers weight is based on the fattening cycle of purchased animals.

In CB units calf-to-weanlings weight derives by the number of weaned calves, fattening weight is based on the fattening cycle of weaners.

Dairy cow-calf weight derives by the number of heads purchased by stockers; stockers weight is based on the fattening cycle of purchased animals.

Table 3.19 Contribution of calf-to-weanlings and fattening phase to LW production per each cattle category

	Young bulls/white veal calves			
	F-I	P	CB	WC
Farms, n	10	3	9	4
Calf-to-weanlings	53.0±5.0	30.0±3.0	38.0±10.0	0.18
Fattening	47.0±5.0	70.0±3.0	62.0±10.0	0.82
	Heifers for fattening			
		P	CB	
Farms, n		3	9	
Calf-to-weanlings		29.0±6.0	39.0±12.0	
Fattening		71.0±6.0	61.0±12.0	

F-I French Italian beef production chain; P Piedmontese beef production chain; CB Calf-to-beef; WC White veal calves

3.2.1 Common *Tier 2* approach

On farm emissions

Direct emissions concerning breeding were estimated starting from the average number of heads reared per farm per year. In the case of stockers the number of purchased weaners and finishing animals sold was obtained adopting the equation proposed by Schiavon (2010) by using the average number of heads, young bulls days in fatten and calf mortality rate. The average adult animal number was converted into livestock units (LU) as figure of reference. In detail to estimate the French cow-calf (weaner) index were considered 0.85 LU per each suckler together with cull cow, 0.3 LU per each heifer as well as male 0-to-1 years old and 0.6 LU per heifer 1-to-2 years or young bull reared (Institut de l'Elevage, 2014). In Italy a common factor of 1.0 LU was assigned to cows, bulls and cattle over 2 years old. For weaners rather than young bulls and heifers was used a common factor of 0.6 LU as suggested by national legislation (MIPAF, 2006). Methane (CH_4) and nitrous oxide (N_2O) emissions are reported to CO_2-eq emissions using global warming potential (GWP) specific values. Set the GWP of carbon dioxide equal to

1, GWP of methane is 25 times larger and that of nitrous oxide even 298 times larger.

Enteric methane

Enteric methane emitted within the French cow-calf (weaner) case study was determined using IPCC (2006) Equation 4.14 starting from diets analytical composition in association with INRA (2007) tables where both chemical and nutritive characteristics, digestible energy included, for each feedstuff are specified. Dry matter (DM) fodder intake per each animal category was evaluated with the equation proposed by *CAP2ER* tool including animal body weight assuming that one suckler cow weighted 750 kg LW, one pregnant cow weighted 600 kg LW, one heifer 1-to-2 years old weighted 450 kg LW and one heifer 0-to-1 year old weighted 300 kg LW.

$$Fodder\ intake\ (t\ DM\ head^{-1} year^{-1}) = \frac{[(\text{animal category BW})^{0.75} * \frac{0.095}{1.05} * 365]}{1000}$$

Information about stockers diets, especially the concentrate mixture list of ingredients and the chemical composition were collected in order to estimate dry matter (DM) and gross energy (GE) intakes. This last one was valued by Schiemann's equation (1988) and subsequently converted in kilograms of methane emitted through the factor 55.65 MJ/kg of CH_4 suggested by the Intergovernmental Panel on Climate Change guidelines (IPCC, 2006) to determine enteric CH_4 emissions. A 4 percent country specific methane conversion factor has been considered for young bulls and heifers (Condor et al., 2008)

Manure methane

As regards to methane released from manure management IPCC (2006) *Tier2* equation 10.23 and 10.24 were applied. Total digestible nutrients (TDN) intake was converted into digestible energy (DE) consumed using the conversion factor of 4.41 kcal per g TDN, recommended by NRC (1989). The other present factors were estimated adopting coefficients proposed by IPCC (2006) guidelines.

Maximum methane producing capacity for manure produced (B_o) was derived from Table 10A-5 choosing the coefficient submitted for "Western Europe other cattle" whose mass was comparable to that one estimated per each sample farm. Fraction of manure handled using manure management system (MS) has been calculated starting from the average cattle number reared with each system type. Methane conversion factors (MCFs), per each manure management system, were determined assuming an annual average temperature of the investigated area between 12 and 14 °C reported by a national survey on climate trend in 2010 (Desiato et al., 2011). For French cow-calf (weaner) farm manure CH_4 was calculated by *CAP2ER* tool in the same way but considering B_o equal to 0.18 m^3 CH_4 per kg manure produced and MCFs equal to 22 % for all animal categories.

N_2O direct

N excretion has been calculated to assess N_2O direct emissions as the difference between N feed intake and N fixed in animal tissues. N feed intake was estimated starting from CP content of the diets while the N fixed was determined utilizing figures proposed by Tamminga (2006). Slurry and solid manure productions per young bull reared by stockers were calculated making use of data proposed by Biagini (2010). Manure N volatilization in the form of ammonia during breeding and management phases has been considered too. Ammonia emitted in the house was considered equal to 11.55 % of N excreted while two different storage emission factors were identified: 23 % and 14.2 % of manure N content for slurry and solid manure respectively. Liquid and solid manure spreading contribution was predicted by coefficients derived from ALFAM model (http://www.alfam.dk) and 2004 Regione Emilia Romagna report respectively. Fertilizers use N_2O emissions, that are included in soil direct and indirect emissions, were estimated using fertilizers N content and specific emission factors per each synthetic product reported by EMEP/CORINAIR (2007). Fertilizers used and their quantities have been provided by breeders.

In *CAP2ER* tool N excretions have been estimated on the basis of CORPEN (2001) guidelines. A slurry and solid manure production of 60 liters per LU per day and 13.5 ton per LU per year respectively.

Slurry N and P_2O_5 content were fixed as 3.5 and 2 kilograms per ton assuming a storage period of 122 days as established by Dexel, Circulaire 20 Décembre 2001. Solid manure N and P_2O_5 content were fixed as 5.8 and 2.3 kilograms per ton assuming a storage period of 183 days as established by Dexel, Circulaire 20 Décembre 2001.

N_2O indirect

Ammonia and nitric oxide atmospheric deposition other than N leaching and run-off losses are included into N_2O indirect emissions that were evaluated using IPCC (2006) equations 11.10 and 11.11.

CO_2 direct

On - farm fuel data consumption for feed production and feeding practice has been deducted from ENAMA, 2005 publication where they were not available while energy consumption in terms of € per farm per year was converted in kWh supposing an emission equal to 410 gCO_2-eq per kWh produced (Brander et al., 2011).

Table 2.20. List of the main emission factors (EFs) used to estimate the global warming potential

	F	P-I stockers
CH_4 emissions		
Enteric	Equation 10.21 (IPCC, 2006)	
GE content per feed	INRA, 2007	Schiemann, 1988
Manure	Equation 10.23 – 10.24 (IPCC, 2006)	
N_2O emissions		
N excretion	Equation 10.31 (IPCC, 2006)	
N retention	CORPEN, 2001	ERM/AB-DLO, 1999
Manure	Equation 10.28 and 10.29 (IPCC, 2006)	
Soil, direct	Equation 11.2 (IPCC, 2006)	
Soil, indirect	Equation 11.11 (IPCC, 2006)	
CO_2 emissions		
Animal transport	Blonk et al., 2011	
Farm inputs	Nemececk and Kagi, 2007; Agribalyse®; Blonk Consultants, 2013	

F French cow-calf (weaner); **I** Italian stockers; **P** Piedmontese stockers

Off-farm emissions

In order to determine CO_2 emissions for self-produced feedstuffs the following primary data were collected on farm: seedling, fertilizers and pesticides active ingredients used per hectare. Carbon dioxide released per each fertilizer was deducted from a review of Wood and Cowie (2004) while emission inventory data concerning seed and pesticides production were found out in Nemecek and Kagi (2007). As regard to purchased feedstuffs, France was identified in 2011 reference year as the main supplier for the Italian market (ICE, 2014). Agribalyse® French inventory database (ADEME, 2015) was adopted to estimate emissions from crops cultivation while Ecoinvent (Nemecek and Kagi, 2007) and FeedPrint inventory data (Blonk Consultants, 2013) including information about electricity rather than other resources consumption were used to estimate emissions from feed production. Data on international trade import in animal feed by sea transport are reported in the tables of ISTAT (2012). On the basis of the information collected, port of Ravenna was considered as arrival point of imported feedstuffs while Rouen was chosen as starting point as indicated the chief cereals trade port in France (Ministère de l'Écologie, du Développement durable et de l' Énergies, 2012). Detailed CO_2 emission factors per each transport summarized by Delcampe (2009) were used to evaluate their contribution to the whole impact.

Animal transport too was taken into account with an emission factor of 1.2 $kgCO_2$-eq per km per load (Blonk et al., 2011). Travel was based on the distance between sample farms and holdings of origin (Google Maps; http://maps.google.it). Technical characteristics of trucks suitable for cattle transport were provided from producers while number of animals per load was estimated according to values fixed by the European Council 2005/1/EC Directive.

3.2.2 *CAP2ER* methodology

This method established by French Livestock Institute for French breeders and available on the network (http://www.idele.fr) was used to evaluate French – Italian cattle carbon footprint and other impacts such as acidification potential, eutrophication potential, non-renewable resources usage and land use. The methods adopted were: *Tier 2* emphasizing how to evaluate CH_4 and N_2O emissions; *CAP2ER* conveys basic farmland data and literature information such as specific emission factors into simple but really exhaustive sample – grids in order to make them available to all the beef chain actors. Acidification and eutrophication potential are expressed in gSO_2-eq and gPO_4-eq. The gases released into the air (NH_3 and NO_x) and the substances released into the groundwater (NO_3 and P_2O_5) are transformed in these reference units thanks to conversion factors proposed by Moreau (2013).

On farm emissions

The main emission factors were calculated as follows:

- enteric CH_4 on the basis of each animal type specific factors (Vermorel et al., 2008) and feedstuffs chemical composition derived from INRA, 2007 chemical and nutritive tables. Methane conversion factors used for young bulls/heifers, suckler cows, dairy cows and white veal calves were 4 %, 6 %, 6.5 ± 1.0 % and 4 % respectively;
- manure CH_4 on the basis of equations proposed by IPCC guidelines (2006) considering B_o equal to 0.18 m^3 CH_4 per kg manure produced and MCFs equal to 22 % for all animal categories
- a slurry and solid manure production of 60 liters per LU per day and 13,5 ton per LU per year respectively;
- N excretions on the basis of CORPEN (2001) guidelines;
- 3.5 kg N/ton of slurry and 2 kg P_2O_5/ton of slurry assuming a storage period of 122 days as established by Dexel, Circulaire 20 Décembre 2001;
- 5.8 kg N/ton of solid manure and 2,3 kg P_2O_5/ton of solid manure assuming a storage period of 183 days as established by Dexel, Circulaire 20 Décembre 2001
- NH_3 emissions based on EMEP-CORINAIR (2007) guidelines;
- NO_x released into water and air following Skiba (1998) and Webb (2001) issues;
- Electricity and fuel emission factors were taken from Dollé and Duyck (2007) report;
- Seedling, fertilizers and pesticide active ingredients used per hectare to estimate CO_2 direct emissions from feedstuffs self-produced.

Nitrate-leaching and P_2O_5 run off have been calculated on algebrical basis as suggested by Nemecek and Kagi, 2007 starting from N and P farm balances based on the methodology described on the IDELE report (2013) in which among input voices we have considered fertilizers placed on farm self-produced cereals and on the main forage area while among output voices there are LW and manure distributed on cash crops. In particular as regards nitrate leaching estimation have to be considered:

- the N fixed by legumes using the following equation:

$$N\ legumes = \left(\frac{Legumes\ \%}{meadow\ \%}\right) * meadows\ yield\ (t\ MS) * 30\ kg\ N\ t\ MS^{-1}$$

in which the legumes percentage among meadows and their yield are referred by the farmer

- a N atmospheric deposition of 10 kg N per hectare per year;
- the nitrogen volatilized in stable and during manure storage and pasture.

As a matter of fact for a complete assessment

- calves weight at birth and beef cattle weight from monthly test days;
- suckler cows grazing feed intake considering as a difference between yearly dry intake and dry intake in the barn (Gac, 2014)

$$Pasture\ DM = Fodder\ DM\ (5\ t\ LU^{-1}) - Fodder\ DM\ (t\ days\ spent\ in\ the\ barn^{-1})$$

- livestock units according to French coefficients reported above (Institut de l'Elevage, 2014)

deserve to be taken into remarkable consideration.

Off-farm emissions

The main source that contributes to environmental impact is represented by purchased feedstuffs. *CAP2ER* tool reports per each feedstuff the emission factors contained in Guide Dia'Terre version 1.13 for global warming potential, acidification and eutrophication, non – renewable resources and land use impact categories taking into account every stage from cultivation to manufacturing process until it is ready to eat.

Animal transport too is included and estimated following the same parameters considered in *Tier 2* approach.

Allocation rules

The biophysical allocation consists in dividing the impacts during animal life cycle. It has been applied to split impacts between the co-products of each system.

The allocation factors are calculated taking into consideration the cattle energy requirements, recommended by National Research Council (1989), the average heads number, the number of days spent breeding for each category.

The French and Piedmontese cow-calf (weaner) case studies include different kinds of animals: suckler cows, replacement heifers (0-to-24 months) and weaned calves. The two co-products are: weaners and cull cows. The allocation factors (AFs) are calculated as follows:

$$AF_{weaner} = \frac{\text{Weaner requirements}}{\text{Weaner requirements} + \text{Cull cow requirements}}$$

$$AF_{cull\ cow} = 1 - AF_{weaner}$$

where

AF_{weaner} is the allocation factor for the weaner

$AF_{cull\ cow}$ is the allocation factor for the cull cow

Weaners requirements which include the mature period of pregnant (heifers 24-to-36 months), multiparous suckler cows and weaned calves requirements are estimated as follows:

$$
\begin{aligned}
Weaner\ requirements & \\
&= Mcal\ d^{-1} pregnant\ heifer^{-1} * Pregnant\ heifers\ (n\ year^{-1}) \\
&* days\ spent\ in\ stable + Mcal\ d^{-1} suckler\ cow^{-1} * Suckler\ cows\ (n\ year^{-1}) \\
&* days\ spent\ in\ stable + Mcal\ d^{-1} weaner^{-1} * Weaners\ (n\ year^{-1}) \\
&* days\ spent\ in\ stable
\end{aligned}
$$

Cull cows requirements, which include the growing period of replacement heifers (0-to-24 months) are estimated as follows:

$$
\begin{aligned}
Cull\ cow\ requirements & \\
&= Mcal\ d^{-1} replacement\ heifer^{-1} * Replacement\ heifers\ (n\ year^{-1}) \\
&* days\ spent\ in\ stable
\end{aligned}
$$

No allocation has been applied for the Italian stockers because only young bulls are fattened in these units.

The P stockers include young bulls and heifers for fattening. The two co-products are young bulls and heifers 12-to-24 months. The allocation factors are estimated as follows:

$$
AF_{young\ \ bull} = \frac{\text{Young bull requirements}}{\text{Young bull requirements} + \text{Heifer requirements}}
$$

$$
AF_{heifer} = 1 - AF_{young\ \ bull}
$$

where

$AF_{young\ bull}$ is the allocation factor for the young bull

AF_{heifer} is the allocation factor for the heifer

each requirement corresponds to the one of each animal category and is estimated as follows:

$$
\begin{aligned}
Young\ bull\ requirements & \\
&= Mcal\ d^{-1} young\ bull^{-1} * Young\ bulls\ (n\ year^{-1}) * days\ spent\ in\ stable
\end{aligned}
$$

$$Heifer\ requirements = Mcal\ d^{-1} heifer^{-1} * Heifers\ (n\ year^{-1}) * days\ spent\ in\ stable$$

Calf-to-beef sampled farms are considered as two separate units: calf-to-weanlings and fattening. Calf-to-weanlings unit includes suckler cows, replacement heifers and weaned calves. The two co-products are: cull cows and weaners. The allocation factors are calculated using the above mentioned equations for each category. Fattening unit includes young bulls and heifers for fattening which are also the two co-products. The allocation factors are calculated using the previous equations.

A biological allocation developed by IDF (2010), has been used to split impacts between the two co-products, milk and meat in exit from dairy farm case study. This method is based on the feed energy required to produce respectively the amount of milk and meat at the farm.

$$AF_{milk} = 1 - 5.7717 * R$$

$$AF_{meat} = 1 - AF_{milk}$$

where

AF_{milk} = allocation factor for milk;

AF_{meat} = allocation factor for meat;

R = M_{meat} / M_{milk}

M_{meat} = sum of live weight of all animals sold included calves and cull cows;

M_{milk} = sum of milk sold;

As described by the M_{meat} index in the dairy cow-calf case study it is possible to distinguish between calves 0-8 days and dairy cull cows. For this reason a biophysical allocation has to be adopted to split impacts among the three co-products.

$$AF_{milk} = \frac{\text{Milk requirements}}{Milk\ requirements + Dairy\ cull\ cow\ requirements + Calf\ 0-8\ days\ requirements}$$

$$AF_{dairy\ cull\ cow} = \frac{\text{Dairy cull cow requirements}}{Milk\ requirements + Dairy\ cull\ cow\ requirements + Calf\ 0-8\ days\ requirements}$$

$$AF_{calf\ 0-8\ days} = 1 - (AF_{dairy\ cull\ cow} + AF_{milk})$$

where

milk requirements, which include dairy cows energy requirements (manteinance, activity, lactation), are estimated as follows:

$$Milk\ requirements = Mcal\ d^{-1} dairy\ cow^{-1} (maintenance, activity, lactation) * Dairy\ cows\ (n\ year^{-1}) * days\ spent\ in\ stable$$

calves 0-to-8 days requirements, which include gestation for dairy cows and pregnant heifers, are estimated as follows:

$$Calf\ requirements = Mcal\ d^{-1} dairy\ cow^{-1} (gestation) * Dairy\ cows\ (n\ year^{-1}) * days\ spent\ in\ stable$$

dairy cull cows requirements, which include all requirements for replacement heifers (0-1 year, 12-to-24 months) are estimated

$$Dairy\ cull\ cow\ requirements = Mcal\ d^{-1} replacement\ heifer^{-1} * Replacement\ heifers\ (n\ year^{-1}) * days\ spent\ in\ stable$$

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Chapter 4

Results and discussion

The beef cattle production systems, analyzed in the present study, show a wide variability of emissions depending on different aspects. The main factor that influences the results is the methodology applied, in particular the equations and the emission factors used to estimate dry matter intake, methane and nitrogen excretion for each animal category. Production cycle and live weight of beef cattle, typical for each system, also contribute to the final impact which is divided, with an allocation factor, among the co-products of each system.

4.1 Emissions at animal scale

Table 4.1 shows figures concerning N and CH_4 excretion per each category . These values are useful to estimate GWP.

From the reported data it is possible to observe a different N excretion due to the DMI estimation, different according to the applied methodology. In *Tier2* DMI has been estimated on the basis of diets provided by breeders and on the basis of chemical characteristics of total mixed ration. In *CAP2ER* DMI has been estimated on the basis of animal body weight. In particular the higher values of *Tier2* N excretion are influenced by the higher CP content of diets. Results are in the range of those reported in literature. Young bulls values are close to those reported by Micol and colleagues (2003) and Schiavon et al., (2010). As regards to heifers for fattening no reference values are available for Italy. The estimated values are lower than the French reference, in which a 650 kg LW heifer has been considered.

An high variability is observed in beef cow N excretion; SC beef cows, whose diets are low in CP, show N excretion similar to MIPAF (2006) reference value while excretions released by the other beef cows are higher and close to the value reported by Micol et al., (2003).

Enteric methane values proposed by Vermorel and colleagues (2008) are applied in *CAP2ER* methodology. *Tier2* estimates are in the range of figures indicated by Condor (2011)

Table 4.1. Nitrogen and methane production per each beef cattle category

	DM intake Kg head^{-1} year^{-1}	CP diet g kg DM^{-1}	N excretion Kg head^{-1} year^{-1}	CH_4 excretion Kg head^{-1} year^{-1}	Heads average n year^{-1}
Veal (8 months at slaughter)					
White veal calf, WC	730±7	178.8±18.8	10.7±0.8	8.1	418±198
Young cattle (12-24 months at slaughter)					
Young bull, F-I					
Tier2	3373±552	139.7±11.4	62.3±14.9	60.7±10.0	372±260
CAP2ER	3316±654	111.5±10.0	46.2±12.8	50.0	
Young bull, P					
Tier2	2866±125	133.5±8.0	50.4±4.1	57.3±2.8	98±40
CAP2ER	3282±231	117.6±9.0	50.8±3.7	50.0	
Heifer, P					
Tier2	2377±526	140.7±8.9	44.9±7.9	46.4±10.8	50±49
CAP2ER	2560±158	107.8±2.6	35.2±7.5	53.0	
Young bull, CB	3275±802	130.5±27.4	47.5±15.7	50.0	20±15
Heifer, CB	2785±245	112.9±26.2	34.6±12.3	53.0	12±9
Beef (> 24 months at slaughter)					
Dairy cow	7849	145.8	100.60	94.0	166
Beef cow, F-I	4531	128.4	91.8	111.0	82
Beef cow, P	4935	117.0	88.4	96.0	199
Beef cow, SC	4812±124	75.0±9.0	58.6±11.2	94.0	55±15
Beef cow, CB	4916±197	121.5±33.2	80.7±21.6	94.0	61±31

F-I French-Italian production chain; **P** Piedmontese fattening production chain; **SC** Suckler-Calf; **CB** Calf-to-Beef; **WC** White calves

4.2 Farm-gate N balance

The farm-gate N balance is reported on Table 4.2. It permits to obtain information on the analyzed systems. Observing results, it is possible, for example, to understand the farm's profile and the breeding system.

Among the N inputs, fertilizers are an important entry. The F-I stockers and the dairy cow-calf unit buy a large quantity of them while CB-units and even more the cow-calf(weaner) ones are characterized by land used for N-fixing cultivations (alfalfa, legumes). Even in the case of feed inputs, the dairy cow-calf unit and the F-I stockers buy more than the other farms. Looking at N-entering farm like live cattle, it is possible to distinguish two different groups of farms: the closed loop system, in which animals are born for replacement and fattening to guarantee future generations or to obtain an income in a short period, and the open cycle system where purchased animals are fattened.

Among N outputs live cattle represent the main entry except for the dairy cow-calf farm producing milk. The French-Italian system is the first as regards live cattle in-exit followed by the white calves and P-stockers. The Piedmontese cow-calf (weaner) unit confirms its characteristic as specialized unit producing 5-months weaners, going beyond the "French cousin" one and leaving behind, by far, the SC-farms in terms of LW production.

The SC and CB farms are characterized, in some cases, by negative N balance. This is due to the use of feeds, on-farm cultivated, and to the use of animal manure as N-fertilizers. In this way these farms reduce feeding costs taking care of environmental issues. Farm negative N balances in suckling cows farms have been estimated, previously, by Bassanino and her team (2007) and Simon and colleagues (1992) respectively.

Table 4.2. Farm gate N-balance of the analyzed beef production systems

	F-I		**P**		**SC**	**CB**	**WC**	
Farms, n	*1*	*10*	*1*	*3*	*3*	*9*	*1*	*4*
N input								
N fertilizer	1980	7103±4912	340	2627±3835	4147±3380	2246±3375	7700	-
Feedstuffs								
Concentrates	1364	14565±13820	2915	4888±2222	310±201	1195±1122	20607	8711±4571
Forages	-	1733±2689	3271	-	895±1550	611±1832	334	107±113
Litter	169	573±978	2587	35±61	-	242±412	-	-
Live cattle	-	6129±3940	-	496±155	-	-	-	894±550
N output								
Milk	-	-	-	-	-	-	9944	-
Live cattle	996	11886±8755	1256	1847±749	348±112	712±534	86	5852±3741
Manure	870	7707±8382	-	1297±143	4624±2347	1479±2282	-	11524±6337
N balance								
Kg N $year^{-1}$	1647	12050±7880	7858	4903±5301	538±3473	2083±4511	18610	-7664±6017
Kg N ha^{-1} $year^{-1}$	18	350±247	10	168±53	-28±115	47±105	186	

F-I French-Italian production chain; **P** Piedmontese fattening production chain; **SC** Suckler-Calf; **CB** Calf-to-Beef; **WC** White veal calves

4.3 Environmental impact assessment

A common *Tier 2* approach is used to evaluate French – Italian and Piedmontese fattening chains global warming potential while *CAP2ER* tool is applied to assess all environmental impacts produced by the three analyzed systems.

The results reported below are referred to each cattle category: weaners, young bulls, heifers for fattening and cull cows.

In addition it is given a description of environmental impacts of the dairy farm case study co-products.

Weaners

The weaner represents an input category, in the case of F-I and P fattening systems as well as in the case of CB farms, in order to estimate the environmental impact of young bulls or heifers. On the contrary in SC units, weaners are analyzed from cradle to the farm exit gate.

The French weaners emit a CO_2-eq per kg LW quantity lower (21.7) than the Piedmontese weaners (38.1) and the CB weaners (48.9) as the unit in which they are bred is characterized by a high birth rate (0.91 calf cow^{-1} $year^{-1}$)which is also a peculiarity of the Piedmontese cow-calf (weaner) unit (0.89 calf cow^{-1} $year^{-1}$). Live weight production per head reared in French cow-calf (weaner) unit is, by far, the highest (296 kg LU^{-1}). All the environmental impacts, not only GWP, are influenced by the allocation factor which is lower in the case of French weaner (82.3 %) in comparison with the Piedmontese one (91 %).

The SC weaners, sold at the age of 7 - 8 months, show wide variable impact results linked either to poor reproductive rates, due to the farmers' care towards cash crops, or to a lack in feed planning.

Young bulls

Global warming potential (GWP)

The F-I young bull impact category, estimated with *Tier2* results to be, on average, 14.28 kgCO_2-eq per kg LW with a great contribution of enteric fermentation (51 %) followed by manure management (12 %) and feed inputs (11 %) even tough pasture (9 %), performed in French cow-calf (weaner) unit, is relevant (Table 4.3). The French phase is responsible for 70 % of global emissions while the remaining 30 % is allocated to Italian stockers. Methane represents the main pollutant released within the French cow-calf (68 %) of which 85 % from enteric source (Figure 4.1). Nitrous oxide contribution is restricted to pasture while CO_2 off-farm emissions prevail on direct ones. On the other hand CO_2 results to be the Italian stockers main contaminant emitted with feedstuffs production, purchased (27 %) rather than self-produced and used in farm (14 %) (Figure 4.2).

CAP2ER results are very close to those obtained using a common *Tier 2* approach (15.23 kgCO_2-eq/kg LW); in this case the percentage of French cow-calf (weaner) is slightly higher (76 %) even if the contribution of each greenhouse gas does not change in percentage.

Methane increase in the Italian phase (56 vs 42 %) is affected by CH_4 house emissions, not considered in the previous model because of lack of country – specific emission factors. Carbon dioxide share (35 %) is mainly determined by feed inputs (19 %) and fuel consumption (11 %).

The P young bull GWP amounts to 17.46 kgCO_2-eq per kg LW on average (Table 4.3). The Piedmontese cow-calf (weaner) unit contributes for 57 % to the global impact while the remaining 43 % is allocated to the stockers phase.

The environmental analysis of the cow-calf (weaner) phase points out that CH_4 is the major pollutant within greenhouse gases (63 %) (Figure 4.1) and enteric fermentation is the most representative source of emission (49 %) (Figure 4.2).

On the other hand the emissions released by the Piedmontese stockers are largely affected by CO_2 emissions (53 %) especially those concerning feed inputs (48 %), feedstuffs self-produced and used in farm included (22 %).

The young bull GWP analysed with *CAP2ER* is higher than the impact estimated with *Tier 2*. It is observed an increase in CH_4 quota (from 40 to 56 %) and a reduction in CO_2 emissions (from 53 to 31 %) respectively. After the enteric fermentation (45 %), manure management (18 %), 100 % based on deep litter, and feed inputs (17 %) are identified as primary sources of emission. Pasture only accounts for 2 % on the whole impact.

The CB young bull GWP is 23.60 kgCO_2-eq per kg LW. The main emission source is enteric fermentation (47 %) followed by manure management (18 %), feed inputs (13 %) and fertilization (10 %). In detail the 74 % of the impact is released during the calf-to-weanlings phase.

Although Condor (2011) considers calf 0-to-1 year as no enteric methane emitter for the reason that the calf is milk fed, white veal calf GWP emphasizes that enteric fermentation accounts for the 48 % and 35 % respectively on the fattening and on the global impact.

Acidification potential (AP)

The emissions released into the atmosphere vary according to the young bull production system. The F-I young bull emits 140 gSO_2-eq per kg LW on average, the lowest value. The highest one, 228 gSO_2-eq, is emitted by CB young bull. The most of impact is due to on-farm activities (86 %). Ammonia results to be the chief gas emitted, range from 80 to 86 % of the whole impact (Figure 4.3). These emissions are observed at animal scale (stable rather than at pasture) but above all for manure management, including storage (from 45 to 61 %) and spreading (from 17 to 25 %). In particular, the larger contribution of the French cow-calf stage is influenced by pasture (23 %) lacking within Italian stocker units (Figure 4.4).

Eutrophication potential (EP)

Eutrophication potential results (Table 4.3) are strongly influenced by the farm gate N balance (Table 4.2). Although nitrate leaching is the main source of emissions in the case of Italian stockers (39 %) (Figure 4.5), due to the highest N balance value (350 kg N ha^{-1} $year^{-1}$), the lowest impact (60.70 gPO_4-eq per kg LW) has been reported for the F-I young bull. This evidence is explained by the higher impact of the French phase (54% equal to 32.74 gPO_4-eq) in which nitrate leaching has no value. The French cow-calf (weaner) feeding system is based on grass and a great portion of manure N is applied on cash crops (30 %). As a consequence N load is equal to 10 kg N per hectare per year. Piedmontese and CB young bull emit a larger number of gPO_4-eq, ranging from 196 to 244, per kg LW (Table 4.2). In the first case nitrate leaching (11 %), as a consequence of much lower farm N balance (10 kg N ha^{-1} $year^{-1}$), is of less importance than manure management (28 %) and feed inputs (25 %). The eutrophication potential of CB young bull, instead, has nitrate leaching (41 %) as main contributor, followed by manure management (28 %) and feed inputs (18 %) (Figure 4.6).

Cumulative energy demand (CED)

White veal calf is a primary user of non-renewable resources with 60.11 MJ-eq per kg LW (Table 4.3). Energy inputs usage has been identified as a key source of losses for water heating to prepare ration and for the ventilation of stables. The CB young bull is the higher emitter compared to other young bulls, in particular calf-to-weanlings phase (73 %) contributes much more than the fattening phase (27 %)

to the whole impact. On-farm emissions prevail on indirect ones, especially fuel consumption for feed production.

Ecological footprint (EFP)

Land area and feed inputs represent the main EFP entries for beef cattle. The first entry is important in the P young bull ecological footprint as the unit, in which he is born, is characterized by a large area consisting of meadows and grassland. On the contrary feed inputs have to be considered a significant entry for all the others young bulls ecological footprint. These animals take much less land area than Piedmontese young bulls (Table 4.3).

Table 4.3.Environmental impact per 1 kg LW of finished male cattle

	F-I		**P**		**SC**	**CB**	**WC**
Animal category	*Young bull 18 months*		*Young bull 19 months*		*Weaner 7 months*	*Young bull 18 months*	*White veal calves*
Farms, n	*10*	*10*	*3*	*3*	*3*	*9*	*4*
Methodology	*Tier2*	*CAP2ER*	*Tier2*	*CAP2ER*	*CAP2ER*	*CAP2ER*	*CAP2ER*
GWP, kgCO_2-eq	14.28±1.07	15.23±0.98	17.46±0.36	19.57±0.88	37.68±5.92	23.60±9.20	7.60±2.20
Enteric fermentation	7.24±0.57	7.77±0.59	7.71±0.32	8.84±0.58	18.52±3.55	9.84±2.21	2.65±0.31
Manure management	1.77±0.15	2.37±0.39	2.10±0.10	3.61±0.21	8.23±1.23	3.83±1.37	1.57±0.72
Pasture	1.30±0.11	1.47±0.14	0.37±0.02	0.49±0.05	-	0.34±0.55	-
Fertilization	1.05±0.12	1.19±0.17	1.09±0.11	1.69±0.18	3.69±2.24	2.04±1.34	0.03±0.03
Energy	0.28±0.01	0.58±0.36	0.50±0.05	0.69±0.28	2.75±0.46	2.72±1.46	0.30±0.04
Feed inputs	1.61±0.73	1.26±0.41	3.34±0.73	3.26±0.45	1.35±1.29	1.25±0.75	1.26±0.41
Other inputs	1.02±0.54	0.58±0.13	2.36±0.37	1.00±0.12	3.15±2.29	0.91±1.16	1.79±0.91
Animal transport	0.02	0.02	0	0	-	-	0
AP, gSO_2-eq		140.16±19.45		195.59±13.52	280.77±63.44	244.74±146.22	112.60±18.73
EP, gPO_4-eq		60.70±14.70		75.73±13.71	124.17±77.63	118.15±108.41	84.43±20.10
CED, MJ-eq		30.92±10.63		28.90±3.51	78.75±16.26	63.75±26.73	60.11±22.73
EFP, m^2-eq		30.20±4.30		95.58±8.55	32.63±8.63	35.42±22.41	17.65±6.22
LW, kg	679±52		639±40		270±43	656±85	273±25
Production cycle,d	571±58		586±19		222±56	512±64	205±10

F-I French-Italian production chain; **P** Piedmontese fattening production chain; **SC** Suckler-Calf farms; **CB** Calf-to-Beef farms; **WC** White veal calves

Figure 4.1. Gas emitted for 1 kg finished male cattle LW

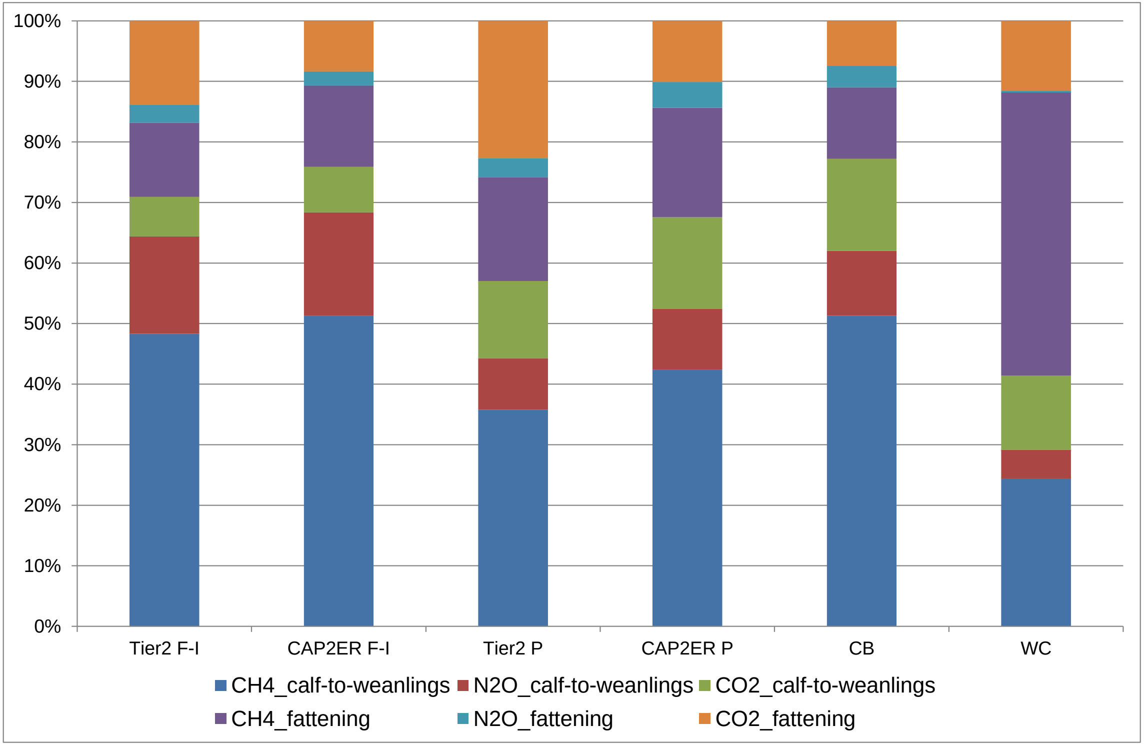


Figure 4.2. Source of GWP for 1 kg finished male cattle LW

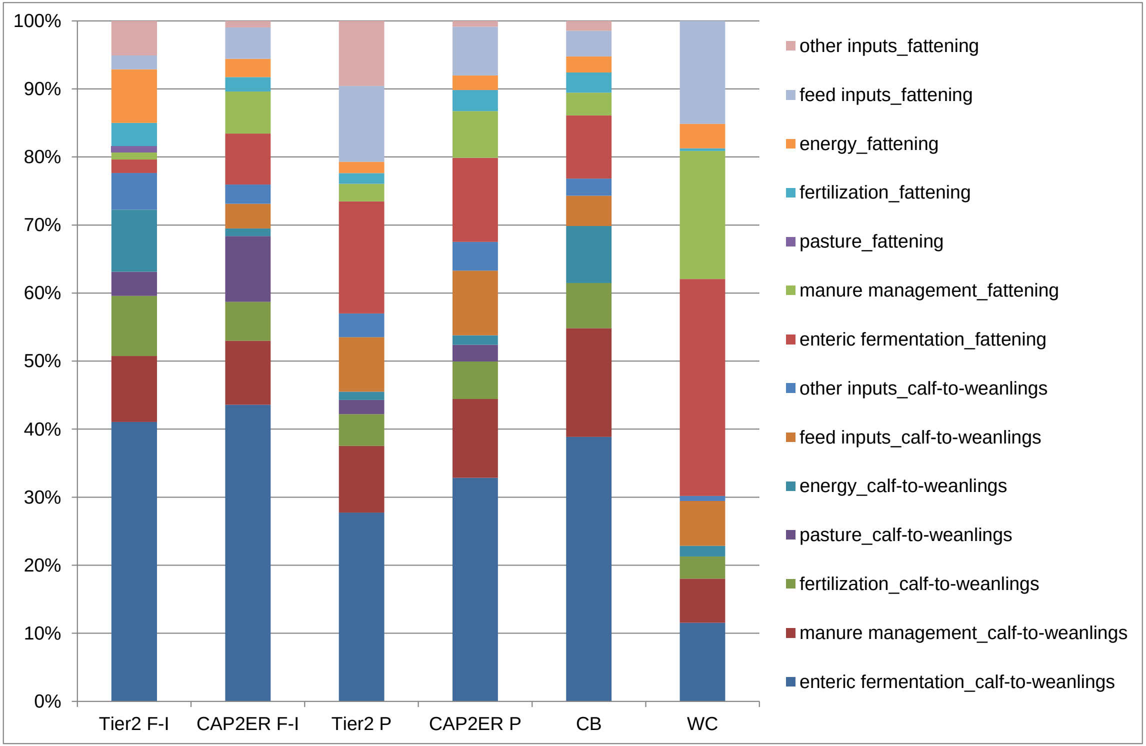


Figure 4.3. Gas contribution to acidification potential (AP) for 1 kg finished male cattle LW

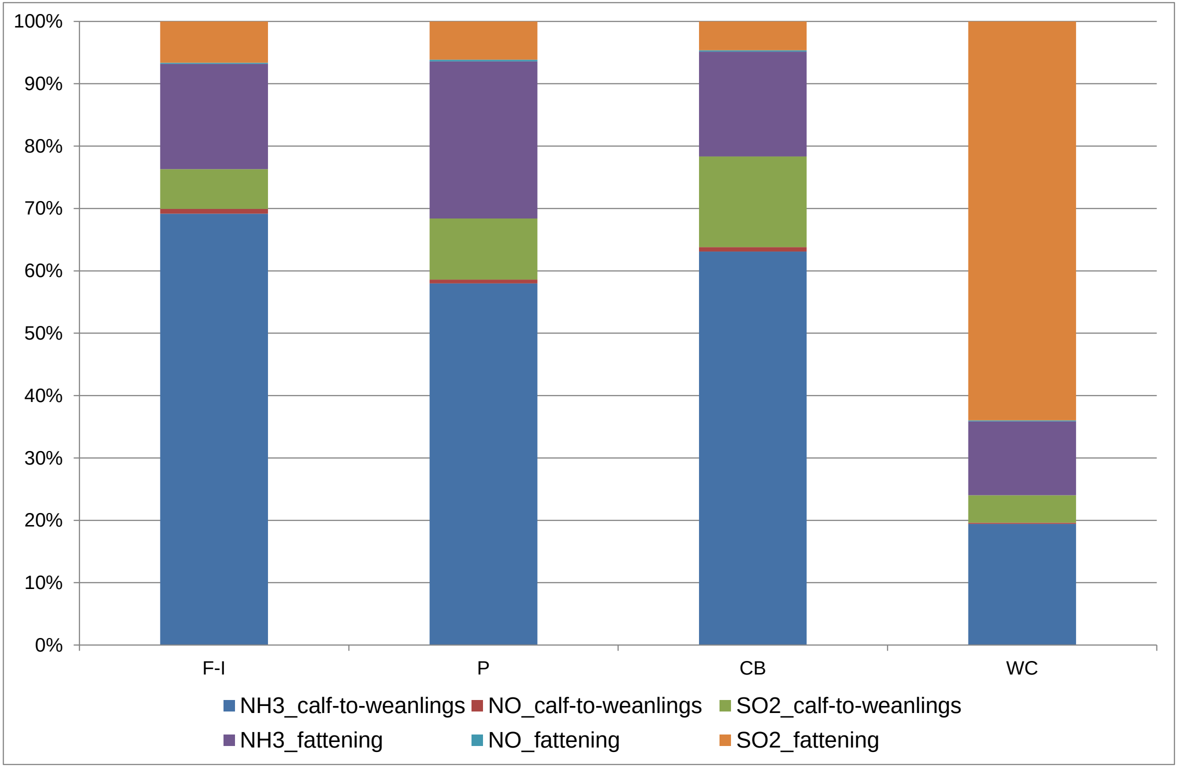


Figure 4.4. Source of AP for 1 kg finished male cattle LW

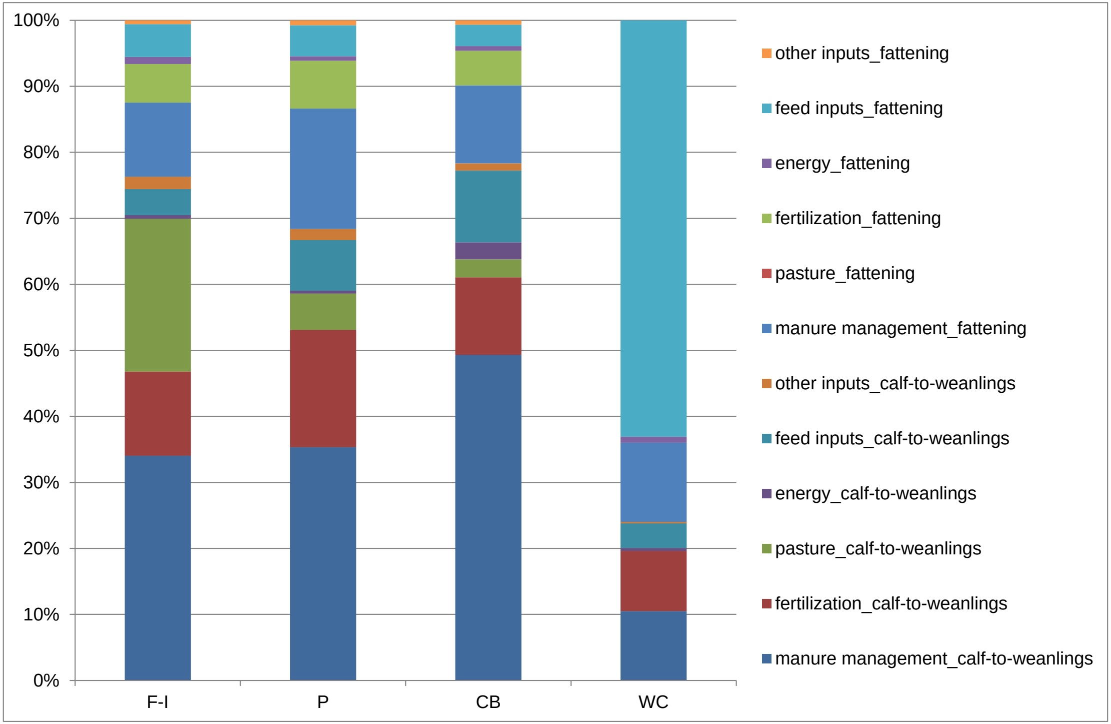


Figure 4.5. Gas contribution to eutrophication potential (EP) for 1 kg finished male cattle LW

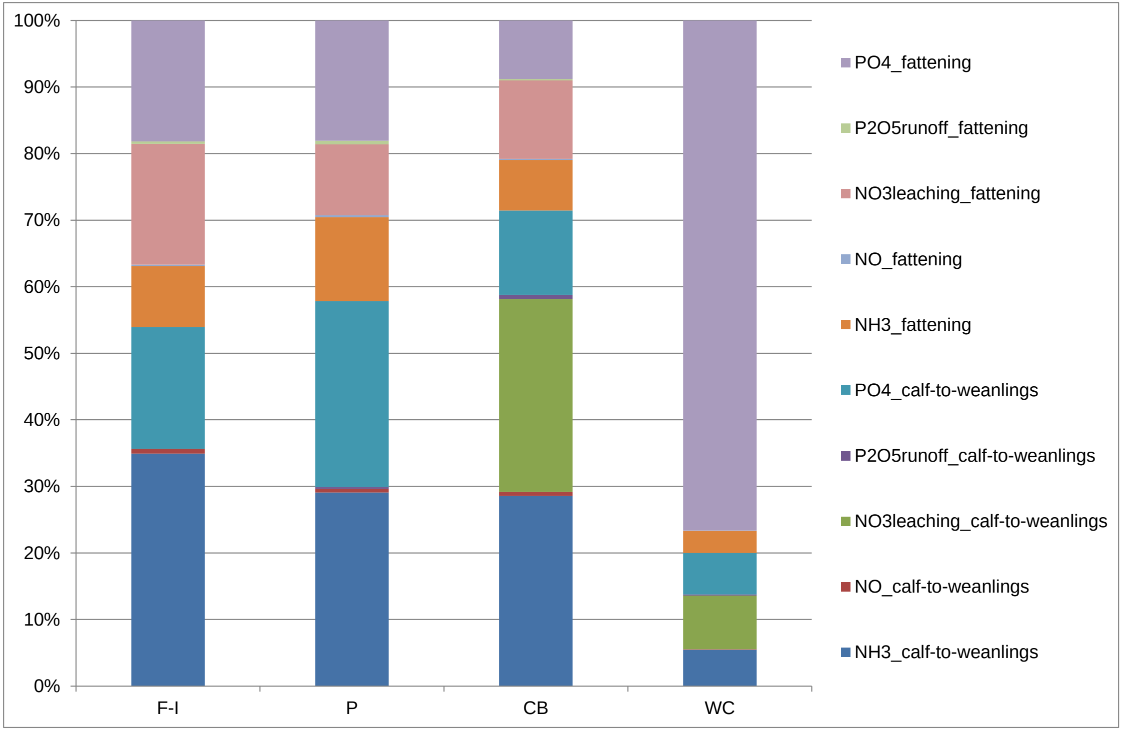
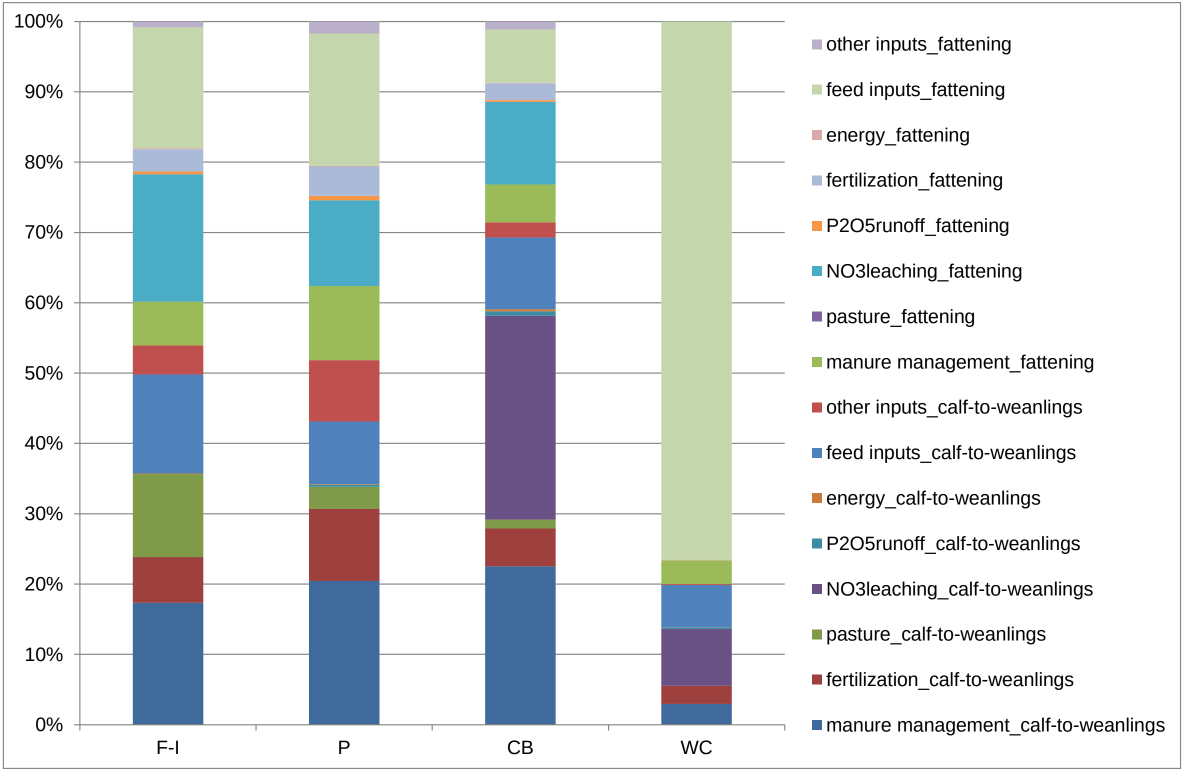


Figure 4.6. Source of EP for 1 kg finished male cattle LW



Heifers

Table 4.4 points out the environmental impacts of heifers fattened in two different farming systems: the fattening system, consisting of two beef specialized units, and the cow-calf one. P-heifers release less emissions in comparison to CB-heifers except for the land use taken that is larger as for the P-young bulls. Focusing on the production cycle of heifers, it is possible to note that P-heifers, even if younger, are more efficient than CB-ones.

Table 4.4. Environmental impact per 1 kg LW of finished heifer

	P		**CB**
Animal category	*Heifer 14 months*		*Heifer 18 months*
Farms, n	3	3	9
Methodology	*Tier2*	*CAP2ER*	*CAP2ER*
GWP, kgCO_2-eq	18.32±3.46	17.93±2.20	21.64±8.63
Enteric fermentation	8.32±1.79	8.19±0.99	10.47±4.33
Manure management	2.49±0.64	3.28±0.30	4.25±2.28
Pasture	0.47±0.14	0.48±0.09	0.30±0.48
Fertilization	1.24±0.35	1.53±0.32	1.97±1.10
Energy	0.39±0.15	0.59±0.24	2.32±1.51
Feed inputs	3.27±0.73	2.94±0.15	1.59±1.85
Other inputs	2.05±0.22	0.94±0.26	0.74±0.76
Animal transport	0	0	-
AP, gSO_2-eq		179.71±18.74	227.77±144.72
EP, gPO_4-eq		70.70±14.01	101.29±89.18
CED, MJ-eq		24.92±3.62	57.07±24.85
EFP, m^2-eq		92.10±15.65	32.64±20.76
LW, kg	457±21		568±66
Production cycle,d	340±47		510±70

P Piedmontese fattening production chain; **CB** Calf-to-Beef

Cull cow

The beef cull cows are also a meat source to which it is assigned an impact in the considered system. The obtained results show that the emissions released by suckler cows reared in specialized beef systems (French-Italian and Piedmontese cow-calf weaner) are much lower than the ones referred to the other beef cows (Table 4.5). This fact is linked partly to the biophysical allocation, according to which the highest part of impact produced is not assigned to the cow itself but to weaners, partly to reproductive parameters such as birth and weaning rates.

Table 4.5. Environmental impact per 1 kg LW of finished cull cow

	Fattening		**Cow-calf**	
	F-I	**P**	**SC**	**CB**
Farms, n	1	1	3	9
GWP, kgCO_2-eq	8.26	7.69	17.92±10.06	15.22±6.29
AP, gSO_2-eq	76.47	77.79	133.81±17.45	149.41±87.21
EP, gPO_4-eq	23.41	22.53	76.31±66.76	72.62±59.30
CED, MJ-eq	10.42	6.73	40.33±13.27	36.95±20.23
EFP, m^2-eq	16.73	52.12	17.40±9.88	16.92±9.90
AF, %	17.7	9.0	17.0±1.0	21.0±6.0
Birth rate, calf cow^{-1} $year^{-1}$	0.91	0.89	0.77±0.14	0.77±0.16
Weaning rate, calf cow^{-1} $year^{-1}$	0.83	0.83	0.73±0.10	0.74±0.15

F-I French Italian beef production chain; **P** Piedmontese fattening beef production chain; **SC** Suckler calf production system; **CB** Calf-to-beef production system
AF Allocation Factor

Dairy farm co-products

Dairy farm environmental performances are shown in Table 4.6. The 87 % of impacts is allocated to milk, the 10 % to the cull cow and the remaining 3 % to calf. As a consequence 1.08 kgCO_2-eq are emitted per 1 kg FPCM, 6.0 kgCO_2-eq are emitted per 1 kg LW of finished cull cow and 15.72 kgCO_2-eq are emitted per 1 kg LW of calf. Detailed estimates per 1 kg of milk, which is the main product in – exit, are summarized in Figure 4.7 and 4.8.

The highest contribution to milk global warming potential is given by methane (59 %), followed by carbon dioxide (30 %). The main source of emission is enteric fermentation (38 %), followed by feed inputs (22 %) and by manure management

(21 %). The value obtained for each one of the other impact categories analyzed is tied up to a distinctiveness of the farm.

The highest contribution to the non-renewable resources consumption is given by the energy used for milking parlor (14 %).

The air emission (acidification) is due to manure management in stable (30 %) and during manure storage phase (13 %) and spreading (38 %).

Eutrophication impact category is, on the contrary, influenced by the nitrate leaching coming from the N farm balance (186 kg N ha^{-1}).

The ecological footprint of milk is equal to 1.06 m^2-eq. Feed self-sufficiency of the dairy farm is approximately 66 % on DM basis; for this reason feed inputs entry accounts for 50 % of the whole impact.

Table 4.6. Environmental impacts of dairy sample farm co – products

	Milk	Cull cow	Calf
GWP, kgCO_2-eq/kg	1.08	6.00	15.72
AP,gSO_2-eq/kg	10.75	59.60	156.14
EP, gPO_4-eq/kg	6.98	38.73	101.47
CED, MJ-eq/kg	3.01	16.71	43.78
Land use, m^2-eq/kg	1.06	5.88	15.40
AF, %	87	10	3

Figure 4.7. Gas and source of GWP for milk production

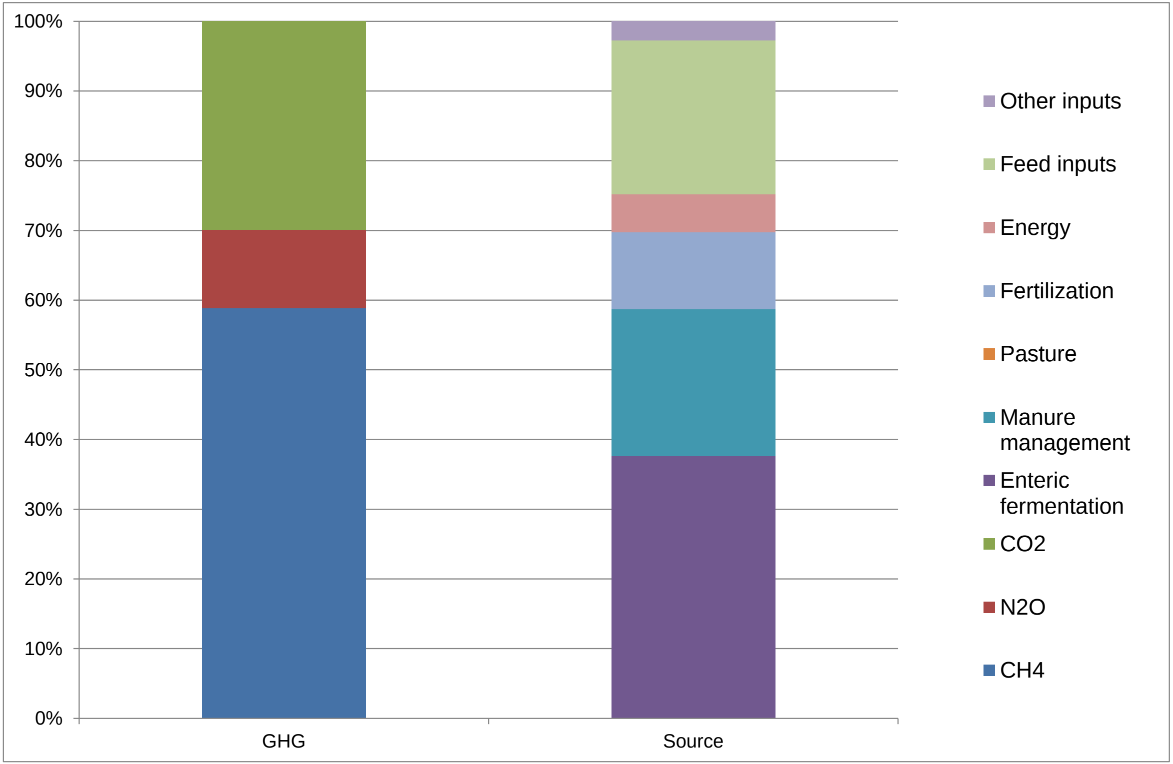
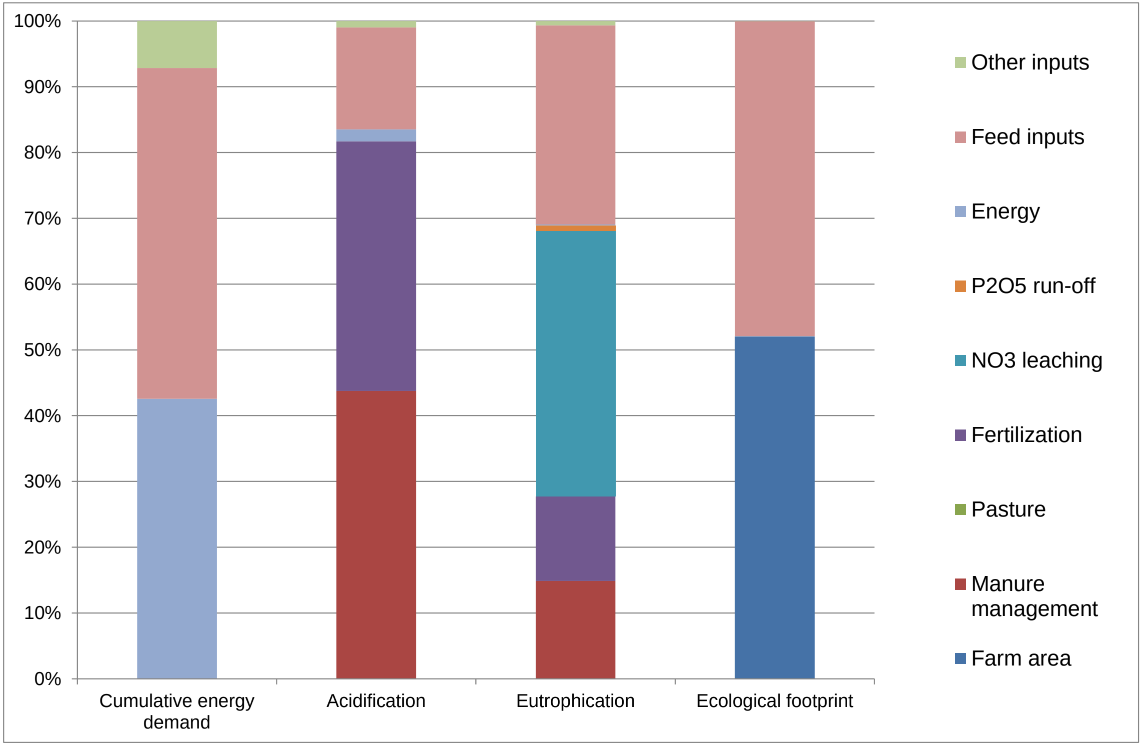


Figure 4.8. On – off farm contribution on milk impacts



A survey recently conducted in 41 North Italy intensive dairy farms, located in the same area of the analyzed case study, has pointed out similar data for each impact category (Guerci et al., 2013). Comparable main structural indicators, such as fat-protein corrected milk yield, self-feed sufficiency and livestock unit support this evidence. In a sample of 285 Southern Italy dairy farms, as reported by Atzori and colleagues (2014), an higher global warming potential per 1 kg FPCM, has been observed, due to a lower milk yield per cow per year. A further confirmation of the estimate can be found on the data about milk carbon footprint reviewed by Pirlo (2012).

In the above mentioned Italian studies, the allocation was based on the split between milk and meat, without distinguishing calf 0-8 days and dairy cull cow (IDF, 2010).

Gac and colleagues (2014), on the contrary, split the whole global warming potential of a French lowland dairy system, based upon maize silage and grass, among the identified co-products showing as the biophysical allocation ascribes a lower factor to milk favoring meat to IDF method. The global warming potential of calf is so higher (14.71 kgCO_2-eq) and comparable to 15.72 kgCO_2-eq found in the present study.

Table 4.7. Environmental impact of 1 kg LW per each cattle category reared in the main beef production systems

	GWP **$KgCO_2$-eq**	**AP** **gSO_2-eq**	**EP** **gPO_4-eq**	**CED** **MJ-eq**	**EFP** **m^2-eq**
Veal (8 months at slaughter)					
White veal calf	7.60±2.20	112.60±18.73	84.43±20.10	60.11±22.73	17.65±6.22
Young cattle (12-24 months at slaughter)					
Young bull, F-I					
Tier2	14.28±1.07	-	-	-	-
CAP2ER	15.23±0.98	140.16±19.45	60.70±14.70	30.92±10.63	30.20±4.30
Young bull, P					
Tier2	17.46±0.36	-	-	-	-
CAP2ER	19.57±0.88	195.59±13.52	75.73±13.71	28.90±3.51	95.58±8.55
Heifer, P					
Tier2	18.32±3.46	-	-	-	-
CAP2ER	17.93±2.20	179.71±18.74	70.70±14.01	24.92±3.62	92.10±15.65
Young bull, CB	23.60±9.20	244.74±146.22	118.11±108.41	63.75±26.73	35.42±22.41
Heifer, CB	21.64±8.63	227.77±144.72	101.29±89.18	57.07±24.85	32.64±20.76
Beef (> 24 months at slaughter)					
Dairy cow	6.00	59.60	30.73	16.71	5.88
Beef cow, F-I	8.26	76.50	23.40	10.42	16.73
Beef cow, P	7.69	77.79	22.53	6.73	52.12
Beef cow, SC	17.92±10.06	133.81±17.45	76.31±66.76	40.33±13.27	17.40±9.88
Beef cow, CB	15.22±6.29	149.41±87.21	72.62±59.30	36.95±20.23	16.92±9.90

F-I French-Italian production chain; **P** Piedmontese fattening production chain; **SC** Suckler-Calf; **CB** Calf-to-Beef; **WC** White veal calves

Starting from basic farm data it is possible to obtain a simplify environmental assessment. To do this it is necessary to use secondary data taken from literature and this is a disadvantage of this method which could be overcome finding country

- specific emission factors and collecting real figures.

In Table 4.7 are summarized the environmental performances of each beef cattle category reared in the main Italian beef production systems.

The analyzed farms differ within themselves for many aspects such as the agricultural area's unit of measure e.g. giornata piemontese, biolca, pertica and farm management. Different agricultural practices, involving more or less synthetic fertilizers and pesticides use according to crop cultivation, are applied. A feeding system based on maize silage or hay diets enriched with purchased concentrates is opposed to pasture and on-farm feed resources use. Bedding litter use is opposed to concrete slatted floor, which implies a distinct manure management. LCA methodology is useful to uniform data and, starting from the results highlighted by single farm, to understand on which elements act to improve its environmental sustainability. Many studies have been performed using an LCA approach to estimate the GWP and the other environmental impacts of the different beef cattle production systems in Europe and other extra EU-countries. Some of these systems are very similar to those ones analyzed in this study. Pelletier and colleagues (2010) have studied three U.S. different beef production systems starting from a cow-calf (weaner) specialized unit. They notice that cow-calf phase is the main responsible of the whole impact (63 %). Enteric methane, manure management and feed inputs are considered the main contributors. The U.S. feedlot system, which has a feeding regimen very close to the French – Italian one, shows similar GWP (14.8 kgCO_2-eq per kg LW) and CED (38.2 MJ-eq per kg LW) values (Pelletier et al., 2010). The EP and the EFP are higher because of pasture and the larger agricultural area used by the U.S. cow-calf (weaner) unit. The U.S. pasture system as the Italian calf-to-beef farms (CB) is characterized by an extensive feeding system including pasture which affects negatively the environmental impact. A longer production cycle together with lower average daily gains determine higher values of impact categories, in particular GWP (19.2 kgCO_2-eq per kg LW) and EFP (120 m^2-eq per kg LW). The U.S. backgrounding/feedlot system is very similar to the P-fattening production system. The ecological footprint is the same (97.8 vs 95.6 m^2-eq per kg LW) while the global warming potential results slightly lower (16.2 vs 17.5 – 19.6 kgCO_2-eq per kg LW).

A very relevant category for the Italian beef chain is the weaner one as pointed out by Sanne and colleagues (2013). The French cow –calf (weaner) unit produces 11-months weaner, the Piedmontese one 5-months weaner and the suckler calf units 8-months weaner. Comparing these animals with those ones studied by Subak (1999) in a U.S. feedlot system it is observed up to a maximum 32 percent reduction in GWP value, from 46.0 to 14.8 kgCO_2-eq per kg LW. This evidence can be explained by herd management of the analyzed systems, for example feeding regimen, average daily gain and lifetime. The estimated global warming potential for French-Italian weaners agree with values reported by Dollé and colleagues (2012).

The environmental impact of all beef cattle categories has been recently reported by Mogensen and colleagues (2015) but also Dollé and colleagues have studied in detail the environmental performances of French beef cattle production (2011, 2012). Danish and French beef production systems are very similar to the Italian one.

The first point is that dairy production represents a very important source in the beef chain. In Denmark dairy cattle breeds account for 85 % of slaughtered animals while in France dairy cattle breeds represent 35 % of the whole beef production. In

Italy white veal calves together with cull cows account for 38 % of slaughtered heads.

The second point is that French cross-breeds are very diffused both in Denmark and Italy in which Limousine and Charolaise breed are respectively the most typical breed reared in intensive farming systems.

Herd management is rather different for each production system. Danish farms are specialized in dairy bull calves production, cow-calf (weaner) and calf-to-beef units are the most diffused in France while in Italy stockers units are dominant.

The young bull reared in French calf-to-beef units seems to have the best environmental performances (13.5 kg CO_2-eq per kg LW) compared to young bull reared in the Italian analyzed systems (14.28 – 23.60 kg CO_2-eq per kg LW). Even the Danish Limousine breed young bull releases 31.0 kg CO_2-eq per kg LW. Referring to heifers the results reflect the values found out for young bulls. The heifer fattened in a calf-to-beef case study located in Limousin district emits 13.1 kg CO_2-eq per kg LW. GHG emissions of P and CB-heifer are higher, ranging from 13.0 to 30.3 kg CO_2-eq per kg LW and comparable to emissions estimated for the Danish Limousine one. These results can be explained by some farm indicators. The number of weaned calves per cow per year, the indicator to which the breeder looks at to understand how he has worked, shows that the most favorable system is the Danish one with 1.0 weaned calf per cow per year. Other indicators, which confirm what hypothesized, are the age at the first birth and the number of heads slaughtered per weaned calf per year. The LW production per head reared changes the condition because it is usually associated to a lower impact. The French calf-to-beef units show an high LW production (380 kg LU^{-1}). The highest LW production of F-I (855 kg LU^{-1}) and P (653 kg LU^{-1}) stockers compensate for the lower LW production of cow-calf (weaner) units permitting to reach a similar impact value. CB units have a LW production of 272 kg LU^{-1}, for this reason the worst impact.

A further aspect to take into account is represented by forage basis supplemented in diet; in fact data reported by Doreau and colleagues (2012) show that young bulls fed hay based diets show higher emissions than young bulls fed maize silage based diets. Dudley (2012) too, on the basis of a survey conducted on U.S. beef cattle production, found that inclusion of pasture emissions from cow-calf phase of young bull life cycle tripled global warming potential compared to the feedlot system, from 6.0 to 16.67 kgCO_2-eq per kg LW.

As regards the other environmental impact categories, the Italian young bull use the same quantity of non-renewable resources than the French (20.6 MJ-eq) and Danish young bull (37.2 MJ-eq). Air emissions are similar to those estimated for the French young bull reared in calf-to-beef units while Danish young bull release much more gSO_2-eq per kg LW. Only Italian and French young bull eutrophication potential can be compared because 1) they are in the same range; 2) they have the same measure unit, gPO_4-eq. Mogensen and colleagues (2015) choose gNO_3-eq to indicate the eutrophication potential category. The Italian young bull ecological footprint is better than the Danish one, except for the Piedmontese breed which takes much more land area. Focusing our attention on Brazilian beef production system, which is completely different by the Italian breeding system and by the other examined systems, it is possible to detect points of likeness. In fact Cederberg and her team (2009) estimates that the Brazilian bull global warming potential is equal (14.0 kgCO_2-eq/kg LW) to that one of the French – Italian young bull, even if you are talking about a 4-years old animal of 450 kg LW. The ecological footprint calculated in 87.5 m^2-eq per year is, on the contrary, very close to estimate for the Piedmontese young bull. No references are available in Dollé and colleagues (2012) about ecological footprint of young bulls as well as for environmental indicators of heifers. The calculated values of cumulative energy demand and ecological footprint are quite similar for the Italian heifer and the

Danish Limousine breed one which releases in the air a very large quantity of gSO_2-eq.

The substitution of replacement heifers with heifers for fattening and the decrease of age at first calving, as suggested by Nguyen and colleagues, (2012) has given positive results on the global warming potential. According to the obtained results in the present study it appears that the Italian beef production system made up by two specialized farms, cow-calf (weaner) plus stocker, is more environmentally-friendly as regards to the cow-calf system. The two specialized units are able to maximize animal performances in terms of calving rate and daily gain while cow-calf farms, characterized by extensive breeding management and cash crops cultivation to integrate farm income, are less environmentally-friendly.

So adopting the cow-calf (weaner) plus stocker system, it is realized the aim proposed by Nguyen and colleagues studies which are set up to identify farming practices with a lower environmental impact.

There are then Casey and Holden (2006) and Ledgard and colleagues' (2011) observations, who have not found positive results simulating the conditions hypothesized by Nguyen. Casey and Holden reply for the Irish beef production system is the use of dairy bred cattle for meat production. This system, in Italy, reflects the white veal calves production system which produces lower emissions (7.60 $kgCO_2$-eq per kg LW) in comparison to young bulls, ranging from 14.28 to 23.60 $kgCO_2$-eq per kg LW. This solution is correct also in the case the dairy cull cow is considered as beef producer instead of beef cull cow because it has a lower global warming potential. The available data for dairy cull cow vary from 7.40 to 11.1 $kgCO_2$-eq per kg LW (Gac et al., 2014; Mogensen et al., 2015). Estimates for suckler cows, on the contrary, go by 14.6 up to 16.2 $kgCO_2$-eq per kg LW (Alig et al., 2012; Lieffering et al., 2012).

On the basis of the results obtained in the present study, of sensitive analyses proposed in literature and in reply to the advanced needs of the breeders who participate to this survey, it has been supposed a change in diets composition in order to reduce young bull GHG emissions.

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Chapter 5

Sensitive analysis

Analysis of different scenarios: soybean meal substitution with alternative protein sources in the Italian finishing diets

The main protein crops cultivated in Italy are introduced in Table 5.1. Alfalfa is certainly the most diffused forage, resulting 50 % of the whole Italian surface area. (ISTAT,2012) In Emilia Romagna and Lombardia it represents, in association with maize silage and meadow hay, the main forage basis in diets supplied to dairy cows whose milk is processed to PDO productions such as Grana Padano and Parmigiano Reggiano cheese. Soybean meal represents the excellence in terms of feeding concentrate for dairy and beef cattle since when animal origin meals usage was banned by the European Union (Directive 90/425/CEE). Secondary grains such as *Vicia faba var. minor* and *Pisum sativum* have aroused a relevant concern among breeders. Actually there are, as a result, positive and negative aspects of broad bean and protein pea use if compared with soybean and corn:

- ✓ cheaper market price (Table 5.2), less agricultural inputs (Table 5.3), greater ground exploitation caused by crop rotation.
- ✗ Crop yield reduction, prospective severe cattle health diseases (meteorism, rumen acidosis, limb pains and lameness) caused by highly soluble starch with an availability of carbohydrates ready to fermentation.

Table 5.1. Italian protein crops trends (year 2011) (ISTAT, 2014; FAOSTAT, 2015)

Crop	**Alfalfa**	**Soybean**	**Broad bean**	**Protein pea**
Cultivated area, .000 ha	728	166	43	7
Yield, q/ha	286	35	19	26
Imports, .000 ton	9[1]	1.241[2]	31[3]	82[4]

[1] alfalfa meal and pellets,[2] soybeans, [3] broad beans dry,[4] peas dry

Table 5.2. Economic and environmental sustainability of targeted protein crops (Associazione Granaria di Milano, 2015; Knudsen et al., 2014)

	Soybean meal	**Faba bean**	**Protein pea**
CP content, %	49.0	29.9	25.6
Market price, €/100 kg	33,08	28,88	28,40
	30,72–38,37	23,50–32,00	26,45-32,05
Feed value on protein basis, €/100 kg	67,51	96,60	110,93
	62,70-78,30	78,60-107,02	103,32-125,20
GWP, gCO_2-eq/kg	901	151	199

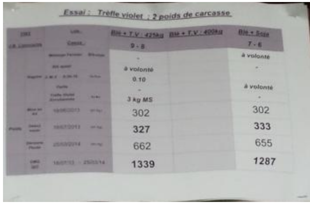
Table 5.3. Means of production used to cultivate protein crops in different countries (Blonk Consultants, 2013; ADEME, 2015)

Crop		**Soybean**		**Broad bean**	**Protein pea**
Country	USA	Brazil	Argentina	France	
Yield, q/ha	28	26	26	51	38
Seed, kg/ha	70	70	70	20	165
Fertilizers, kg/ha					
P_2O_5	29,5	42,0	42,0	45,5	22,0
K_2O	28,0	-	-	15,9	18,7
N	-	-	-	-	-
Lime	362	400	400	-	-
Pesticides, kg/ha	1,6	2,3	2,3	2,9	3,0
Fuel consumption, l/ha	35	52	52	79	94

Broad bean and protein pea were *in vivo* tested in order to check animal performances and product quality. The result as a matter of fact proved these alternative meals to be suitable replacers of soybean meal in terms of milk quality, cheese yield and dairy cows performances as well as young bulls average daily gains (Formigoni et al., 2007; Cocca et al., 2005).

NEOBIF research project aimed at investigating new feeding strategies for weaners designed to Italian market. Bastien and colleagues (2013) have identified farm cases in which young bulls were fed new pulses (alfalfa and red clover) as forage basis without including soybean meal (Figure 5.1).

Figure 5.1. (a) Young bulls experimental diet with no soybean meal supplementation; (b) red clover (c) Pôle herbivores Chambre d'Agriculture de Bretagne Station expérimentale de Mauron (56); (d) young bulls daily feed consumption data collection



(a) (b)

(c) (d)

5.1 Materials and methods

A sample of thirteen Italian beef specialized farms, including the 10 F-I stockers units and the 3 Piedmontese ones, is used. Cow – calf case studies are not involved in the simulation because alternative protein rich – crops (broad bean and protein pea) have already been incorporated in beef cattle mixtures.

Aim of this sensitive analysis is to verify if global warming potential of the whole fattening production system can be reduced by the introduction of alternative protein sources in finishing diets.

LCA methodology was applied as a rule. Soybean cultivation and meal industrial processing stage contribution to global emissions were estimated using references collected by Vellinga and colleagues (2013). AGRIBALYSE French database returned information about protein rich crops practices. Estimated values, taking into account transport session, are respectively 1.460 gCO_2-eq per kg soybean meal, 327 gCO_2-eq per kg broad bean and 371 gCO_2-eq per kg protein pea.

Starting from the physicochemical properties of feedstuffs in focus and from diets really provided, a total replacement of soybean meal has been applied. Two different diets have been virtually tested in which broad bean and protein pea respectively have replaced soybean meal. Diets were formulated in order to save starting physicochemical characteristics. Soybean meal protein content (490 g kg DM^{-1}) has been taken away and substituted with broad bean protein (299 g kg DM^{-1}) or with protein pea protein (256 g kg DM^{-1}). To balance diet's starch content maize grain quantity has been reduced. In the former case 1 kilogram of soybean meal has been substituted by 2 kilograms of broad bean reducing of 0.56 kilograms maize grain content; in the latter 1 kilogram of soybean meal has been replaced by 2.2 kilograms of protein pea reducing of 0.79 kilograms maize grain content.

Table 5.4. Virtual diets: analytical and chemical composition (DM % basis)

	FI-YB			P-YB			P-H		
	SB	BB	PP	SB	BB	PP	SB	BB	PP
Soybean meal	7	-	-	6	-	-	4	-	-
Broad bean	-	13	-	2	13	-	1	10	1
Protein pea	-	-	16	-	-	12	-	-	11
Maize grain	25	18	14	21	15	11	19	13	11
CP, g kg DM^{-1} $head^{-1}$	134	134	134	133	137	138	120	120	120
CF, g kg DM^{-1} $head^{-1}$	149	154	157	171	169	177	204	211	211
EE, g kg DM^{-1} $head^{-1}$	37	34	34	39	36	36	37	36	35
NfE, g kg DM^{-1} $head^{-1}$	629	623	620	588	587	577	573	568	567

FI-YB French Italian young bulls; P-YB Piedmontese young bulls; P-H Piedmontese heifers

SB Soybean meal diet; BB Broad bean diet; PP Protein pea diet

CP Crude protein; CF Crude Fibre; EE Ether extract; NfE Nitrogen free-extract

5.2 Results

Global warming potential's results obtained in the three different scenarios are shown in Table 5.5.

The substitution of soybean meal has decreased GHG emissions from 9 to 22 % on the total GWP with the introduction of broad bean or protein pea. The emissions produced into the F-I stocker phase pass from 4.15 (SB) to 3.76 (BB) and 3.69 (PP) kgCO_2-eq/kg LW decreasing of 9 and 11 % respectively.

The introduction of broad bean and protein pea, made in the Piedmontese fattening system, has produced a decrease of GHG emissions which pass from 7.50 (SB) to 5.85 (PP) kgCO_2-eq/kg LW of young bull and from 5.47 (SB) to 4.71 (PP) kgCO_2-eq per kg LW of heifer.

This decrease is observed in feed inputs and is connected to the lower impact generated by cultivation of alternative protein sources, as pointed out by Knudsen et al., 2014, in comparison to soybean meal and to a lower quota of maize grain provided to cattle. Other inputs category, which contains N-fertilizers, shows a reduction in kgCO_2-eq connected to a minor purchase of maize and of N-fertilizers if the maize is on-farm cultivated. Greenhouse gases decrease is emphasized in the case of Piedmontese young bulls and heifers as production cycle is longer than F-I young bulls.

Table 5.5 Effect of alternative protein sources on beef cattle global warming potential

	FI-YB			P-YB			P-H		
	SB	BB	PP	SB	BB	PP	SB	BB	PP
Farms, n		10			3			3	
GWP, kgCO_2-eq	**4.15**±0.76	**3.76**±0.78	**3.69**±0.67	**7.50**±0.18	**6.70**±0.37	**5.85**±0.78	**5.47**±0.74	**4.90**±0.82	**4.51**±0.88
Enteric fermentation	1.38±0.18	1.36±0.17	1.36±0.18	2.87±0.24	2.85±0.24	2.81±0.29	2.08±0.09	2.07±0.08	2.05±0.05
Manure management	0.51±0.16	0.45±0.15	0.47±0.14	0.45±0.10	0.39±0.04	0.38±0.07	0.28±0.01	0.28±0.01	0.28±0.03
Fertilization	0.28±0.11	0.28±0.11	0.32±0.12	0.27±0.08	0.27±0.07	0.28±0.10	0.20±0.05	0.20±0.05	0.20±0.06
Energy	0.13±0.01	0.13±0.01	0.14±0.01	0.29±0.06	0.29±0.06	0.29±0.05	0.21±0.04	0.21±0.04	0.21±0.04
Feed inputs	1.12±0.75	0.92±0.76	0.56±0.44	1.94±0.72	1.28±0.77	1.25±0.70	1.46±0.73	0.98±0.71	0.96±0.55
Other inputs	0.73±0.52	0.62±0.58	0.79±0.49	1.67±0.35	1.62±0.34	1.09±0.16	1.24±0.16	1.17±0.19	0.81±0.20

FI-YB French Italian young bulls; P-YB Piedmontese young bulls; P-H Piedmontese heifers
SB Soybean meal diet; BB Broad bean diet; PP Protein pea die

The obtained results are confirmed by Nguyen and colleagues (2012) who have noted a lower impact released by young bulls fed with a starch lipid rich diet (6.3 kgCO_2-eq/kg LW) without soybean meal and characterized by a high protein content during finishing phase, in comparison with maize silage based diets (> 8.0 kgCO_2-eq/kg LW). The estimated values for young bulls dry matter intake considered by Nguyen et al., (2012), resulted to be lower if compared with the present study in which dry matter intake agree with values suggested by NRC (2000) guidelines.

The sensitive analysis' results are encouraging but it has to be considered:

- the needs to verify, in vivo, the effect of broad bean and protein pea supplementation on young bulls performances;
- the needs to verify the compatibility between the economic and environmental aspects as considered by Glendining and colleagues (2009);

This idea raises the question as how to solve the low cattle capacity to convert vegetable origin proteins into animal proteins that Pilorgè (2014) estimates equal to 9.9 kilograms of vegetable protein per beef kg.

It might be interesting, on the basis of the positive in vitro results, shown by Cattani and colleagues (2015), to introduce plant extracts, with antimicrobial properties in young bulls' diets in order to reduce their global warming potential.

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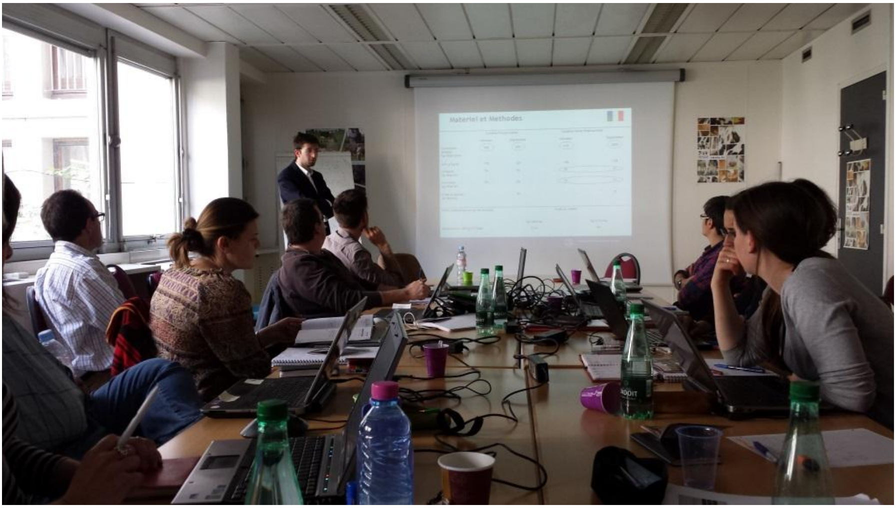
Chapter 6

General Conclusions



The study analysed the environmental impact of the main North Italy district beef production systems using a cradle-to-farm exit gate perspective.

Beef and dairy cattle give a high impact compared to other animal categories because their life cycle is longer and in the same time they have greater feed requirements to reach the daily gain.

Summarizing it has been observed that:

1. there is a wide variability of emissions intra and within systems;
2. the higher impact is due to the cow-calf phase apart from the considered typology;
3. the so-called open cycle system, made up by cow-calf (weaner) plus finishing farm is more sustainable from the point of view of environment than calf-to-beef, the so-called closed system.

The analysis trough the LCA methodology cannot give threshold values which identify a system as environmentally friendly or not but indications are given to breeders as support to improve farm management. For this reason the next step will be to consider a wider sample of beef farms.

This study does not represent the solution for the Italian beef system but goes towards the support and development of the system itself, of the available resources which, always more often, are not considered or, when they are, are seen as a problem.

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