1 Introduction

Since their origins in prehistory, humans have dominated most of the earth´s ecosystems (Beddoe et al., 2009; Hilgenkamp, 2006) due to their advantage over the rest of fauna and flora, i.e. their intelligence and their large and increasing population (Hilgenkamp, 2006). Since the discovery of fire by the very first human beings up to humans´ current increasing desire for improved living standards, material and energy consumption has fulfilled humans´ demands and satisfied their desire for a better life. Hence, constant population growth and improved living standards have become the main drivers of increased anthropogenic natural resource consumption, land use, and environmental pollution.

At the same time, attaining high quality of life is a matter of the greatest concern for humanity. So in search of a sustainable, high quality of life, approaches have been done. Even in the 1880s, research into a kind of a product life cycle consideration (stone coal) with a focus on energy supply by a Scottish economist and biologist was conducted (Klöpffer, 2006).

Environmental Life Cycle Assessment (ELCA), in the modern sense, was developed in the USA in the late 1960s and early 1970s (Hunt & Franklin, 1996). At that time, the Midwest Research Institute (MRI) carried out a study on behalf of the Coca-Cola Company in order to evaluate the life cycle of several beverage packages from an environmental point of view (Hunt et al., 1992; Hunt & Franklin, 1996). Such studies have been called "Resource and Environmental Profile Analysis" (REPA) since 1970 (Hunt & Franklin, 1996). At nearly the same time, similar studies were in progress in Europe (Boustead, 1996; Hunt & Franklin, 1996; Oberbacher et al. 1996).

The world´s ecological and environmental awareness was particularly ignited in 1972 and following the report of the Club of Rome "The Limits to Growth". Increased amount of waste and the oil crisis in 1973/1974 spotlighted the issue (Klöpffer, 2006). In 1980s the attention finally turned to the issues of healthy, enduring ecosystems and the chances for long, sustainable consumption of natural resources. The discussions around the issue of sustainable consumption of natural resources resulted in 1987 in the first governmental and the most famous definition of sustainable development from the World Commission on Environment and Development, WCED (Brundtland Commission, 1987) of the United Nations:

> "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*"

Report of the World Commission on Environment and Development: Our Common Future, Chapter 2

Later social and economic elements have complemented the term “sustainability”. Since then, several methodologies have been developed for assessing the environmental impacts associated with products. General environmental risk assessments (Hunt et al., 1992), carbon footprint (BSI, 2008a), food miles, and Life Cycle Assessment (LCA) are some examples hereof. In addition, methods of working environment in Life Cycle Assessment (WE-LCA), such as MUP chemical screening method (Denmark), STØ chemical screening method (Norway), EuroMat screening method (Germany), or IVL sector method (Sweden) can be included in an LCA and carried out parallel to an LCA. Application of such methods depends on the goal and scope of an LCA. (SETAC, 2004)

The term Life Cycle Assessment (LCA) in today´s sense came into use in the USA in 1990 (Hunt & Franklin, 1996). The Society of Environmental Toxicology and Chemistry (SETAC) has attended to the LCA since the same year, due to increased interest in this topic (Klöpffer, 2006). In 1997, the International Organization for Standardization (ISO) published its first guidelines for environmental management - Life Cycle Assessment which have been improved and published again in 2006 and 2009. These publications are employed as guidelines within this dissertation thesis.

1.1 Statement of the problem

1.1.1 General introduction to global climate change

Global climate change is today unequivocally a growing crisis. Ecosystems, industries, societies as well as the human health are already affected by its present and future impacts. If no additional climate change mitigation activities, beyond those of today, are undertaken, the global mean surface temperature in 2100 will have an increase from 3.7°C to 4.8°C compared to pre-industrial levels (IPCC, 2014a). The increases in global average air temperature (resulting from increases of greenhouse gas (GHG) concentrations in the atmosphere and consequently increases of radiative forcing in the climate system) are the particular reason for these impacts. Small changes in average air temperature can result in serious environmental consequences. Indeed, rising global temperatures are changing the environment: snow and ice extent is decreasing, soil temperatures are increasing, oceans are becoming warmer, and the global average sea level is rising. (EPA, 2010; IPCC, 2007a)

The driver of all these environmental changes is both natural and anthropogenic (EPA, 2010). The recent assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2014b) shows, however, that the global GHG emissions due to anthropogenic (human) activities between 2000 and 2010 have increased since the pre-industrial times by about 10 Gt CO_2 equivalents (eq). Total anthropogenic GHG emissions in 2010 were about 49 Gt CO_2 eq (IPCC, 2014b). Economic growth, population growth, technology advances, and accordingly new human lifestyles are key drivers of anthropogenic GHG emissions (EPA, 2009). Carbon dioxide (CO_2) is the most important GHG and has the greatest emissions between all anthropogenic GHGs. In 2010, it represented approximately 76% of total anthropogenic GHG emissions (IPCC, 2014b). Methane (CH_4) is the second greatest GHG emitted by human activities with a share of approximately 16% of the total anthropogenic GHG emissions in 2010, followed by nitrous oxide (N_2O) accounting for approximately 6% of the total anthropogenic GHG emissions in 2010 (IPCC, 2014b). Fluorinated gases accounted in 2010 for about 2% of the total anthropogenic GHG emissions in 2010 (IPCC, 2014b). CO_2, CH_4, and N_2O concentrations in 2010 were larger by far than their natural concentrations in the last 800,000 years (IPCC, 2014c). Anthropogenic CO_2 emissions are mostly due to fossil fuel consumption and land use change. Anthropogenic CH_4 and N_2O emissions, however, are particularly due to agricultural practices (IPCC, 2007b). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) belong, according to the Kyoto Protocol, Annex A, to the category GHGs (Kyoto Protocol, 1998).

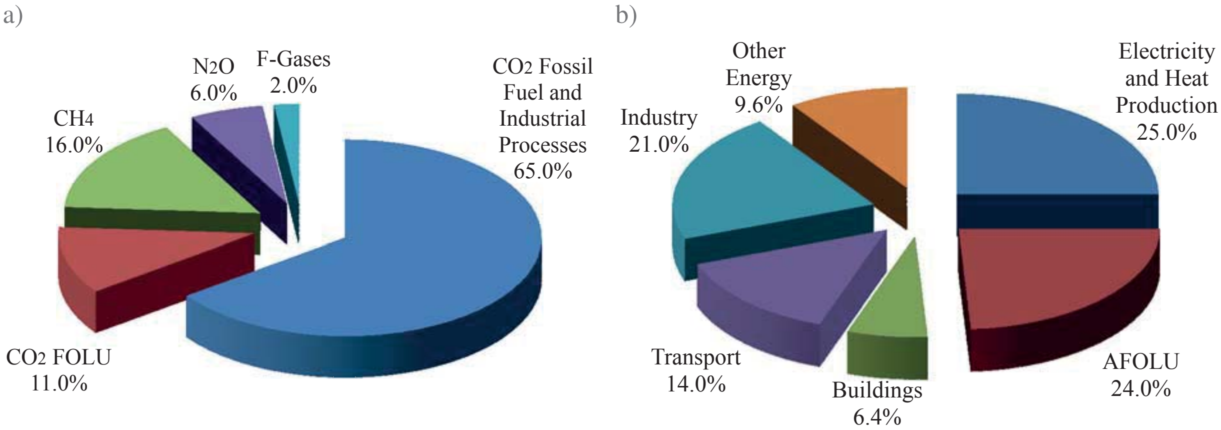

Figure 1: **Total anthropogenic GHG emissions in 2010; a) Approximate share of different GHGs in total anthropogenic GHG emissions in 2010, b) Share of different economic sectors in total anthropogenic GHG emissions in 2010 (according to IPCC, 2014b, p. 46-47)**

The Intergovernmental Panel on Climate Change (IPCC, 2014b) reports, furthermore, that GHG emissions (in terms of CO_2 eq) are increasing even more rapidly than before (comparing the two periods 1970-2000 and 2000-2010). Energy, industry, and transport sectors had the largest growth in GHG emissions (2000-2010). The share of agriculture, forestry and other land use (AFOLU) in the total anthropogenic GHG emissions in 2010 in terms of CO_2 eq has been about 24%. In average, agriculture, alone, contributes yearly to at least 10-12% of global GHG emissions (5.1-6.1 Gt CO_2 eq) (FAO, 2009). The share of different GHGs in total GHG emissions in 2010 (a) and the sectoral share in total anthropogenic GHG emissions in 2010 (b) are illustrated in Figure 1.

GHGs, such as CO_2, CH_4, N_2O, halocarbons (IPCC, 2007a), and sulphur hexafluoride (SF_6) (MED, 2008) are long-lived substances, in contrast to other pollutants and ozone which resulting in regional hot spots and disappear after sometime (MED, 2008). GHG concentrations (in terms of CO_2 eq) of about 450 part per million (ppm) could avoid the impacts of global climate change on ecosystems and societies. With concentrations between 445 – 490 ppm, however, serious consequences of the global climate change and consequently global warming are unavoidable. In this case, increases of the annual mean temperature of the Earth's surface of 2.0°C – 2.4°C above pre-industrial levels are anticipated resulting in the global impacts mentioned before (MED, 2008). Scientific evidences show that the GHG concentrations in the climate system have already reached the levels of 450 ppm or they will reach this level very soon (MED, 2008). Hence, immediate action against climate change in every sector is needed.

Global climate change affects the whole world; in particular, the poor and developing countries since their economies are especially dependent on natural resources and the associated economic sectors (e.g. agriculture, forestry, and fisheries). In this respect, climate change is also a danger to economic development and poverty reduction in these countries. (UNEP, 2010; EU, 2003) The South Caucasus (Armenia, Azerbaijan and Georgia) is an economically poor region, and is also already affected by the consequences of climate change (WWF, 2008). This research study deals, therefore, with the topic climate change in the Republic of Armenia with a special focus on the milk industry sector.

1.1.2 Armenia: national, political, and environmental situation

The Republic of Armenia was established on 21^{th} of September 1991 (UNDP/GEF/ARM, 2010). Armenia is a country located in southwestern Asia (south of the Caucasus) with highland continental climate meaning hot summers and cold winters (CIA, 2013; FAO, 2013a). The World Factbook (CIA, 2013) describes Armenia as a country with mountains, little forestry, fast flowing rivers, and good soil in the Aras River valley.

However, wrong land use (e.g. overgrazing) is currently causing desertification, formation of steppes, and erosion in Armenia (EU, 2007). Other agricultural practices, such as application of toxic chemicals (e.g. dichlorodiphenyltrichloroethane, DDT), have resulted in soil pollution over the course of time (CIA, 2013; IZK, 2003). Soil monitoring, however, cannot be carried out at present in the country "due to absence of corresponding capacities" (EEA/ARM, 2011, p. 12). Hence, information concerning the current situation of the soil quality in Armenia is not available.

Pollution of water resources is another significant environmental issue in the republic (EU, 2007). Armenia is a country with limited natural resources (FAO, 2013a; UNDP/GEF/ARM, 2010), such as petroleum and natural gas (IZK, 2003). A large part of the energy consumed in Armenia is generated, therefore, by hydro power (IZK, 2003). In 2009, over 34% of the total installed electricity capacity in Armenia was generated in hydroelectric plants (CIA, 2013). Lake Sevan, one of the most important national mountain lakes of Armenia (FAO, 2006), has had, therefore, a drop in its water level of over 20 meters (IZK, 2003), as it is one of the significant sources for hydropower in Armenia (CIA, 2013). Other water sources in the country, such as the Hrazdan (Razdan) and Aras Rivers, are polluted as well (CIA, 2013), partly as a result of utilization of the hydro power (IZK, 2003).

The water of Lake Sevan is also used intensively for irrigation (FAO, 2006) which illustrates the other reason of the drainage of this lake. In addition, industry and agriculture together, caused serious pollution in Lake Sevan which is also an important source of drinking water in Armenia (Good Practice UN-Habitat, 2000). Armenia´s old infrastructure and facilities also affect the quality of drinking water (EU, 2007). Waste water treatment facilities (20) require urgent improvement (UNDP/GEF/ARM, 2010), as all of these 20 facilities with exception of one facility in the capital city, Yerevan, are inoperable (UN/ARM, 2012). Waste water (household, commercial, and partially industrial waste water) discharges, therefore, into surface waters currently without any kind of treatment (UNDP/GEF/ARM, 2010).

Concerning solid waste management, there is still no special waste collection and treatment system for hazardous, toxic waste in Armenia (EU, 2007). Waste management (sorting, separating, recycling, etc.), in general, is a serious Armenian problem (EU, 2007). All these affect the country´s biodiversity as well (EU, 2007). In addition, the landfilling of municipal solid waste (MSW) and resulting anaerobic fermentation result in CH_4 emissions (UNDP/GEF/ARM, 2010). A European Union project in Armenia, implemented by the European Environment Agency explains the current situation of waste and waste management in the republic as follows: “at the moment, there are no landfills in Armenia corresponding to sanitary requirements and norms, and the existing landfills are rather burial sites, where open-air low temperature burning takes place. In the Republic there are numerous non-licensed landfills, which in reality are dump sites. In addition, there are no designated landfills for industrial, production and construction waste, and all such waste is dumped together with other waste in the landfills” (EEA/ARM, 2011, p. 11). Waste monitoring does not exist in the country as well. However, enterprises are expected to inform the Armenian government annually about the amount of waste they have produced and transported to the burial sites (EEA/ARM, 2011). Furthermore, since 2008 new projects are implemented, in order to use the biogas emitted from MSW for energy production (UNDP/GEF/ARM, 2010).

In 1990s, the Armenian energy crisis resulted in deforestation of the country´s already sparse forests, as firewood was the only easy to get and available heating material (CIA, 2013; IZK, 2003). In general, Armenia´s economic crisis in 1995 (compared to the year 1990) resulted in several national challenges, such as 70% reduction of Gross Domestic Product (GDP), 75% reduction of industrial production, and 30% reduction of agricultural production. As a result, the quality of life in Armenia has decreased seriously. Both of these crises (economic crisis and the energy blockade) have been the main reasons for the reduction of general energy consumption by 3.6 times and less production in general in the country for the period between 1990 and 1995. Accordingly, the GHG emissions have reduced by about 76% (comparing the rates in 1990 and 1995). (UNDP/GEF/ARM, 1998)

Table 1 illustrates the rates of population growth, GDP, power consumption, and GHG emissions in Armenia during 1990 to 1995.

Table 1: **Determining factors and GHG emissions in Armenia, 1990-1995 (according to UNDP/GEF/ARM, 1998, p. vii)**

Years	Population[1]		GDP		Power		GHG emisssions[2]		GHG emisssions per capita		GHG emisssions per unit of GDP	
	Million people	Rate % by 1990	In actual prices, million $	Rate % by 1990, in fixed prices	PJ	Rate % by 1990	kt CO_2 eq	Rate % by 1990	t CO_2 eq / people	Rate % by 1990	t CO_2 eq / $1000	Rate % by 1990
1990	3.574	0.0	8770.0	0.0	350	0.0	25312	0.0	7.08	0.0	2.9	0.0
1991	3.450	1.9	8390.0	- 19.8	336	- 4.0	23165	- 9	6.3	- 10.4	3.3	11.4
1992	3.724	4.0	4312.0	- 51.7	168	- 52.0	11323	- 55.2	3.0	- 57.7	2.7	-7.3
1993	3.728	4.1	447.3	- 74.4	142	- 60.0	8255	- 67.4	2.2	- 69.0	3.7	12.7
1994	3.737	4.4	651.4	- 73.0	82	- 76.6	4779	- 81.1	1.3	- 82.0	2.0	-30.6
1995	3.765	5.1	1290.0	- 70.0	96	- 72.6	6193	- 75.5	1.6	- 77.0	2.4	-17.3

[1] Without taking into account the emigration of 677 thousand people in 1991 - 1994
[2] Excluding the emissions connected to the land use change and forestry

Armenia, however, could stabilize its economic situation again. From 1995 to 2000, the Armenian economy grew with an annual average of 5.4%. From 2001 to 2006, the rate of average economic growth was 12.4%. In 2006, 17.9% of the GDP in Armenia was related to industrial production and 18.1% to agricultural production (in addition, 24.5% to construction, 32.2% to services, and 7.2% to net taxes). Accordingly, GHG emissions have been increased from 1994 to 2006. However, rates of the GHG emissions in 2006 were not as high as emissions in 1990, before the economic crisis (Table 2). (UNDP/GEF/ARM, 2010)

Table 2: **GHG emissions in Armenia in terms of Gg CO_2 eq (according toUNDP/GEF/ARM, 2010, p. XIX)**

Years	CO_2	CH_4	N_2O	Total emissions, without LULUCF[1]	Total emissions, with LULUCF
1990	21,558.5	3,200.5	195.9	24,954.9	24,218.9
1994	2,994.8	1,557.3	106.9	4,679.0	n/e[2]
2000	3,187.2	1,733.3	151.8	5,071.3	6,634.9
2006	4,157.0	1,986.5	279.3	6,422.8	n/e

[1] Land use, land use change and forestry
[2] not estimated

In 2006, the energy sector emitted the most GHGs (Table 3) followed by agriculture, waste, and industry (UNDP/GEF/ARM, 2010).

Table 3: **GHG emissions / removals by sectors in terms of Gg CO_2 eq (according to UNDP/GEF/ARM, 2010, p. XIX)**

Years	Energy	Industrial processes	Agriculture	Waste	LULUCF[1)]
1990	22,777.0	630.3	982.6	564.9	-736.0
1994	3,268.6	53.0	812.6	544.9	n/e[2)]
2000	3,550.6	119.7	840.7	560.3	1,563.62
2006	4,441.40	323.8	1,149.5	508.0	n/e

[1)] Land use, land use change and forestry
[2)] not estimated

In 2011, CO_2 emissions in Armenia (only from consumption of energy, i.e. released by the burning of fossil fuels in the process of producing and consuming energy) were about 11.74 million metric tons (11.74 Megaton, Mt). The world contribution to CO_2 emissions from consumption of energy in the same year was about 33.4 billion metric tons (terminology in American English (AE); 33.4 billion metric tons (AE) = 33.4 milliard metric tons). (CIA, 2013)

GHG emissions in Armenia are increasing currently as a result of economic and industrial development (UNDP/GEF/ARM, 2010). Table 4 shows the projections of GHG emissions by gases for the period between 2005 and 2020 under the assumption of a 6% average annual economic growth scenario and expected range of activities in various economic sectors. Projections within the scenario “business-as-usual” calculate the emissions for the case if the existing activities were to continue and some process modernizations according to the international trends were carried out. Projections within the scenario “with measures” mean with reduction activities; they calculate the emissions up to the year 2020 if activities regarding the reduction of GHG emissions were to be performed. (UNDP/GEF/ARM, 2010)

Table 4: **Projections of GHG emissions by gases in terms of Gg (according to UNDP/GEF/ARM, 2010, p. XXII)**

Years	CO_2	CH_4	N_2O
Business-as-usual			
2005	4,633.20	71.78	0.15
2010	9,553.30	94.88	0.15
2015	16,222.20	128.38	0.15
2020	19,435.30	173.51	0.15
With measures			
2005	4,633.20	71.78	0.15
2010	8,197.20	83.47	0.15
2015	12,932.70	114.52	0.15
2020	11,862.80	157.50	0.15

In general, it is forecasted, as a consequent of economic and industrial growth, that the average air temperature in Armenia will have increased by 1.7°C by 2100 (CC Armenia, 2013b; UNDP/GEF/ARM, 1998). Reduction of precipitation, reduction of soil humidity, desertification, hot dry winds, erosion, changes in the structure of ecosystems, and human diseases (e.g. malaria, Crimean-Congo fever, and West Nile fever) are further consequences of global climate change to be expected in Armenia (UNDP/GEF/ARM, 2010).

In order to reduce the GHG emissions, Armenia has prepared a draft action plan on energy efficiency and application of renewable energy sources (EU, 2011). Installations deploying hydro power, wind power, sun light (photovoltaic), geothermal and bio ethanol are already planned for Armenia (EU, 2011). Nuclear power plants, however, remain a relevant energy source (EU, 2011; UNDP/GEF/ARM, 2010; IHK, 2008). They could generate up to 50% of the electricity needed in Armenia until 2025/2030 (IHK, 2008). In 2010, nuclear fuels were the source of 10.8% of the total installed electricity capacity in Armenia. The share of fossil fuels was about 55.6% and the share of hydroelectric plants was about 33.5% of the total installed capacity. The contribution of other renewable sources to electricity generation in 2010 was about 0.1% of the total installed capacity (CIA, 2013).

Armenia is on the way to adapt to and to mitigate climate change (EU, 2007; IZK, 2003). Accordingly, Armenia is already party to relevant international agreements. Examples are: Convention on Wetlands (since 1971), Convention for the Protection of the Ozone Layer (since 1985), Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (since 1989), Convention on Biological Diversity (since 1992), Convention on Combat Desertification (since 1994) (CIA, 2013; UNDP/ARM, 2002), and the United Nations Framework Convention on Climate Change (UNFCCC) since 1993, as well as the Kyoto Protocol since 2002 (UNDP/GEF/ARM, 2010). Armenia submitted its "First National Communication of the Republic of Armenia on Climate Change" to the UNFCCC in 1998 (UNDP/GEF/ARM, 1998). The "Second National Communication on Climate Change" was issued in 2010 (UNDP/GEF/ARM, 2010). In addition, since 1993, Armenia has been a member of FAO (Food and Agriculture Organization of the United Nations) (FAO, 2013a). Besides improving food security, quality, and safety, as well as rural development, environmental issues, such as sustainable management of natural resources are the main FAO focus areas in Armenia (FAO, 2013a). The Clean Development Mechanism (CDM), defined in article 12 of the Kyoto-Protocol (EU, 2011; EU-Consult, 2008) and the Cancún Agreement (2010) are further initiatives in which Armenia participates (EU, 2011).

At the national level, Armenia is trying to balance industry and the environment. However, despite the establishment of the Ministry of Nature Protection of the Republic of Armenia in 1991 (MNP, 2013), some other Armenian ministries (e.g. Ministry of Finance, Healthcare, Agriculture, and Justice) are still responsible for environmental issues (EU, 2007). On the other hand, coordination between governmental and regional agencies (e.g. governmental environmental agency for emission control and regional control agencies) illustrates other administration and management problems in the republic (EEA/ARM, 2011; EU, 2007). The lack of the "know-how of the administration" (EU, 2007, p. 31) seems to be still a challenge in Armenia.

Despite all these challenges, in 1994, Armenia passed its law on atmospheric air protection. In 1995, the Armenian law of environmental auditing was adopted, in order to provide consumers with environmental information concerning products (EU, 2007). The Climate Change Information Center of Armenia was established in 1997 for establishing and maintaining connections with other national and international climate change information centers and exchanging knowledge in this field (CC Armenia, 2013a). In 1998, a program for saving Lake Sevan and its ecology was developed (EU, 2007; UNDP/ARM, 2002). As a result, since 2001, the level of Lake Sevan has increased by over 3.6 meters (UN/ARM, 2012). In the same year (1998), an environmental program was prepared which was refined in 2004. Accordingly, the air, soil, and water pollution in Armenia must be decreased, and consumption of natural resources must be improved (EU, 2007). In 2001, Armenia passed a new law for land rights (EU, 2007). Only one year later (2002), the Armenian law for water resources (ARM, 2002), and a new national environment and health program were developed (EU, 2007). In addition, in the same year, a Public Environmental Information Centre was established (OSCE, 2002). In 2003, the environment was a significant issue within the national program for poverty reduction (EU, 2007). In 2004, the law on energy saving and renewable energy was passed (ARM, 2004). In 2005, the forest code was developed (ARM, 2005a). In the same year, a development strategy for the energy sector was planned (ARM, 2005b) in order to ensure energy security. In 2008, the Sustainable Development program (ARM, 2008) and the Second National Environmental Action Plan were developed (UNDP/ARM, 2008). Other environmental laws already in force (UN/ARM, 2012) could also provide the republic by mitigating climate change, as the consequences of this global issue are affecting Armenia as well.

1.2 Aim, purpose, and motivation

In order to adapt, reduce and mitigate climate change in Armenia strong actions are required. Protection of water resources, atmospheric air protection, establishment of waste management systems, soil management, and biodiversity protection are priority areas in the Republic of Armenia to which all sectors and industries should pay attention (EEA/ARM, 2011). The food industry, in this context, is no exception. In particular, activities throughout the life cycle of milk affect the environment to a significant degree by releasing various emissions (Benbrook et al., 2010). Soil and water quality as well as ecosystems are also affected as a result of land use and the application of fertilizers and pesticides (Benbrook et al., 2010). The global dairy sector (including both milk and meat production) contributes about 4% to the global anthropogenic GHG emissions. Global milk production, processing, and transportation are responsible for approximately 2.7% of the total global anthropogenic emissions. (FAO, 2010)

Armenia already has more than 265 milk processing centers (Freda, 2009). As milk production is one of the most important occupations for Armenian rural communities and due to milk production increasing approximately by 34% in Armenia in the last 15 years (The Civilitas Foundation, 2011), sustainable production practices for the milk sector in Armenia are urgently necessary and should be analyzed and studied. Such studies are, however, rare in Armenia. Furthermore, an LCA study, most probably, does not currently exist in the Republic. Hence, this dissertation thesis deals with the contribution of the Armenian milk industry to climate change, using the methodology of ELCA, by taking a medium-sized, semi-automated Armenian milk processing plant as an example. The full statement of the goal and scope of this study is expressed in Chapter 3 of this study, research material and methodologies.