INTERREG V-A COOPERATION PROGRAMME
GREECE – BULGARIA 2014 – 2020
Reinforcing Protected Areas Capacity through an Innovative
Methodology for Sustainability
– BIO2CARE –
(Reg. No: 1890)

WP3
Deliverable 3.4
One (1) case study/model assessing the symbiotic potential of the existing and future activities within the examined areas & One (1) comparative study based on the Life Cycle Apporach, presenting the benefits of circular economy for the environment (existing situation vs symbiotic situation)

Contributing Partners

LB - Democritus University of Thrace - Laboratory of Environmental Management and Industrial Ecology
PB4 - Greek Biotope/Wetland Centre
PB6 - Regional Inspectorate of Environment and Waters - Blagoevgrad
PB8 - South-West University “Neofit Rilsky”
PB9 - Pirin Tourism Forum

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Chapter 1 - Introduction

1.1 Industrial Symbiosis Background

1.1.1 Definitions

Industrial Consciousness aims at "involving traditional businesses and industries in a comprehensive approach to competitive advantage, including physical exchange of materials, energy, water and by-products" (Lowe E, Warren J., 1996). Within this plan, the basic elements of industrial coexistence are defined as "cooperation", "cooperative possibilities offered by geographic proximity" and "cooperative enterprises" (Lowe E, Warren J., 1996).

Recently, a new, different definition and a different perspective of industrial ecology was presented, emphasizing that industrial ecology is an innovative tool for environmental development. Their definition is more like a "professional" definition based mainly on the ideas of professionals and policy makers, and gives a new position in the field of industrial co-existence as a professional opportunity and tool for eco-innovation. According to this definition, 'industrial coexistence' activates different organizations in a network to promote eco-innovation and the long-term change of mentality / culture. Creating and sharing knowledge within the network brings favorable transactions for input supplies, value-added destinations for discarding by-products, and improved business and technical processes. " (Saeid Hatefipour, 2012).

Since referring to the definition of Industrial Ecology for physical exchange of materials between companies, Chertow presented five types of different exchanges that determine the existence of industrial co-existence (Saeid Hatefipour, 2012):

- Type 1: Waste exchange
- Type 2: In-line exchange
- Type 3: exchange between cooperative enterprises
- Type 4: Exchange of neighboring companies that are not co-located
- Type 5: Exchange between businesses organized in a wider area

Eco-Industrial Parks are defined as concrete implementations of industrial co-existence. According to this, several definitions have been developed for Eco-Industrial Parks. One of the most prevalent definitions is represented by Eco-Industrial Parks as:

"... a community of various companies producing products and services looking for enhanced environmental and economic performance through co-operation in managing environmental issues and resources such as energy, water and materials. With this collaboration, the business community seeks a collective benefit that is greater than the sum of the individual benefits if each one acts alone. " (Cote, Raymond P. & E. Cohen-Rosenthal, 1998)

The chairman of the Sustainable Development Council in 1997 said that an Eco-Industrial Park is a "community of businesses that work together and with a local community to efficiently share resources (information, materials, water, energy, infrastructure and the natural environment), aiming at economic profit, environmental gain and the equitable use of human resources for businesses and the local community. "

In 2001, Lowe proposed a wider view and presented a new perspective by claiming that a real Eco-Industrial Park should be more than a cluster of waste, recycling and green technology companies. (Lowe, 2001)

In a similar approach, in order to clarify the terms, Lowe proposed three different sub-definitions (Lowe, 2001):

- Eco-Industrial Park - an industrial park that has been developed and managed as a real estate that targets environmental, economic and social gains, as well as business excellence.

- By-product exchange - a set of businesses wishing to use all by-products despite being disposed of as waste.

- Eco-Industrial Network - a set of businesses working together to improve their environmental, social and economic performance locally.

The use of the term Eco-industrial Park usually involves geographical coexistence of the co-operating enterprises. Thus, the main differences between an eco-industrial park and an "ordinary" industrial park are (Anja-Katrin Fleig, 2000):

- Enhanced cooperation between businesses, park management and local decision makers

- Joint pursuit of these actors in the direction of the vision of industrial activities that are of the utmost sustainability in terms of economic, ecological and social issues.

Understanding how businesses of an eco-industrial park need to interact with and the resulting strategies cover a wide range of features. While some writers simply refer to the connection of material and energy flows, others go beyond that mentioned eg. (Cote, Raymond P., E. Cohen-Rosenthal, 1998). Others now include the social factor, noting that "the valuation of natural resources also means valuation of human resources "(Lowe, 2001).

In order to highlight the high-quality approach to the concept of eco-industrial parks, there have been some proposals to avoid the already widespread use of the term "Eco-industrial Park". So a partnership to be considered an "Eco-industrial Park" should be more than (Anja-Katrin Fleig, 2000):

- exchange of a by-product or exchange network
- a cluster of recycling businesses
- a partnership of environmental technology companies
- a partnership of companies that produce "green" products
- an industrial park designed around a single environmental theme (eg a solar-powered park)
- a park with an environmentally friendly construction
- a mixed use development (industrial, commercial, residential)

1.1.2 Benefits of IS

Industrial Symbiosis aims to achieve economic, environmental and social benefits and seek new ways to increase professional competitiveness. Reducing the cost of raw materials, waste, energy and emissions also means reducing the overall costs of businesses. Compared to rival companies with many waste, the highest environmental and professional performance is a way to achieve cost competitiveness and professional advantage. Consequently, finding competitive advantages is one of the main reasons why an enterprise wishes to join such a network. Such networking can offer competitive advantages only by accessing critical resources, saving costs and providing knowledge within the organization (Starlander, 2003). There are also benefits based on non-physical interconnections, such as transport networks, office and information sharing, and security services (M.Chertow, 2000). Eco-industrial Parks use resources efficiently and are flexible operators on the market. Networks typically gain flexibility in tensions and changes. Their organization is such that they use information and resources in the most optimal way. (Laura Saikku, 2000)

Raw materials and energy use are reduced and replaced by waste and by-products produced in the region. It also reduces emissions and protects the biodiversity of the area. Social benefits in the region include job creation and improved working conditions. Full attention is paid to the welfare of the entire community. (Laura Saikku, 2000)

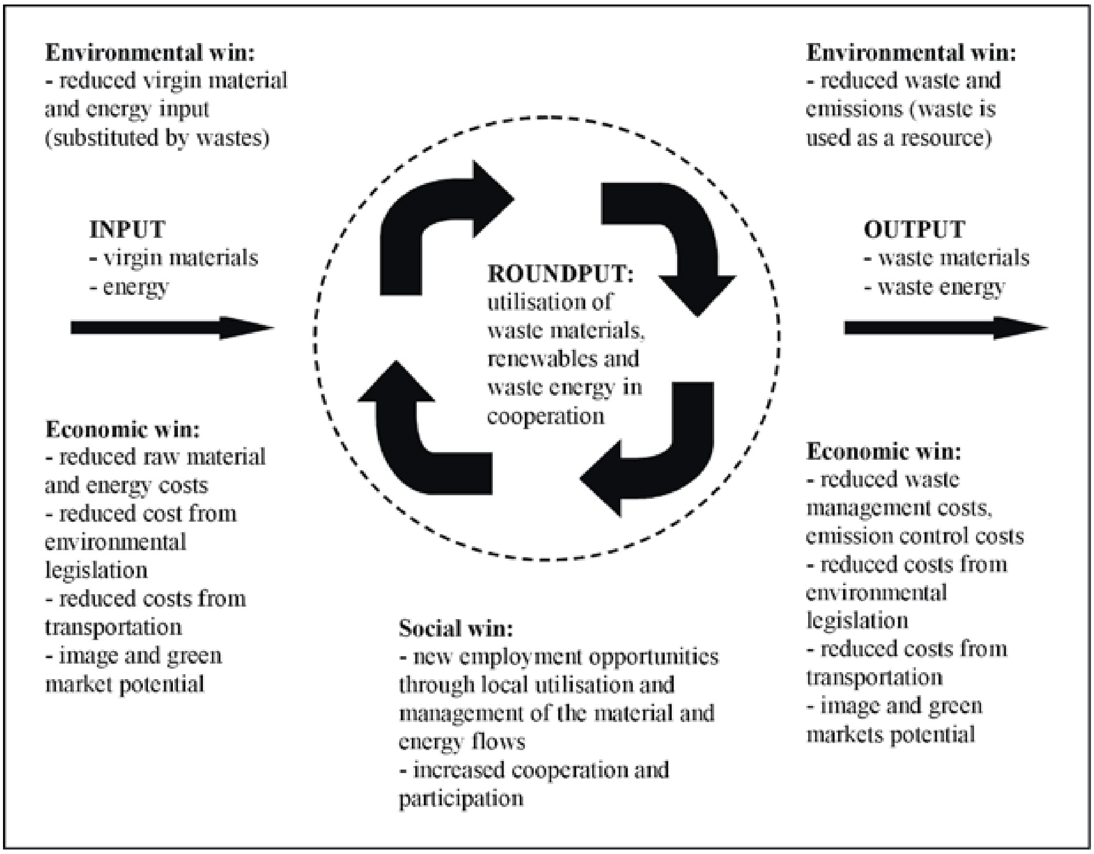


Figure 1-1: Environmental, economic and social gains in relation to energy and materials flows
Source: (Laura Saikku, 2000)

1.1.3 Challenges

A challenge to the idea of Industrial Symbiosis/Eco-industrial Parks is the definition of the boundaries of the system. The question arises as to whether the system includes only a few main companies involved in the construction of the park or also local communities in the region. The physical flaws of materials and energy are expanded by product, process, business boundaries as well as local and national boundaries. In a defined system there is import and export of products. In addition, its production and its environmental impact are spreading far in relation to resources. The boundaries of the system greatly determine its management and administrative structures.

Another challenge is the role of a business in relation to the whole park. When the goal is to increase the environmental performance of the entire park, then this for an enterprise may mean an increase in waste generation or water and energy consumption. This is the case if waste replaces non-renewable materials or energy with other companies. (Laura Saikku, 2000)

Waste optimization is a guideline for design. The minimization of passing materials by designing processes around existing waste streams, or even by creating new flows, is able to keep back the transition to more sustainable technologies and lead to a technological stagnation. For example, in Kalundborg, Denmark, the central element in the cooperative network, which stores natural resources and virgin materials, is a coal-fired power plant that maintains cell fuel use and produces CO2.

1.1.4 Choosing the right location

One of the key features of Eco-industrial Parks is that their location is made taking into account not only economic and social criteria but also environmental issues. The siting of such a project is critical because it affects all its operating parameters. An important feature of the park is that it cannot be changed throughout the park's existence and operation. (Mourtsiadis, 2012)

An illustrative method of spatialisation of a park based on the literature and general principles of environmental planning will be presented below. In this method, which emphasizes the environmental criteria, without overlooking the economic and social ones, the following stages can be distinguished:

- Recording elements of the natural and anthropogenic environment of the wider region.
- Selection of the first suitable placement sites of the park.
- First, an assessment of the park's chosen locations.
- Final evaluation - selection of the park's final position.
- Evaluation of the final position of the park, with elements of the natural environment.
- Assessing the compatibility of the park's final position with the elements of the anthropogenic environment.
- Environmental impact assessment, from the operation of the park.
- Landscape-sensitivity sensitivity assessment of the natural area sensitivity of the park's final position.

According to this method, the elements of the natural and anthropogenic environment are initially recorded in the wider area where the park is proposed. A number of alternative locations are then selected in the proposed area, which are first suited for the park's siting. These areas are primarily all industrial land use areas which comprise a significant number of industrial / craft units. Subsequently, these areas are assessed on criteria related to the adjacent anthropogenic and natural environment. The final selection of the site is carried out using a multi-criteria environmental assessment method, defining priority factors for each criterion.

The final position selected by the polyclarity method is then evaluated with each of the above criteria separately. Taking into account the elements of the natural environment, the compatibility of the final position of the park with elements such as topography, geological composition, underground and surface waters, climate and vegetation are evaluated. The compatibility of the final position with the anthropogenic environment is determined by elements such as land use, land ownership and infrastructure.

Finally, the environmental impacts from the operation of the park as well as the sensitivity of the natural area of the park's final site are taken into account. The environmental impacts that are assessed are: gaseous wastes, liquid wastes, solid waste, odors, noise and also a summary of all possible environmental impacts from the operation of the park.

1.2 Industrial Symbiosis Best Practices

1.2.1 Kalundborg - Denmark

When referring to the concepts of Eco-Industrial Parks and Industrial Symbiosis, Kalundborg is a classic example of the demonstration of industrial ecology profits and methodologies that need to be implemented so that an existing industrial area develops into an Eco-Industrial Park. The Kalundborg case is often cited because it is simple enough to understand the idea of an industrial ecosystem. It also helps to illustrate the benefits of industrial ecology, the main criteria for the application of such ecosystems, and how to build the methodology of industrial ecology. (Salah M. El-Haggar, 2007)

Kalundborg was initially not designed as an Eco-Industrial Park. Gradually, a business network was developed over 30 years with the final result taking the form of industrial co-existence. The current form of symbiotic relationships is shown in Figure 2.3. The case of Kalundborg began in 1961 with the central idea of reducing the use of already limited groundwater and replacing its use with water from the surface of Lake Tisso. The first company with this idea was the oil company Statoil. The initial collaboration took place between the city of Kalundborg (town hall), which took over responsibility for the construction of pipelines and Statoil, which undertook the project financing. Based on this initial collaboration came the realization of the benefits of such a move. Today Kalundborg is one of the largest business clusters. The main partners of this industrial cluster are (Salah M. El-Haggar, 2007):

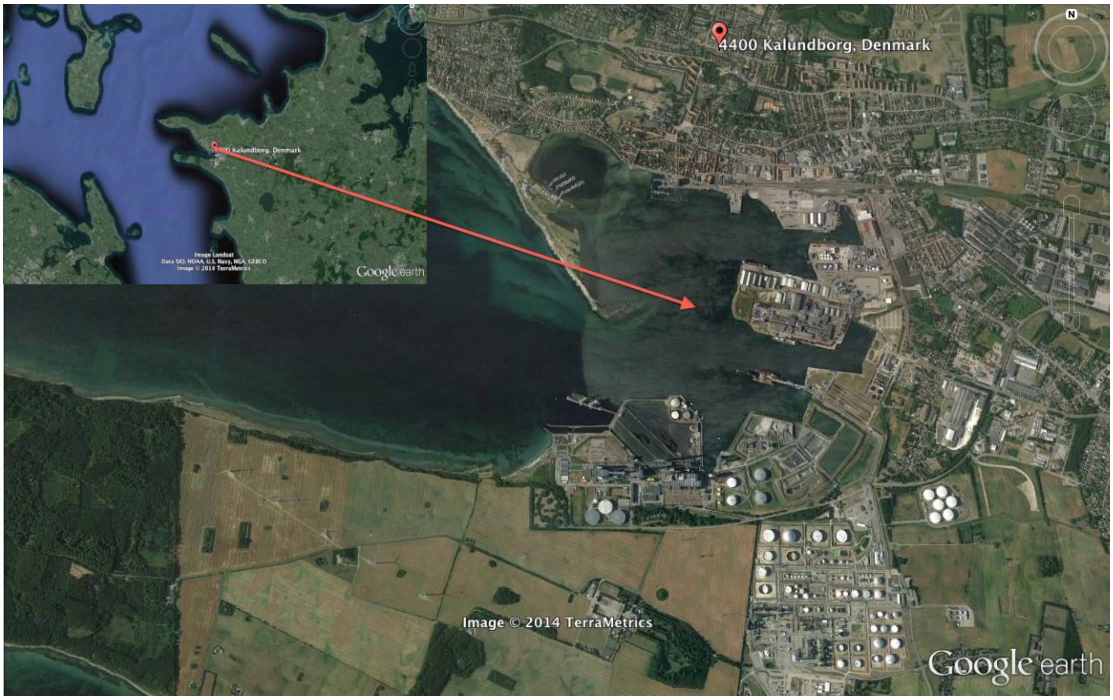


Figure 1-2: Satellite view of Kalundborg

- Asnaes Power Station, Denmark's largest coal power plant. It produces electricity with a capacity of 1500 MW. It also generates heating for the city of Kalundborg (4500 households) and other industries in the region.

- Statoil refinery, the largest refinery in Denmark with a capacity of 3.2 million tonnes per year. Recently, this capacity reached 4.8 million tonnes.

- Gyproc, a Swedish company producing 14 million square meters of gypsum per year.

- Novo Nordisk, a global biotech and pharmaceutical producer company, including 40% of global supplies of insulin as well as industrial enzymes with annual sales of more than $ 2 billion a year.

- The Kalundborg Town Hall, mainly by supplying water to homes and industries.

The other partners were integrated into the co-existence based on the waste of key partners as a byproduct. These partners are:

- Bioteknisk Jordrens Soilrem - a soil remediation company that joined in 1998.

- Fish farms consisting of 57 lakes with fish.

- Farms
- A cement manufacturing company.
- Kemira - a company producing sulfuric acid.

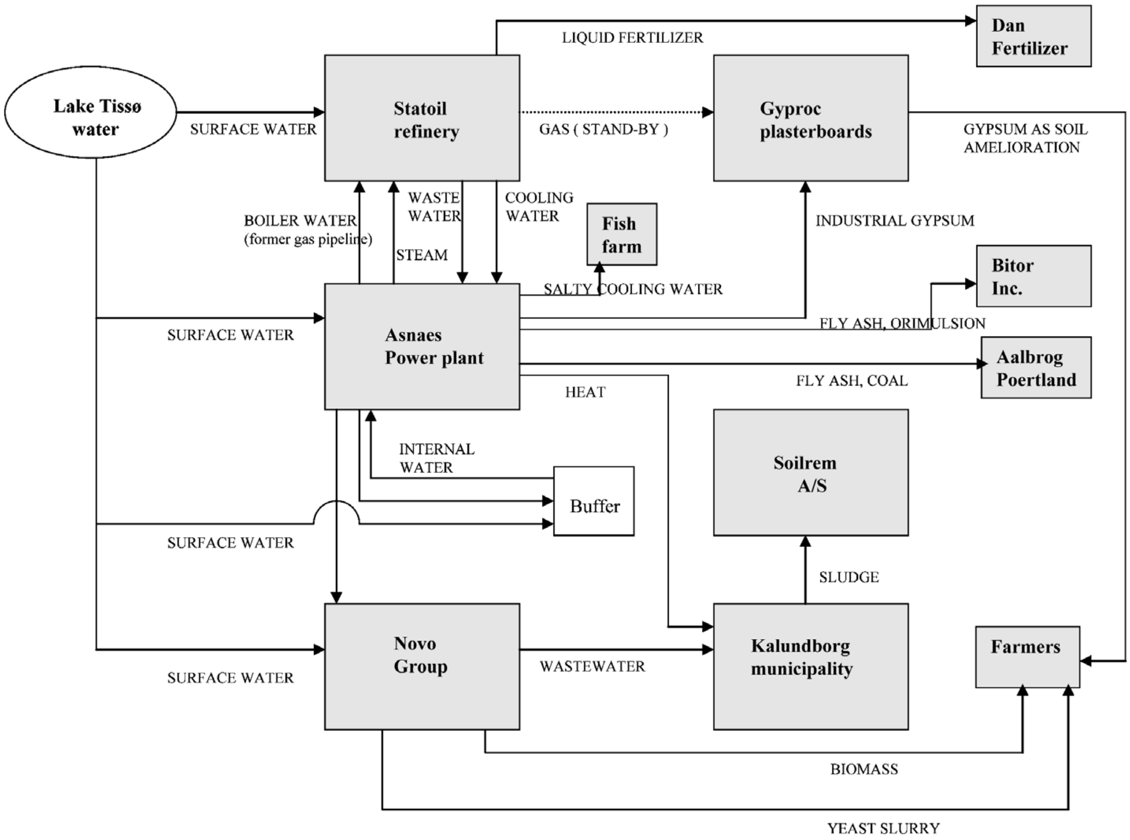


Figure 1-3: Material flows in Kalundborg Industrial Symbiosis

In ecological terms, Kalundborg presents the characteristics of a simple food chain: organisms that consume each other's waste materials and energy, thus becoming interdependent. Exchanges of used and recycled materials and energy from the by-products of industries have led to large profits. In 1993, a $ 60 million investment in infrastructures (for materials and energy) yielded $ 120 million in revenue. In 1998 the capital cost for this project was about 75 million dollars. The money to be saved from this project was estimated to be $ 160 million with a 5-year depreciation period. At the same time, tens of thousands of tons of water, fuel and other products are saved annually. Reductions in consumption of natural resources are as follows: 45,000 tons of oil / year, 15,000 coal / year and 600,000 cubic meters of water / year.

Waste reduction and pollution reduction are also significant: 175,000 tons of carbon dioxide / year, 10,200 tons of sulfuric acid per year, 90,000 tons of calcium sulphate / year and 130,000 tons of ash / year. (Salah M. El-Haggar, 2007)

Although the industrial partnership in Kalundborg was developed through the interaction of businesses for more economical use of by-products and waste materials, the outcome has given both economic and ecological / environmental benefits. Materials are exchanged in a closed loop, businesses earn and the environment is protected by reducing air, water and soil pollution. (Salah M. El-Haggar, 2007)

1.2.2 Kwinana – Australia

The industrial area of Kwinana is located 40 km south of Perth and is the largest industrial area (10,000 acres) in western Australia. It consists of industries with a wide range of activities, from manufacturing and production to high-tech chemical and biotechnology plants and resource industries. Kwinana is an important source of revenue both locally and for the Australian state, which is quantitated at $ 4.3 billion for 2001.

Figure 1-4: Satellite view of Kwinana

Kwinana is an example of industrial symbiosis with the world's most exchanges of waste, with 106 symbiotic relationships amongst park businesses. An example of such a symbiotic relationship is the supply of hydrochloric acid waste from a dye station to a nearby chemical production plant to produce ammonium chloride.

The starting point for the Eco-Industrial Park was in 1991 when local industries founded the Kwinana Industries Council (KIC) to organize the monitoring of air and water pollutants as a whole, in response to the increased demands of the community and the government, as well as for security reasons. The KIC has since developed into a coordinating body that handles, helps and promotes industrial co-existence in the region. The KIC also contributes to research on new examples of symbiotic relationships with government support through a collaborative research center on sustainable resource management.

Since 1990, the number of major businesses in the Kwinana industrial area has risen from 13 to 21. Also, symbiotic relations have risen from 27, initially to 106, as already mentioned.

The Center for Cleaner Production at Curtin University has calculated that the symbiotic relationships of Kwinana Park have brought many and varied benefits including:

- 72 GWh of electricity / year
- Reducing carbon dioxide emissions by 377,000 tonnes per year
- Saving 6 GL of water per year
- Saving 260,000 tons of landfill
- $ 500,000 Australian is allocated each year for research

The main member companies that make up the KIC are:

- ALCOA, the third largest aluminum company in the world (the company's headquarters are located in New York, USA).
- BHP Billiton, a global metal and oil mining company.
- BP (British Petroleum), a petroleum and gas company.
- CBH Group, one of the leading grain companies in Australia.
- Cockburn Cement, Cement Production Company.
- Coogee Chemicals, a chemical manufacturing company.
- CSBP, a production company and a supplier of chemicals and fertilizers.
- Fremantle Ports, a state-owned seaport management company.
- TRONOX, a titanium, zirconium and titanium dioxide manufacturing company.
- Verve Energy, power station.
- Water Corporation, a state-owned company in Western Australia, supplies water, wastewater keeps sewerage services.

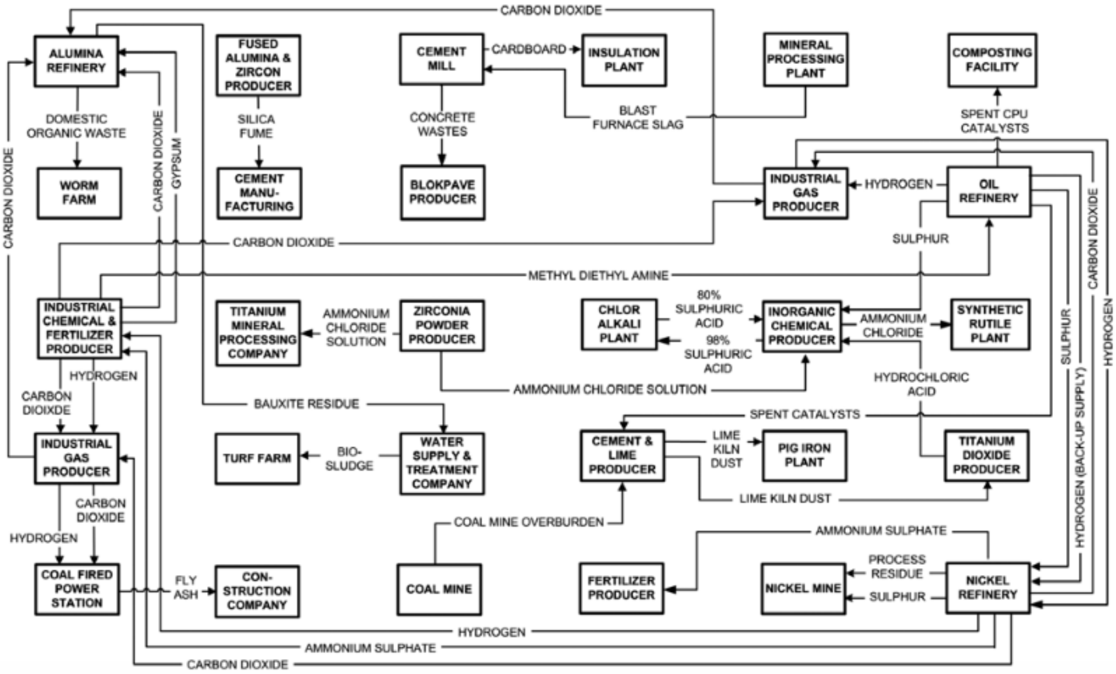


Figure 1-5 Material flows in Kwinana Industrial Symbiosis

1.3.3 Bruce Energy Center – Tiverton, Canada

The Bruce Energy Center industrial park is located on the east coast of Lake Huron, north of the Inverhuron community and close to Bruce Nuclear Power Development (BNPD). This location is suitable for a wide variety of industrial uses. The neighboring nuclear power station is one of the world's largest independent stations and produces enough clean electricity to cover about 20% of the Ontario city's energy needs. (Municipality of Kincardine, 2005)

Figure 1-6: Satelite view of Bruce Energy Industrial Park

This Eco-Industrial Park was built on the successive use of energy. In the park there are six companies located next to the nuclear power plant to take advantage of waste and steam generation capacity (steam can be used as a possible source of thermal energy for a wide variety of industrial and agricultural processes). The main businesses in the park are:

- Bruce Tropical Produce Tomato: A company that grows 1150 tonnes of tomatoes annually in hydroponic greenhouses. Steam from BNPD is used to heat greenhouses, which is transferred into hot water coils and the concentrate then returns to BNPD for reuse.
- Bruce Arga: Company producing food with processed fruit and vegetable concentrates, sauces and purees. Food processors use steam energy from BPND to collect 2700 tons of products per day.
- Bruce Arga II: The second unit of the company dehydrates local crops for the production of nutrient-rich foods for livestock and horses. The unit uses steam to give energy to the dehumidifiers. The company produces 90,000 tons of feed cubes per year.
- Commercial Alcohols: The largest manufacturer and supplier of alcohol in Canada. It produces 23 million liters of alcohol from 58,000 tonnes of corn (cultivated in the area). Steam from BPND is used for the distillation process and alcohol ethanol process.

- BI-AX International: A specialized company producing polypropylene special film for local and international markets. Polypropylene is heated in steam ovens.
- St. Lawrence Technologies: A research and development unit specializing in finding ways to convert renewable sources to develop a wide variety of products. (Salah M. El-Haggar, 2007)

Figure 1.6 represents material flows at Bruce Energy Center, Canada.

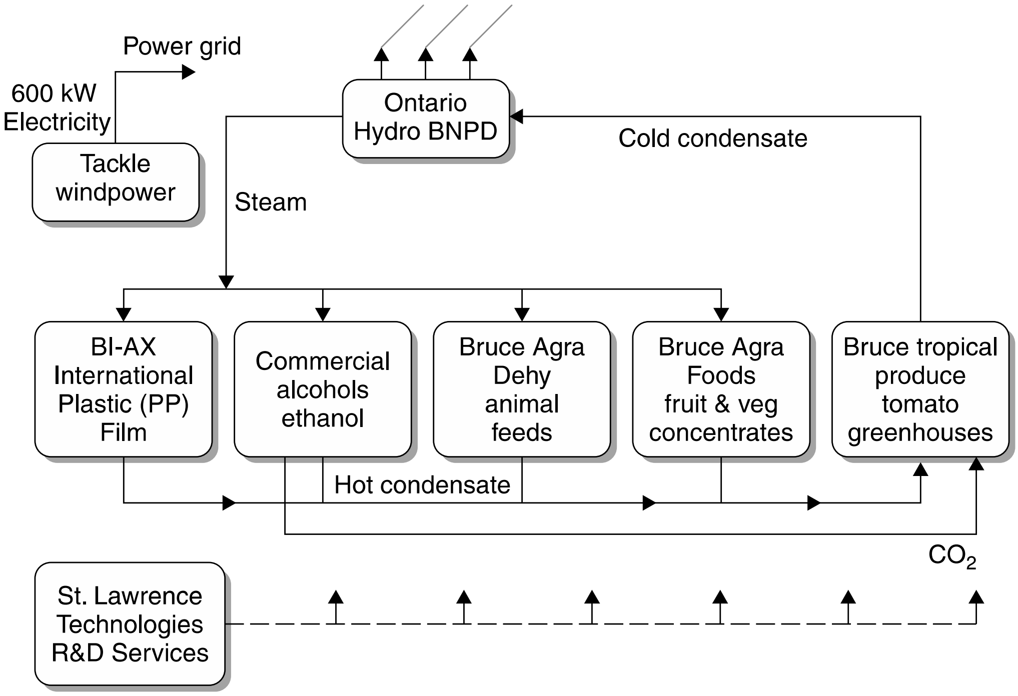


Figure 1-7: Materia and energy flow analysis of Bruce Energy Center Industria Park
Source: Salah M. El-Haggar, 2007

The initial plan for the park was to be divided into 5 areas, with a view to methodical development (Municipality of Kincardine, 2005) These areas are: industrial development area, risk area, mineral / corridor and sensitive area.

- <u>Industrial Development Area</u>

  The main use in soils defined as Industrial Development Area should be industrial and / or agricultural uses of high energy intensity which:

  - They use electrical, thermal energy and / or any other BNPD products or by-products and should be close to BNPD's facilities to use the product or by-product due to economic and physical factor.

  - They produce products required from the uses specified above, and must be close to industries or BNPD to allow their products to be used properly and efficiently.

Secondary uses allowed in this area are:

  - Service center facilities
  - Parks and open spaces designed to maximize the protection of the area’s natural features
  - Residences for owners / shareholders of companies

- Mineral / Mineral Resources Area

  The main authorized use of this area is mining operations licensed by the Ministry of Natural Resources. Other uses allowed are:

  - Extension of existing extraction facilities
  - Industrial development as this development will not have a higher priority than the extraction of aggregates, it will not exclude the extraction of aggregates and will be scheduled to take place after the export operation.
  - Gradual soil rehabilitation

- Auxiliary runway

  The main authorized use of the auxiliary corridor includes a corridor for various linear services of general interest, such as electric transmission lines and steam ducts.

  Other uses such as agricultural uses, parking spaces, parks and open spaces may be permitted.

- RIsk zone

  The use of the risk area is limited to conservation, forestry, wildlife, passive recreation, public parks, non-intensive agriculture, horticulture and hydroelectric power plants.

- Sensitive zone

Any development plan in this area should be considered in cooperation with the Ministry of Natural Resources.

The total area of the Park is mainly owned by two major companies, the Bruce Energy Center (from which it is named Park) and by Kincardine Energy Land Inc. These two companies hold about 2000 acres. (Municipality of Kincardine, 2005)

On Table 1-1 various Industrial Symbiosis projects from around the world are presented.

Table 1-1: Industrial Symbiosis Projects around the world

Area	Characteristics
Cape Charles Port, Virginia	Sustainable technologies, natural coastal features
Fairfield, Baltimore, Maryland	Conversion of an existing industrial area, cogeneration, waste reuse, environmental technologies
Brownsville, Texas	Local approach to exchange of waste materials Agricultural industrial park, bio-energy, waste management
Chattanooga, Tennessee	Development of the city from the beginning and development of green areas, environmental technologies
Green Institute, Minneapolis, Minnesota	Small scale green incubator, reuse of waste materials
Plattsburgh, New York	Re-deploying a military base, waste and resource management
East Shore, Oakland, California	Resource recovery park, landscaping, energy efficiency
Londonderry, New Hampshire	Small scale, community-based
Rotterdam Harbour Industrial Ecology Project, Netherlands	High Growth Coalition, characterized by a network of materials and energy exchanges, has been developed over the last 25 years

Ecopark Moerdijk, Netherlands	Redesign of an existing industrial area, restoration of contaminated soil
Eco-Industrial Park Karlsruhe, Germany	Virtual eco-industrial park, about 40-50 companies, exchange of organic and mineral offshore, information and communication network
Raymond, Washington	New park with forest growth, recycling of solid and water waste
Burnside Industrial Park, Nova Scotia, Canada	University research and development, large area, 1200 small and medium-sized enterprises, building materials and energy cycles, use of renewable energy, information center, communication loops
Sarnia, Ontario, Canada	Industrial co-existence between refineries, synthetic rubber plant, petrochemical plants, power station
Fujisawa Factory Eco-Industrial Park, Japan	Combination of industrial, commercial, rural, residential and recreational features, energy exchange and saving technologies, solar greenhouses, water treatment plant, conversion of waste into cement and ceramics etc

1.3 Industrial Symbiosis and Biodiversity

Together with climate change, biodiversity preservation is one of the major challenges currently faced by humanity. It directly influences our economy, health and wellbeing. The air we breathe, the water we drink, the food that feeds us and most of the material we use in our daily life directly depend on biodiversity.

According to the EU biodiversity baseline report published by the European Environmental agency in 2010, up to 25 % of European animal species were facing extinction. The European Commission responded to this situation by adopting an EU biodiversity strategy to 2020, with the objective to 'halt the loss of biodiversity and ecosystem services, to restore ecosystems in so far as is feasible, and to step up the EU contribution to averting global biodiversity loss'. (Europa, 2016)

Biodiversity is a fundamental component of long-term business survival. Businesses rely on genes, species, and ecosystem services as critical inputs into their production processes and depend on healthy ecosystems to treat and dissipate waste, maintain soil and water quality and help control the air composition. For example, agribusiness relies on the diversity of wild relatives of major food crops, as a resource to ensure crop resistance to disease and pests.

At the same time, business and industry can have major negative impacts on biodiversity resources Yet, while the private sector is part of the problem, it is also part of the solution. The resources and influence of the private sector offer important opportunities for innovative and effective contributions to conservation. (International Finance Corporation, 2018)

The environmental impacts of an industrial project can be broadly separated into two categories: ‘direct’ and‘indirect’. Direct impacts result specifically from project activities or operational decisions and maybe predicted based on planned activities and knowledge of the ecosystem. Indirect impacts are induced by, or ‘by-products’ of, project activities. Predicting indirect impacts is more complex as they derive from interactions of multiple factors and stakeholders with the project. Indirect impacts are sometimes called ‘secondary impacts’,but their negative consequences for biodiversity are often very large. (Biodiversity Consultancy, 2013)

Direct Impacts:

- Stem primarily from land use and waste generation.
- Usually occur at the same time and place as business activities.
- Can include habitat loss and degradation, erosion, species loss, air and water pollution, soil and water contamination.
- Introduction of non-native species can disrupt surrounding ecosystems.
- Can affect local communities by reducing access to natural resources or disrupting ecosystem services, such as erosion control.
- Location is key for determining the potential for direct impacts: pristine or remote locations may pose higher risks.
- Can frequently be reduced, and even avoided, through early identification and careful planning

Indirect Impacts:

- Result from the actions of others, triggered or caused by business activities.
- Can occur in a different place and at a different time from the actions that trigger them. May represent a company's most significant risk for damage to biodiversity.
- Often the most challenging to predict, identify, manage and control.
- Can be caused by third party suppliers in the sourcing and production of goods and services used by a company. (See the Grupo Granjas Marinas case study [PDF])
- Can result from the use or disposal of a company's products by consumers or other business users.

- Changes in behavior by others, including local people and employees, that are prompted by a company's operations may lead to induced negative impacts to biodiversity, including habitat loss and conversion from unplanned settlements and agricultural expansion, or increased demand for and depletion of natural resources as a result of in-migration.

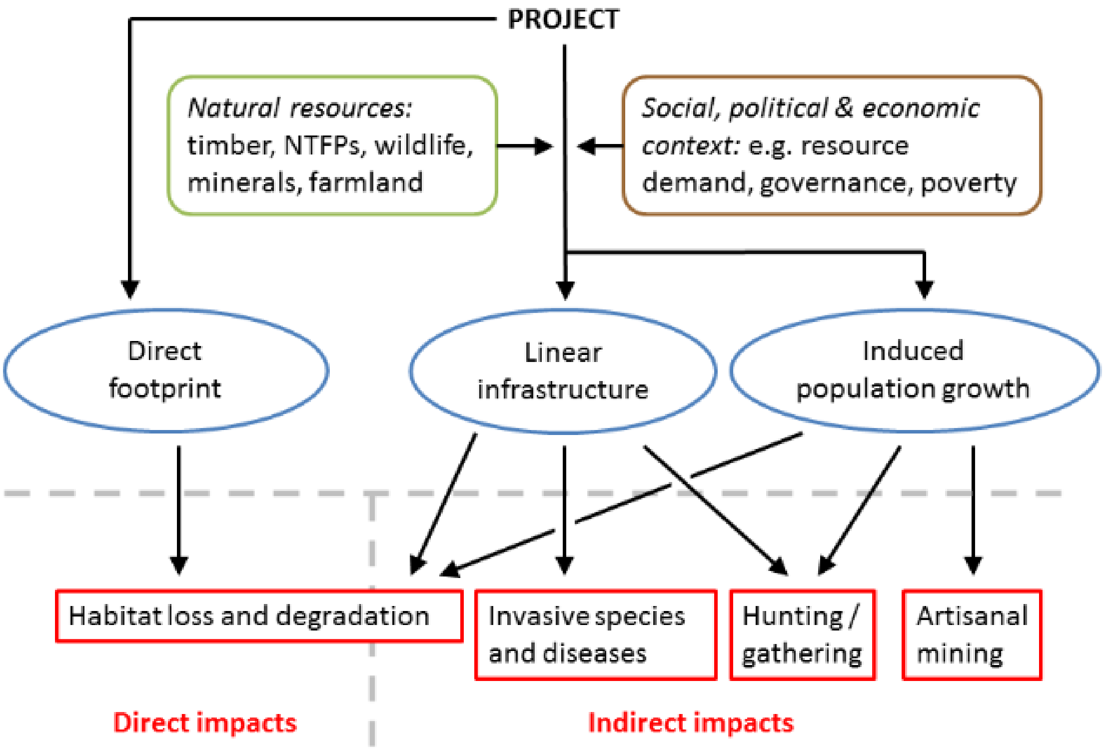


Figure 1-8: Major direct and indirect biodiversity impacts of the industry
Source: International Finance Corporation, 2018

On Table 1-2, examples of commercial industrial sectors and their environmental impacts on biodiversity are presented.

Table 1-2: Examples of commercial sectors and their relevance to biodiversity

Industrial Sector	**Significant biodiversity environmental effects**
Oil and gas industry	Intervention in the ecosystem as a result of exploration and resource utilization. increasing demand has led to exploitation in ecologically sensitive regions (extraction of oil sand and deep-sea deposits)
Mining industry	Intervention in the ecosystem as a result of exploration and resource utilization. raw material extraction is usually associated with large-scale land use and intervention in ecosystems (e.g. deforestation). as mining activities also consume large volumes of water, underground water reserves may also be exhausted, especially in arid regions.
Chemical/Pharmaceutical plants	More than 25.000 types of plants are used for medicinal purposes worldwide. their use can also promote species extinction. in Western Europe, over 150 plant species are threatened with extinction due to over-extensive harvesting.
Forestry/wood/building material industry	Logging at rates that exceed the natural tree regrowth rate put the continuance of forests at risk. rapid deforestation adversely affects biodiversity; ecosystem services such as the protection of catchment areas and soil protection disappear; this results in losses and lower quality in the timber, furniture and building material industry. it should be noted that even nature oriented, sustainable forestry with alien tree species provides major services, such as CO2 storage, wood, water formation/purification and air filtration.
Fishing/Fish-processing industry	Overfishing has resulted in drastic reductions in fish stocks.it is estimated that the fish population has been reduced by more than 80% since the introduction of industrialized fishing techniques. impacts of climate change affect both the regional supply and quality of the fish supply. this results in adverse effects on the fish-processing industry

Source: Europa, 2016

Industrial Symbiosis, as a tool of Industrial Ecology towards Sustainable Development could potentially play a crucial role in addressing those issues, leading the way of biodiversity preservation through the industrial sector.

Based on several case studies conducted during the past years, the environmental benefits of Industrial Symbiosis are quantified, and can be sub-categorized in: Ecological/Biological, Water Savings, Energy Savings, Solid Residue Reduction, Liquid Residue Reduction, Gaseous Residue Reduction. In Table 1-2, the quantified environmental benefits of 5 famous case studies are presented.

1.4 Industrial Symbiosis and policies

Recent European policy documents have supported IS as an integral part of economic and environmental policy. Perhaps the most significant advance has been via the Resource Efficiency Flagship Initiative,1 part of the Europe 2020 Strategy, the growth strategy for Europe, whose vision is a “smart, sustainable and inclusive Europe.” The launch of the Resource Efficiency Flagship Initiative led to the publication of the Roadmap for a Resource Efficient Europe,2 in which Industrial Symbiosis is embedded with the recommendation that opportunities to exploit resource efficiency gains through Industrial Symbiosis should be a priority for all member states.

The UK’s National Industrial Symbiosis Programme (NISP) is cited as a best practice exemplar of concrete action already being taken by member states (COWI 2011). It is further recommended as an approach that should be replicated across the 27 member states of the European Union (EU), having previously been cited as best practice within the EU Waste Framework Directive.3 The Directorate-General (DG) Enterprise and Industry has also advocated IS as a policy instrument in its strategy document “Sustainable Industry: Going for Growth and Resource Efficiency,”4 which cites Kalundborg as a practical example of IS underpinning local and regional growth. This document is important for its connection to the growth agenda.

The UN World Summit on Sustainable Development, held in Johannesburg in 2002, recommended the development and promotion of a 10-year framework of regional and national initia- tives for sustainable consumption and production. Jointly with the UN DESA (United Nations Department of Economic and Social Affairs), the UNEP leads the Framework of Programmes on Sustainable Consumption and Production (SCP).

Based on the work at the UN World Summit 2002, a strategy for sustainable consumption and production was launched in Finland in 2005 (Commission for Sustainable Consumption and Production (KULTU Commission) 2005). This programme aims to improve eco- efficiency through production chains. According to the programme, the main challenges facing Finland lie in greenhouse gas emissions, consumption of natural resources, and the amounts of waste. Strict waste legislation has complicated waste utilisation, giving too much importance to definition of the boundary between by- products and waste. At the moment, the goals of waste policy emphasise waste prevention, but some outlines indicate that it should be aimed at material-efficiency and eco-efficiency (Lilja, 2009). For more details on the Finnish SCP programme, see the work of (Honkasalo, 2011) in this Special Issue, and for a critical analysis of the use of the programme, see (Berg and Hukkinen, 2011).

An increasing number of global, international, and national institutions and representative groups are championing further development and support of IS. The Organisation for Economic Co-operation and Development (OECD) cited IS as a form of systemic eco-innovation “vital for future green growth” (OECD 2010) and is currently producing a case study of NISP as an exemplar innovation network. The World Wildlife Fund (WWF) commissioned a report examining the private-sector innovation contributing to green growth that highlighted International Synergies’ (the company that devised and manages NISP) approach to IS as one of the “world’s top 20 green game-changing innovations” (WWF 2010). The Nordic Council of Ministers commissioned desk research and interviews to identify existing local, regional, national, and international policies within this area that have successfully supported IS, and barriers to its dissemination. In Portugal, the National Waste Management Plan, 2011–2020, explicitly identifies IS as a key strategy to be pursued.6 The influential British business organization Confederation of British Industry published a report calling for the UK government to review its policies concerning business waste and resource efficiency.

Further support that IS is being seen as addressing main- stream economic agendas was that Invest Northern Ireland (a body responsible for economic development) recently issued a contract for facilitated IS services exclusively to create jobs, generate additional sales and cost reductions, and attract investment.

Industrial symbiosis is not immune, however, to the vagaries of political and administrative decision making, as 2011 has brought the United Kingdom examples where both the Scottish government and Welsh assembly government have cancelled investment in IS programs despite overwhelming evidence of their value. IS must be doing something right, however, if both business organizations and environmental advocates are united in their support. Certainly there have been very significant pol- icy advances within the EU in the last few months specifically citing IS; these policy initiatives are expected to permeate into effective action across the global economy (also influencing overseas development initiatives). It is exciting to see recognition that IS has direct relevance to a broad policy agenda covering innovation, green growth, and economic development, in addition to “traditional” resource efficiency. Unfortunately, evidence does not always yield the best decision making in political and administrative circles.

1.5 Life Cycle Assessment Background

1.5.1 What is Life Cycle Assessment and why it’s important

In the beginning of the industrial era, the solution to environmental problems resulting from production processes and anthropogenic activity was thought to be the reduction of the concentrations of harmful substances. Instead of releasing the emissions close to humans, pipes and chimneys were built. Later on, people saw that the consequences of the emissions were still present, so they tried to treat them with filters, chemical treatments or combustion. The wastes from the processes were now less hazardous but large amounts of it were produced. The next step towards environmentally friendly processes was to make the process itself cleaner and more efficient to reduce the amounts of waste sent to landfill and to lower the extraction of raw material from non-renewable resources. In our days instead of this process perspective, it is now more common to have a product perspective whereas sustainability is the ultimate goal. For many products, the largest environmental impact does not come from production stage. For example, a car has the most significant impact on the environment during the years of use by the customer due to the fuel consumption.

Sustainable development concepts have resulted in increasing environmental pressures to improve the efficiency of products and processes in terms of resource utilization and reducing waste generation and emissions. Due to call for sustainability, industries and developers are challenged to incorporate systemic thinking into their environmental assessment of their products or processes. This is because environmental problems are too multidimensional and dynamic to be examined in isolation. These concerns have in turn focused attention on the supply chains and life cycles in which minerals and energy resource processing take part. Under these circumstances, a number of environmental assessment tools and methodologies have been developed by the scientific community such as Environmental Impact Assessment (EIA), Ecological Risk Assessment (ERA), Material Flow Analysis (MFA), Cost Benefit Analysis (CBA) and Life Cycle Assessment (LCA).

Life Cycle Assessment (LCA – also called Life Cycle Analysis in a number of cases) is a holistic tool for examining the overall environmental performance/impact of a product, process or system, taking into account every step of its life cycle - from raw materials acquisition to manufacturing, transportation, its use and its final disposal to the environment. It is an environmental management and decision support tool designed to assess the effects of energy use and materials processing including waste disposal on the environment and to assess the potential for environmental improvements combined with the rational use of raw materials and energy in each stage of a system's life cycle.

The key benefits derive from a LCA can be summarized as follows:

- ✓ Offers a common reference base for comparing alternative products, materials and activities in terms of their environmental performance.
- ✓ It highlights those parts of the lifecycle of a product, process or system that are most burdening the environment. Effort needs to be focused on those parts for improving environmental performance.
- ✓ Helps develop new products and productive processes with less environmental impact.

- ✓ Provides the scientific background to characterize systems / processes / products as friendly or non-environmental.

- ✓ Provides substantial help in evaluating the results of environmental policies and actions in relation to raw materials savings, recycling, emissions, etc., as well as pollution prevention or pollution prevention training.

1.5.2 How to implement a LCA – generic steps

The LCA methodology follows specific standards (ISO 14040 series), and is carried out in four (4) distinct steps, summarized in Table 1-3 and comprehensively presented on the following sections. LCA methodology is based on the creation of a model, which is developed by the user trying to describe a system as realistically as possible.

Table 1-3: LCA implementation steps (according to ISO 14040 series).

STEP	Description
1. Goal and Scope Definition	Definition of the aim of the study, functional unit, system boundaries and quality of data.
2. Life Cycle Inventory Analysis	Data collection, material/process flow diagram development.
3. Life Cycle Impact Assessment	Classification and characterization of the data (compulsory steps) and normalization and weighting (optional steps).
4. Life Cycle Interpretation	Analysis and assessment of the assumptions and results. Amelioration of previous steps.

1.5.3 Goal and Scope Definition

Definition of the objectives (Goal)

Determining the goal and scope of the analysis is an important step in the implementation of LCA because it determines the time, human resources and financial resources that will be needed (EPA, 2006). The clear definition of the objectives of the analysis is for the designer a focal point in which it must be ascertained that assumptions and simplifications are such that they do not cause significant alteration to the end results. The most important issues related to the goal and scope of LCA are:

- The precise mapping of the purpose for which the LCA is made;
- The detailed definition of the life cycle;
- Specifying the functional unit;
- The definition and description of system boundaries;
- Defining the quality specifications for the data/information to be used;
- Cases, constraints and requirements for subsequent interpretation.

The definition of goal and scope results from the need for consistency during LCA implementation. In fact, the context of the study is to determine the level of detail required to implement the results. The outcome of the study mainly depends on the accuracy of the input data. The purpose of this LCA is to assess the symbiotic potential of the existing and future activities within the examined protected areas and evaluate the benefits of circular economy for the environment (existing situation vs. symbiotic situation).

Functional Unit

The functional unit expresses the functionality of the system under study and provides a reference for both inputs and outputs, allowing the comparison of two different systems. For example, the functional unit for a dyeing system can be defined as the surface unit covered for 10 years. An environmental impact comparison of a paint system and a wallpaper system is therefore possible.

Boundaries of the system under examination (Scope)

Setting the boundaries of the system determines which processes should be included in the LCA study. Determining the boundaries of the system is partly subjective, and is usually done when defining the scope of the study. In this case a variety of anthropogenic activities within the boundaries of study areas (as described in D3.1) in GR and BG will be included in the LCA.

Quality of Data

The validity of the results from the LCA studies depends on the quality of the data being utilized. The following parameters should be taken into account: time, geographical and technological coverage, accuracy and representativeness of the data, consistency and repeatability of the methods used to collect the data, and finally potential errors and data gaps. In this study, the elements that simulate as much as possible the existing/symbiotic situation of the two examined areas will be selected (see Chapters 3 and 4).

1.5.4 Life Cycle Inventory Analysis

Data collection

To develop a LCA model, it is necessary to collect data for each material and process within the system boundaries. The data needed is a combination of inputs and outputs in each process included within the system boundaries. Data collection is the most resource and time-consuming stage in an LCA. In the past few years, databases have been developed and are available for many processes. Reusing data from previous studies can simplify data collection, but this should be done with great care so that data is representative.

However, for several of the system processes either no data are available or the data available is not representative of the process involved in the life cycle under consideration. These processes are known as foreground processes and require the collection of primary data from the system under study.

Material/Process flow development

The Material/Process flow diagram forms a qualitative graphical representation of all the relevant processes involved in the life cycle of the system being studied. It consists of a sequence of processes associated with material and energy flows. Its aim is to focus on the most relevant processes rather than the full depiction of the system. Particular attention should be paid to processes likely to produce the greatest environmental interventions. The contents of a process in a flow diagram for a particular boundary system are shown in Figure 1-1. It is extremely important that all references to the input of the collected data in the model are made in the module to maintain the mass and energy balances.

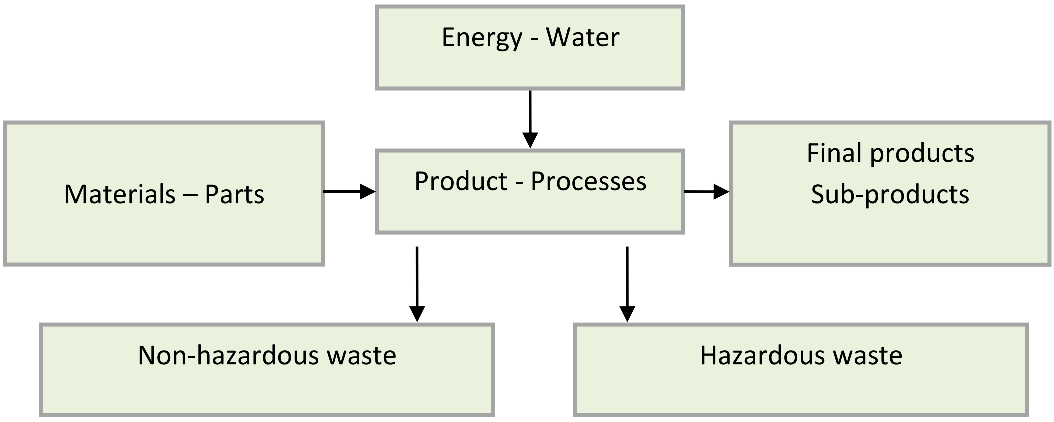


Figure 1-9: Requirement model for process data.

The result of the data inventory is an extensive inventory of inputs (resources) and outputs. Inputs and outputs of the system are presented in the form of a summary table. A problem that arises is that it is difficult to compare the different types of environmental burdens that result from the inventory of data. One way of dealing with this problem is to "translate" all environmental charges into the same unit or even convert all data in the data inventory into a single environmental index. This problem can be solved by applying a method of impact assessment in the third stage of the methodology.

The Life Cycle Inventory developed for study area 1 (GR) and study area 2 (BG) for existing situation and symbiotic situation is analytically presented in Sections 3.1, 3.2 and 4.1, 4.2 respectively.

1.5.5 Life Cycle Impact Assessment

In order to further interpret the results of the life cycle inventory it is necessary to match them with specific impact categories (see also section 1.5 for an analytical presentation of the impact categories to be applied in this study). For example, calculating during the life cycle inventory step that 2kg of CO_2 is emitted from a particular process is difficult to understand for people who do not specialize in the subject. But when this emission value is attributed, for example, to specific cases of carcinogenicity, the LCA result becomes more understandable. This assignment is done in the third stage of the LCA, the impact assessment, which is one of the most important methodological challenges of LCA. The difficulty in converting the results of data inventories into their respective environmental impacts lies in the fact that many scientific uncertainties still exist today.

As defined in ISO 14042, the general context of the Impact Assessment step consists of:

- Compulsory steps (i.e. classification and characterization of data) that convert the results of data inventory into an index for every impact category, and
- Optional steps (i.e. normalization and weighting of data) to produce a single impact indicator using numerical normalization and weighting factors.

The compulsory and optional stages of the impact assessment step are summarized as follows (by order of implementation – Figure 1-2):

- ✓ Selection of the impact categories and indicators best representing each impact category. For example, the impact of "climate change" is better represented by the "CO_2 equivalent" indicator.

- ✓ Classification of data inventory in the selected impact categories. For example, CO_2 emissions, CH_4, N_2O should be classified as 'climate change' as they are greenhouse gases.

- ✓ Calculation of the overall impact category indicators, using the characterization coefficients (characterization). For instance, according to the above, the index of the "climate change" impact category is CO_2 equivalents. Therefore, CH_4 emissions should be multiplied by characterization coefficient 21 to convert to equivalent CO_2 emissions over a 100-year time horizon.

- ✓ Calculation of the results of the total indicator by impact category in relation to some reference values (normalization). This stage is optional.

- ✓ Grouping and weighting the Impact Assessment results, which are also optional.

- ✓ Quality analysis of data. This stage is mandatory when the LCA has a comparative purpose and its results are for the general public.

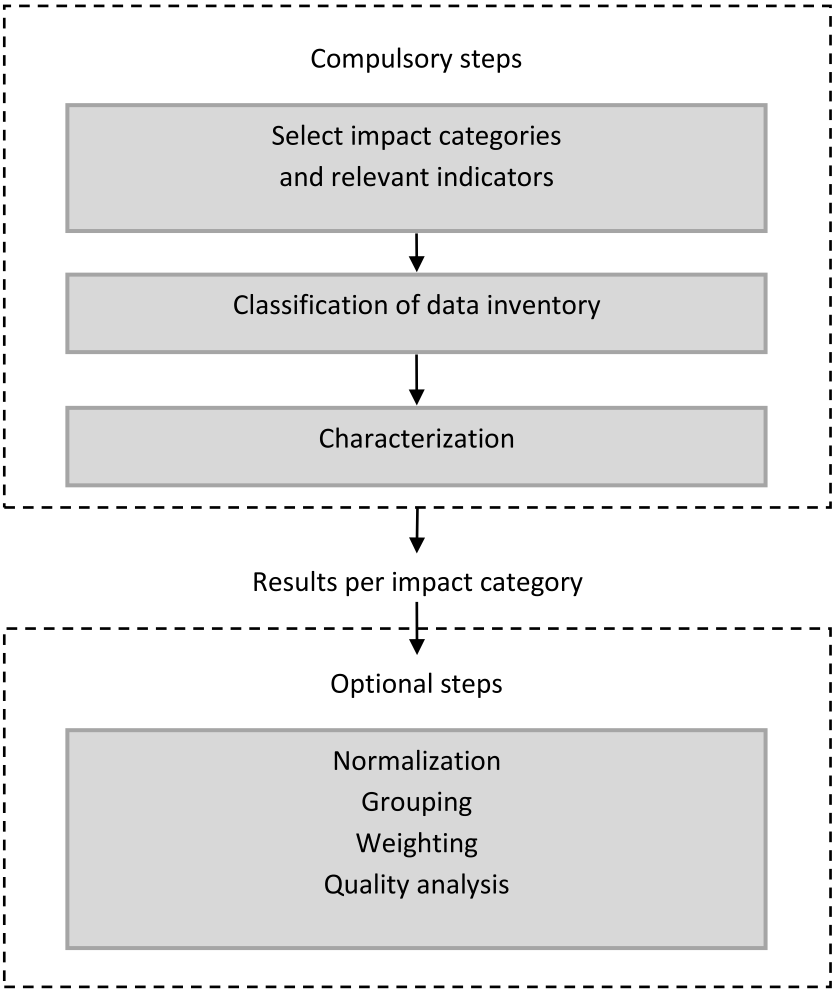


Figure 1-10: LCA impact assessment steps.

In Sections 3.3 and 4.3 more details on the LCA model developed to assess the existing and symbiotic situation respectively in study area 1 (GR) and study area 2 (BG) are presented.

1.5.6 Life Cycle Interpretation

Interpretation is the step at which previous results and assumptions are examined and evaluated in terms of completeness and robustness. The main elements of the interpretation step are the evaluation of the results (in terms of consistency and completeness), the analysis of the results (in terms of robustness), the drawing of conclusions and the formulation of proposals for future research. More specifically:

- Consistency check: The purpose of consistency check is to determine whether assumptions, methods, standards and data are consistent with the goal and scope of the study.

- Completeness check: Completeness check ensures that all information and data required for the interpretation phase are available and complete. The study should be screened for false assumptions, misleading model choices, incomplete and obsolete data.

- Contribution analysis: Contribution analysis explains the contribution of particular environmental flows, processes or effects to a given environmental outcome. Contributions are usually expressed as percentages of the total.

- Sensitivity and uncertainty analysis: This element of the interpretation phase evaluates the influence of variations of data, models and other variables on study results. Sensitivity analysis deliberately introduces variants of data to determine the robustness of the exported results and their sensitivity to specific factors.

- Conclusions and recommendations: In this last step, conclusions and suggestions are made on the content and purpose of the study, based on the information gathered in the previous stages of the LCA and in combination with the results of the previous steps of the interpretation phase.

In Sections 3.4 and 4.4 the interpretation of the results for the existing and symbiotic situation respectively in study area 1 (GR) and study area 2 (BG) is comprehensively presented.

1.6 Life Cycle Assessment Impact Assessment Methods

1.6.1 LCA software and applied databases and impact methods

LCA methodology requires a great extent of data to implement. Widely used software for processing LCA studies is SimaPro. SimaPro (System for Integrated Environmental Assessment of PROducts) is a well-known, accepted and valid tool, which has been used in a large number of life-cycle analysis studies conducted by consulting organizations, research institutes and universities. This software allows complex life cycle analysis in a systematic and transparent manner, following the specifications of ISO 14040. In Sections 3.3 and 4.3 more details on the

LCA model developed to assess the existing and symbiotic situation respectively in study area 1 (GR) and study area 2 (BG) are presented.

The software includes a number of databases from a wide range of industrial processes, transport and materials that cover geographic data from Europe and America. Indicative databases are as follows:

- BUWAL 250: Contains packaging materials (plastic, carton, paper, glass, tin, steel, aluminum), power generation, transportation, waste treatment. It was set up by the Swiss Ministry of the Environment.

- Ecoinvent: Includes over 2,500 up-to-date processes, covering a wide range of materials and processes.

- ETH – ESU 96: Energy / Economic Database.

- FranklinUSA 98: Includes data from North America for energy production, transport, steel, plastics and various processing methods.

- IDEMAT 2001: Includes engineering materials, such as metals, alloys, plastics, wood, and energy and transport processes.

This study will mostly utilize the Ecoinvent and ETH-ESU databases. These databases were selected because:

- ✓ They include a significant number of processes related to energy production and transportation, elements necessary for the modelling of the anthropogenic activities presented in Del3.1 of BIO2CARE.
- ✓ They concern European data.
- ✓ These databases are widely used and the results will be more comparable and comprehensible.

As described in Section 1.4, the third LCA step (impact analysis) requires the choice of an impact assessment method. The choice of the appropriate impact assessment method is made in the light of the objective of the analysis. The SimaPro software contains several methods, the most important of which are the following (Angelakoglou and Gaidajis, 2015):

- CML 2001: CML 2001 method (Guinée et al., 2002) was developed by the Institute of Environmental Sciences (Centrum Milieukunde Leiden – CML) in Leiden University. It follows a midpoint approach (focus on environmental mechanism), according to the principles of ISO 14040. Environmental sustainability is assessed with the application of a wide set of indicators-impact categories their number of which varies according to the needs of the study (obligatory, additional and other impact categories are available). The impact categories are mostly referring to a worldwide level, whereas normalization is performed using global data (European Commission, 2010). Indicative impact categories included in CML are ecotoxicity, global warming, ionizing radiation, land use and others. Data utilized are available in spreadsheet for further analysis and adaptation (European Commission, 2010).

- Eco-Indicator 99: Eco-indicator 99 (EI99) method (Goedkoop and Spriensma, 2001, Pre Consultants, n.d.) follows an endpoint approach (focus on damage). Environmental sustainability is assessed through eleven (11) impact categories which are further organized into three (3) damage categories namely: a) damage to resources (expressed in MJ surplus energy), b) damage to ecosystems (expressed in % of species per m^2 per year) and c) damage to human health (expressed in disability adjusted life years - DALY). Damage is estimated with the application of a model that integrates fate, exposure and effect analysis. Normalization and weighting is performed with reference to European data (European Commission, 2010).

- EDIP 2003: EDIP 2003 method is an update of the EDIP 97 method and was developed by the Institute for Product Development at the Technical University of Denmark (Potting and Hauschild, 2005). It follows a midpoint approach with a closer focus to damage assessment. Environmental sustainability is assessed through eight (8) impact categories such as global warming, stratospheric ozone depletion, ecotoxicity and others. A special characteristic of the method is the integration of characterization factors for various European regions. Normalization is performed based on the impact of an average European citizen for all impact categories. Weighting factors from EDIP 97 are applied in EDIP 2003.

- ReCiPe: ReCiPe method (ReCiPe, 2011) was developed by Radboud, Leiden and Delft universities and Pre Consultants, and is considered the evolution of Eco-indicator 99 and CML 2001 methods (Goedkoop et al., 2009; Goedkoop et al., 2011). The specific method offers the possibility to assess a system with the application of both midpoint and endpoint approaches. In total, eighteen (18) midpoint and three (3) endpoint (human health, ecosystems, resource surplus costs) impact categories are addressed. Characterization factors are calculated on the basis of a cause-effect chain. The endpoint categories can be weighted and aggregated into a single score.

➢ IMPACT 2002+: Impact 2002+ method is a combination of IMPACT 2002, Eco-indicator 99, CML and IPCC methods (Goedkoop et al., 2008; Goedkoop et al., 2010), Jolliet et al. 2003). It combines both the midpoint and endpoint approach through the assessment of fourteen (14) midpoint and four (4) damage categories. Damage categories include human health, ecosystem quality, climate change and resources depletion. Normalization is performed per annual impact score for an average European citizen for all impact categories (Jolliet et al. 2003). If aggregation is needed, weighting can be performed either by the users or by utilizing default weighting factors.

In this study, the assessment of the existing and symbiotic situation in study area 1 (GR) and study area 2 (BG) will be carried out using the ReCiPe and Eco-Indicator 99 methods. These methods were selected because:

✓ They represent relatively recent European data.
✓ They are widely used impact assessment methods.

More detailed information about the two impact assessment methods is given below. The reason why two evaluation methods were selected is to evaluate both midpoint environmental indicators and endpoint indicators. The midpoint indicators focus on the environmental mechanism (cause), while endpoint indicators indicate the relative importance of the emissions by targeting the effect (e.g. impact on health) (Bare et al., 2000). Endpoints are more understandable, particularly among executives, but involve a higher degree of uncertainty. Therefore, it is proposed to use both types of indicators for the full life cycle analysis of a system (Goedkoop et al., 2011).

1.6.2 The ReCiPe method (Midpoint)

Applying the ReCiPe method will quantify a number of important environmental indicators (Table 1-4). However, as mentioned above, beyond the midpoint indicators, it is important to evaluate the endpoint indicators as well. Although ReCiPe provides the ability to evaluate endpoint indicators, it was preferred that the Eco-Indicator 99 method to be used as it has been applied more extensively in the international literature, whereas it follows a similar assessment methodology (indicators, normalization, etc.) with ReCiPe.

Table 1-4: Impact Categories and category indicators of ReCiPe method (Midpoint)

	Impact Category Name	**Abbreviation**	**Unit**
Midpoint Indicators	Climate change	CC	kgCO_2 eq.
	Ozone depletion	OD	kg CFC-11 eq.
	Terrestrial Acidification	TA	kg 1,4-DB eq.
	Freshwater eutrophication	FE	kg NMVOC
	Marine eutrophication	ME	kg PM_{10} eq.
	Human Toxicity	HT	kg U^{235} eq.
	Photochemical oxidant formation	POF	kg SO_2 eq.
	Particulate matter formation	PMF	kg P eq.
	Terrestrial ecotoxicity	TET	kg N eq.
	Freshwater ecotoxicity	FET	kg 1,4-DB eq.
	Marine ecotoxicity	MET	kg 1,4-DB eq.
	Ionising radiation	IR	kg 1,4-DB eq.
	Agricultural land occupation	ALO	m^2×yr
	Urban land occupation	ULO	m^2×yr
	Natural land transformation	NLT	m^2
	Water Depletion	WD	m^3
	Mineral resource depletion	MRD	kg Fe eq.
	Fossil resource depletion	FD	kg oil eq.

1.6.3 The Eco-Indicator 99 method (Endpoint)

The Eco-Indicator 99 method aims to capture the damage caused by environmental impacts. The results of the data inventory are captured in eleven categories of impacts, which by utilizing weight coefficients are organized into three major areas of final losses:

- Losses in human health, which are expressed as the sum of the years of life lost and of the years in which one lives. This sum is expressed by the DALY (Disability Adjusted Life Years) index, which is used by the World Bank and the World Health Organization.

- Losses in the balance of the ecosystem, which are expressed as losses of species in a particular geographical area and during a certain period of time.

- Losses in the stock of natural resources, which are expressed as the extra energy required for future extraction of ores and fossil fuels.

Emission coefficients for emissions to the atmosphere, the hydrosphere and the soil are calculated at the final level of losses. The loss estimation model is a function of exposure, fate analysis, and effect analysis. In particular, the model applies to the following categories of impacts:

- Carcinogens: Carcinogenic effects are investigated due to emissions of carcinogens into the atmosphere, the hydrosphere and the soil. Losses are measured in DALY / kg of emission.

- Respiratory organics/inorganics: The respiratory problems caused by winter smog due to the emission of dust, sulphur and nitrogen oxides in the atmosphere, as well as the respiratory problems caused by summer smog due to the emission of organic substances in the atmosphere. Losses are measured in DALY / kg of emission.

- Climate change: The increase in illness and death due to global climate change is being considered. Losses are measured in DALY / kg of emission.

- Radiation: The effect of radioactive radiation is examined. Losses are measured in DALY / kg of emission.

- Ozone layer: An increase in diseases and deaths due to increased UV radiation resulting from the emission of ozone-depleting substances is being considered. Losses are measured in DALY / kg of emission.

- Ecotoxicity: The impact on ecosystem quality as a result of emitting ecotoxic substances in the atmosphere, the hydrosphere and the soil is examined. Losses are measured in Potentially Affected Fraction (PAF) * m^2 * year / Kg of emission.

- Acidification / Eutrophication: The effect on the quality of the ecosystem as a result of the emission of acidifying or eutrophication substances is considered. Losses are measured in Potentially Disappeared Fraction (PDF) * m^2 * year / Kg of emission.

The above impact categories refer to emissions of pollutants and substances. In addition to emissions, land use is also being considered. Biodiversity depends on the type of land use and the extent of the exploited area. The following category takes into account both local and regional effects:

- Land use: the effect of either change in land use or land occupation is examined. Losses are measured in Potentially Disappeared Fraction (PDF) * m^2 * year / m^2 of land.

With regard to the extraction of natural resources, it is assumed that mankind first draws the best exploitable resources, leaving for the later subordinates. Future generations will require extra effort to extract natural resources. This extra effort is expressed as "surplus energy".

- Minerals: losses are measured in extra energy per kilogram of ore or ore as a result of the lower quality of minerals.
- Fossil fuels: losses are measured in extra energy per MJ, Kg or m^3 of fossil fuel as a result of lower fuel quality.

The normalization of the data takes place at the level of losses, with a European reference point 1993 or later. Data weighing is also at the level of losses. Weights are the product of the scientific opinions and assessments of a team of experts.

1.7 Assessing the benefits of Industrial Symbiosis using LCA

With the worlds numerous environmental problems, companies and municipalities need to find ways to become more environmentally sustainable, as they need to balance between lowering their effect on global issues such as global warming and toxicity, whilst simultaneously working to sustain the companies own future (Gustafsson, 2018). Jelinski et al. (1992) suggest that industries need to learn from the ecosystem, that there is a need to stop viewing processes as linear flows with products and by-products being used and then disposed, but to instead see all these things as resources to be utilized (Fig. 1). These principles also laid down the foundation of the circular economy concept, and important aspects of seeking this circularity is focusing on reducing, reusing, and recycling materials and energy (Hond, 2000). One way to work like this is through industrial symbiosis, a concept where regional actors exchange things such as materials, energy, knowledge, and other resources to achieve win-win situations (Mirata et al., 2005).

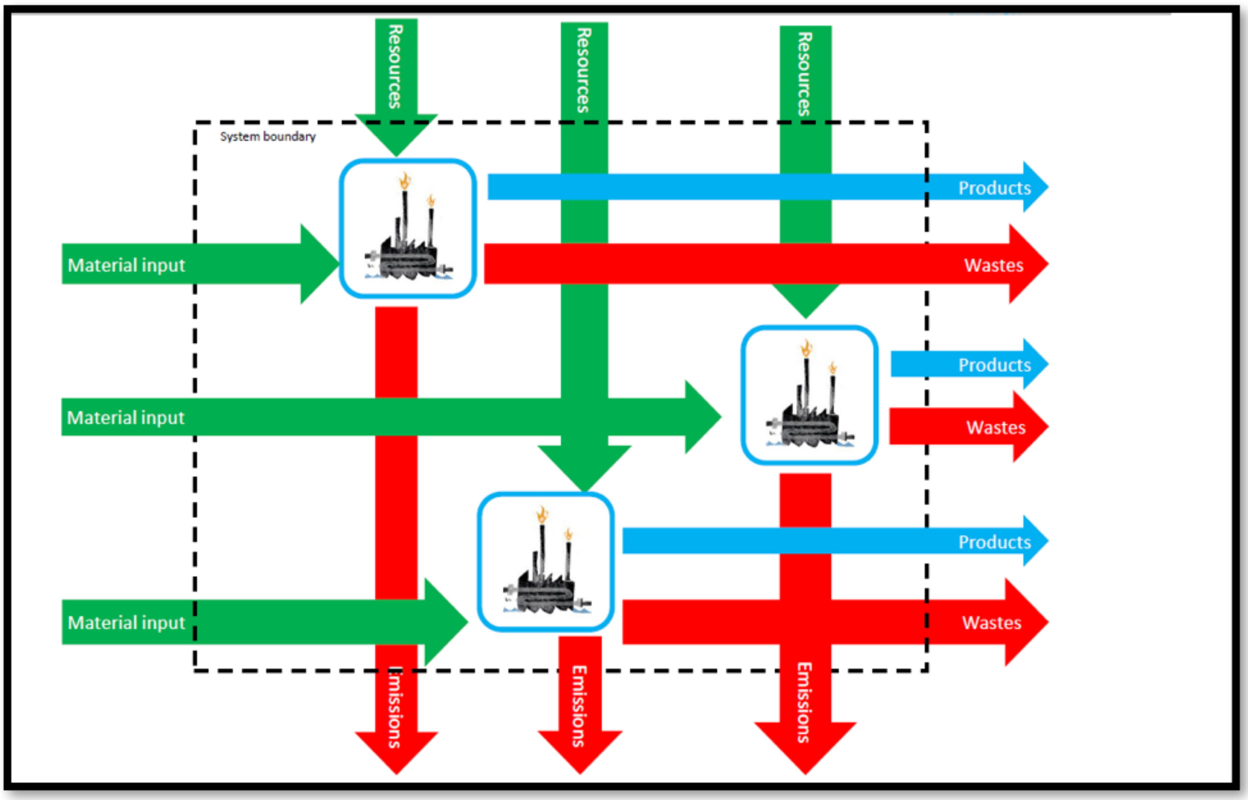


Figure 1-11: Linear industrial system (source: www. sharebox-project.com)

Industrial symbiosis (IS) can be described as waste or byproduct exchange and utility-sharing networks among collocated firms (Chertow 2000). Resource consumption and costs are reduced through utilization of materials that would otherwise be classified as by-products or waste and jointly providing energy, water, and waste treatment services for associated partners (Fig. 2) . Most symbioses have self-organized in order to improve economic profits and comply with stricter environmental permit requirements (Chertow 2007), but also some policy instruments can promote their development (Lehtoranta et al.2011). The practical applications of IS include expanding existing symbioses (Chertow 2007), planning new eco-industrial parks (EIPs) (Baas and Huisingh 2008; Gibbs and Deutz 2005; Heeres et al. 2004; Mirata 2004; Van Leeuwen et al. 2003; Veiga and Magrini 2009; Zhang et al. 2010), and even restructuring the whole nation into a circular economy (Geng et al. 2009;Yuan et al. 2006).

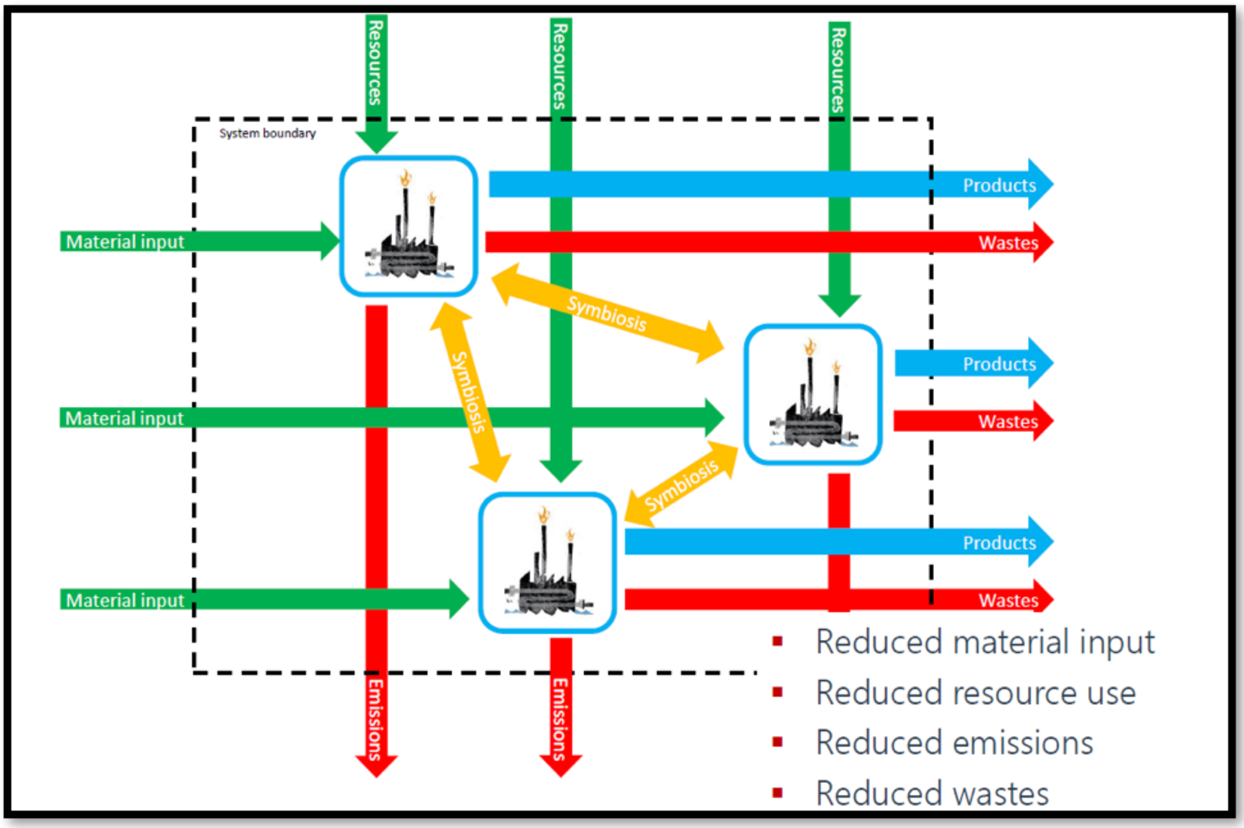


Figure 1-12: Symbiotic industrial system (source: www. sharebox-project.com)

However, there exists multiple barriers that can hinder symbiotic exchanges, including economical, organisational, and social (Siskos and Van Wassenhove, 2016; Chertow, 2000; Aid et al., 2017; Ceglia et al., 2017). The industrial symbiosis leads to environmental, economic and social benefits to all involved. To evaluate the scale of the environmental, economic and social impacts , methodology of assessment is needed. Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCC) are methods commonly used for that (Finnveden et al., 2009). LCAs and LCCs have been applied to industrial symbiosis networks as a whole (Røyne et al., 2015; Yu et al., 2015), and to evaluate changes as a whole (Mohammed et al.,2016; Secchi et al., 2016; Lim, 2010). Martin et al. (2015) and Mattila et al. (2012) looked into how LCAs can be applied to industrial symbiosis and what guidance exist, with Martin et al. (2015) mentioning that emission allocation and distribution can be important for multiple reasons. Päivärinne et al. (2015) highlighted in their study the importance of transparency and mutual gain in industrial symbiosis business arrangements. These methods can be applied on any planned projects to see the collective benefits tighter with the benefits for the individual companies.

Setting up an industrial symbiosis exchange is not always simple; knowing who benefits from what, and who should pay for what investment can be complicated. Moreover, it is often assumed that industrial symbiosis exchanges are environmentally sustainable, but it is not always the case. To better understand how costs should be allocated, and how exchanges should look to be both economically and environmentally sustainable, the methods life cycle analysis (LCA) and life cycle cost analysis (LCC) are suitable to use, as they allow a full view of the system, which can be broken down into different processes ((Gustafsson, 2018).

As it was stated above one of the most often used tools for environmental assessment is LCA, which also has a central role in Industrial Ecology (Graedel and Allenby, 2003). This method is broadly used and has many applications, but has also been criticized (Finnveden, 2000; Ayres, 1995; Ehrenfeld, 1998). The major difficulties concerning LCA and other environmental assessment tools that have been discussed in the literature are issues of boundaries and time perspectives, allocation problems, lack of knowledge regarding how certain emissions affect the environment, data gaps, and the valuation and weighting of different environmental problems (*e.g.*, Ammenberg, 2003; Finnveden, 2000; Russel *et al.*, 2005).

The main reason for the uncertainty in environmental assessment is that the results often depend on the peculiarities of the environment. Finnveden and Ekvall (1998), found that when comparing the recycling of paper to incineration, it is important to consider, for example, what fuel is used for heat production and what happens to the wood that is saved if paper is recycled. Finnveden (2000) suggests that such aspects can be determined in descriptive studies, but are very uncertain in change-oriented studies, since the future is always uncertain. Scenario analysis can be used to describe the future (Börjesson *et al.*, 2006), but is always uncertain and will furthermore never produce simple results such as 'product a is better than product b' or 'industry x will have impact y on the environment'.

To overcome the complexity of environmental assessment, indicators can be used to describe the environmental pressure from companies (Tyteca *et al.*, 2002; Svensson *et al.*, 2006). There are physical indicators – energy and water inputs, waste generation, emissions into air, emissions into water; business indicators, such as ISO 14001/EMAS certification; and impact indicators, for example, emissions of ozone-depleting substances into air (Tyteca *et al.*, 2002). The use of indicators enables some of the problems in environmental assessment to be avoided, such as evaluating, weighing and deciding how emissions affect the environment. However, concerns such as system boundaries, emissions accounting and allocation may remain, depending on the type of indicator. It is also important to realize that indicators often reflect the environmental issues in focus at the time, and that their usefulness might depend on the type of process or product studied and on the system they operate in (Svensson *et al.*, 2006).

The energy sector accounts for a large part of the contribution to CO2 emissions, and energy indicators are often used to measure companies' environmental performance (Svensson *et al.*, 2006). In energy systems research, CO2 emissions are often used as the only indicator (although not using that specific terminology). Although this simplification might seem an easy way of assessing environmental performance, some difficulties remain in accounting for CO2 from energy use. Accounting for emissions from energy use and the production of energy carriers is also an important parameter in LCA and other environmental assessment tools. Grönkvist *et al.* (2003) showed that this is a problematic step leading to very different results depending on the assumptions made. Depending on how the electricity or heat used is assumed to be produced (average annual production, different types of marginal production, labelled electricity, *etc.*), the emissions vary considerably. In LCA, the average grid electricity production is mostly used, at least in practice, although the usefulness of the marginal electricity approach is also being discussed (Finnveden and Moberg, 2005; Ekvall *et al.*, 2005). One common view is that marginal data should be used for change-oriented studies, whereas average data is more appropriate for accounting studies (Ekvall, 2002; Finnveden and Moberg, 2005; Ekvall *et al.*, 2005). Some authors also suggest that labelled electricity might be appropriate (Kåberger and Karlsson, 1998). In the field of energy systems analysis, opinions differ, but many authors suggest, or use, some type of present or future marginal approach (*e.g.*, Sjödin and Grönkvist, 2004; Werner, 2001; Trygg, 2006; Knutsson *et al.*, 2006; Carlson, 2003). Grönkvist (2005) suggests a more pragmatic view, where the analysis should be focused on the specific situation and openness to change is essential. This is contradictory to the discussion, for example in LCA, that it is important to endeavor to achieve greater harmonisation of the methodology (Finnveden, 2000).

Conclusions

A Life-Cycle Assessment (LCA) is the proper methodology for investigating the life-cycle impacts of industrial processes and their redesign, and it must follow the objective of environmental performance optimization. It provides a framework for estimating the environmental impact of products or processes from cradle to grave, that is, from raw material extraction and processing through manufacturing, distribution, retail, consumption, and product disposal. Consequently, the LCA allows for the management of complex information; the information can be processed consistently toward the general optimization of systems. On the other hand, the LCA results can represent the starting point for further applications with different purposes and targets. The European Commission stated that the best way to demonstrate the efficacy of the LCA approach is to apply it to various practical applications (European Commission 2003). The analysis case studies can help design national pilot projects and can drive progress toward the ultimate goal: sustainability.

Chapter 2 - Industrial Symbiosis Case Study

2.1 Identification of potential symbiotic activities in study area 1

The implementation of circular economy and industrial symbiosis practices within the boundaries of each study area is considered a desirable step towards a more sustainable production and consumption behavior. The identification and selection of the appropriate symbiotic activities is based on literature review of successful practices and aiming to potential environmental, economic and social benefits, while taking into account the specific features of study area 1 and its reach biodiversity (further examination of the identified symbiotic activities on Chapter 2.3).

Upon examining the area, the residential needs, the business, agricultural and tourist sectors, comparing the results to relevant literature, the identified activities for study area one are as follow.

2.1.1 CO2 capture and reuse for the development of local Greenhouse

As stated in Deliverable 3.2, the estimation of the Carrying Capacity and Carbon Footprint of a protected area should take into account the impact of all activities taking place within the boundaries of the area, but also in a broader spectrum all the activities that affect the area. Given that premise, industrial activities that occur within 5 kilometers of the boundaries of the study area, are having an impact on the area.

Such an industrial activity, is a local fertilizer production plant that is located within 5-10 kilometers from the boundaries of NP-EMATH. Within the facilities of the fertilizer production plant there is also an ammonia production stage. Ammonia is produced with the method of natural gas reforming. During that process, carbon dioxide is produced as a by-product:

$$\mathrm{CnHm} + 2\mathrm{nH_2O} \longrightarrow \mathrm{nCO_2} + \left(2\mathrm{n} + \frac{\mathrm{m}}{2}\right)\mathrm{H_2}$$

$$\mathrm{CH_4} + \mathrm{H_2O} \longrightarrow \mathrm{CO} + 3\mathrm{H_2}$$

$$\mathrm{CO} + \mathrm{H_2O} \longrightarrow \mathrm{CO_2} + \mathrm{H_2}$$

The total amount of carbon dioxide produced, based on official documentation of the fertilizer plant is 200kt of CO_2 annualy. This carbon dioxide, as of today, is released to the atmosphere, however it is possible, using appropriate technology, to capture it and reuse it in various applications.

Once of these applications is greenhouse enrichment. Enriching greenhouses with carbon dioxide is a common procedure used to facilitate photosynthesis and thus to increase production. In northern Europe, this process is used daily for tomato production and has caused a 30-40% increase in production. Increasing the carbon dioxide concentration leads to an increase in the optimal plant growth temperature and can therefore prove to be beneficial in warmer climates as well. In warmer climates, however, one of the major problems of carbon dioxide enrichment is that it is in conflict with the need to bleed the greenhouse. During the venting process, in order to reduce the temperature or humidity of the greenhouse, the carbon dioxide is depleted and its concentration in the greenhouse is reduced, which can increase the cost of enrichment (Ron Amir et al., 2005).

In areas with warmer climates, several studies have been carried out which relate to the optimal way of enriching with carbon dioxide. All studies have shown that enriching with carbon dioxide in warmer climates requires a delicate balance between the need for bleeding and the desire for enrichment. Zipori in 1986 suggested intermittent enrichment and reported that it had a significant advantage over another alternative method tested, selective enrichment (Zipori et al., 1986). On the other hand, Ioslovich in 1995 showed that for slowly changing weather conditions, optimal carbon dioxide enrichment is not intermittent, but an almost stable situation. It was reported that as the frequency of weather disturbances increases, the solution of the almost steady state becomes less optimal. However, this method was chosen because of the difficulty in applying a truly optimal solution (Ioslovich et al., 1995). In 1998 Linker presented the advantage of using evaporative cooling measures to significantly reduce the rate of bleeding required to keep the greenhouse in a desired temperature range, thus extending the duration of the enrichment. (Linker et al 1998)

In cold weather, for example in the winter months, bleeding is usually low. A relatively small dose of carbon dioxide can maintain the overall concentration at high levels. As a result, production is significantly increased. It is obvious that the effects of carbon dioxide are retained only for the period of application of the enrichment. When enrichment stops, for example, when more bleeding is needed in the spring, the enrichment effects stop. In case the main production is done at the end of spring and summer, greenhouse enrichment in the winter does not have a big effect. (Elly Nederhoff, 2004)

In warmer weather when venting is necessary, it is evident that it is more difficult to increase the carbon dioxide concentration. This is primarily a financial issue: how much carbon dioxide has to be channeled into the greenhouse so the proposal is profitable? Generally, it is cheaper to feed less carbon dioxide, so as not to deplete carbon dioxide in the greenhouse. This quantity is the amount required by plants for photosynthesis, which corresponds to 5 g / m2 / h (grams per square meter per hour), in good light conditions. This quantity is able to reach the carbon dioxide concentration levels in the greenhouse, as it is in the environment, with the result that there is no carbon dioxide loss in the greenhouse to the outside. Enrichment with larger amounts of carbon dioxide should be considered on the basis of costs and benefits. As mentioned, the cost of enrichment depends on greenhouse gas emissions. (Elly Nederhoff, 2004)

Let's see, however, how it affects the venting of carbon dioxide. Initially, there are three cases. In the first case there is depletion of carbon dioxide, with the concentration of carbon dioxide in the greenhouse being lower than in the outside environment. Bleeding will bring fresh air (and therefore carbon dioxide) into the greenhouse into the greenhouse and is considered beneficial to the greenhouse. (Elly Nederhoff, 2004)

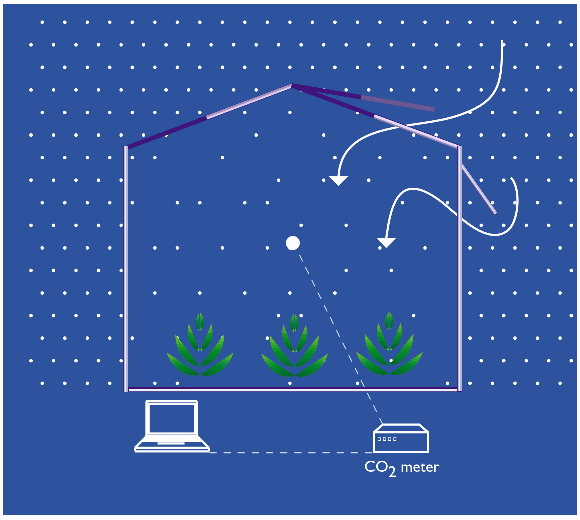


Figure 2-1: Reduced CO2 in the greenhouse that causes CO2 to enter from the outside environment
Source: Elly Nederhoff, 2004

In the second case, the carbon dioxide concentration in the greenhouse is the same as the outside environment (about 360 ppm). This happens when carbon dioxide intake is exactly compensated by the fresh air inflow. In this case there is no amount of carbon dioxide lost in the external environment. (Elly Nederhoff, 2004)

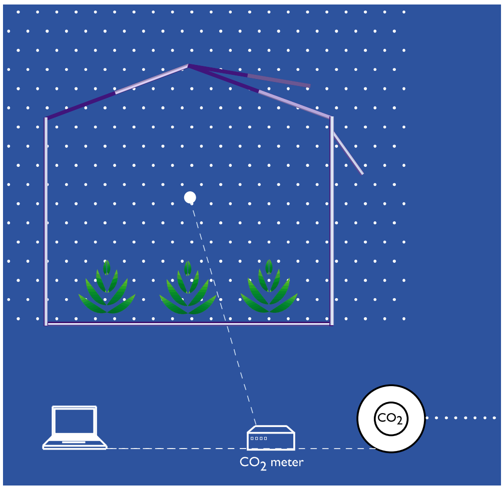


Figure 2-2: Balance CO2 concentration inside and outside the greenhouse
Source: Elly Nederhoff, 2004

In the third case we have increased amounts of carbon dioxide due to enrichment. Part of the carbon dioxide will escape from the greenhouse due to bleeding. The amount leaking out will depend on the opening of the bleed, the air velocity and the concentration of carbon dioxide. (Elly Nederhoff, 2004)

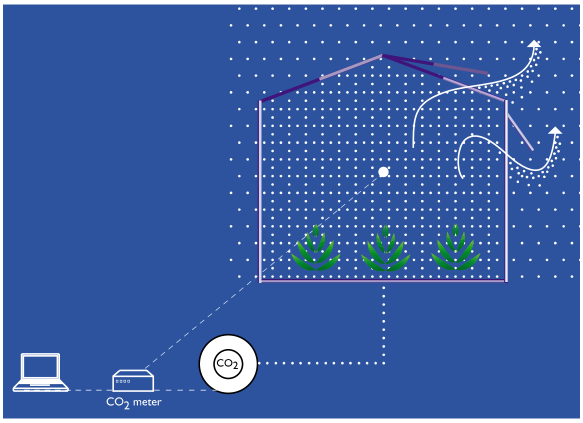


Figure 2-3: Increased CO2 concentration, due to CO2 enrichment
Source: Elly Nederhoff, 2004

Some numerical examples: When the CO2 concentration in the greenhouse is 500 ppm and the ventilation is closed, it leaks around 2-3 g/m2/h in the environment. With the ventilation open, the leakage will be approximately 10-25 g /m2/h. If there is a CO2 concentration of 900 ppm then the leak with closed ventilation will be 3-5 g/m2/h, while with open air ventilation it will be 15-50 g / m2 / h. These figures are not absolutely accurate as there is no precision in these examples in the type of greenhouse, the type of bleeding, the air velocity. (Elly Nederhoff, 2004)

At the beginning of 1980, when carbon dioxide enrichment was started in the Netherlands, the recommended amount of supply was 5 g/m2/h. At this time, this is the minimum figure. The table below shows that 5 g / m2 / h is enough to maintain the carbon dioxide level equal to that of the outside environment. This quantity is sufficient to cover plant prevention needs without exhausting CO2. Under low light, carbon dioxide uptake by plants can be less than 5 g/m2/h and the supply of this amount can increase the concentration of CO2 in the greenhouse to 500 ppm. In this case supply and demand are in balance.

Today, growers import larger amounts of carbon dioxide, for example about 20 g/m2/h, or even more. This rate of supply is far greater than the percentage of CO2 intake from plants, increases the concentration of CO2 and can keep it high even during venting. (Elly Nederhoff, 2004)

Based on all of the above, it is possible to draw the first conclusions about the greenhouse associated with this case study. The case of a greenhouse with a minimum area of 50 acres (50,000 m^2) is being considered, as the aim is to increase the production process in the local area. The enrichment of carbon dioxide will take place for 6 months, from October to March, to avoid the collision of enrichment with frequent ventilation due to the summer heat. According to the above, two cases have to be considered: providing the minimum amount of CO2, ie 5 $g/m^2/h$, and supplying a quantity of 20 $g/m^2/h$. These cases were chosen because they have already been applied to similar projects and are the lowest and highest price values for the applications so far.

In the first case, the amount of carbon dioxide required is 1,080 tonnes of carbon dioxide per year. In the latter case, the required quantity is 4.320 tonnes of carbon dioxide per year. As the fertilizer plant’s CO2 waste volume reaches 200,000 tonnes per year, the percentage of waste required for greenhouse enrichment is in the range of 0.54 - 2.16%.

2.1.2 Development of biomass power plant

From a recent research, it is estimated that the total available biomass in Greece consists of 7,5 tonnes of agricultural crop residues (corn, cotton, tobacco, sunflower, brandy, coconut, kernel, etc.) and from 2,7 mt forestry residues (branches, bark etc.). Besides the fact that most of this biomass remains unused, it is often the cause of many unpleasant situations (fires, difficulty in carrying out work, spreading diseases, etc.). In Greece, in particular, available biomass dynamics per year is equivalent to 3-4 million tons of energy, while the potential of potential energy crops can, at present, easily overcome those of agricultural and forest waste. This amount corresponds to 30-40% of the amount of oil consumed in our country. It is worth noting that a ton of biomass equals about 0.4 tons of oil.

Generally, biomass is defined as matter that has organic (organic) origin. In practice, the term biomass includes any material derived directly or indirectly from the plant world (CRES, 2018). In particular, they include:

- Plant materials derived either from natural ecosystems, such as wild plants and forests, or from energy crops (so-called plants grown specifically for the production of biomass for energy production) of agricultural and forestry species, e.g. sorghum, sugary, reed, eucalyptus, etc.

- By-products and residues of plant, animal, forest and fishery production, straw, corn cobs, cotton stalks, tree branches, algae, animal wastes, the vine shoots, etc.

- By-products derived from the processing or processing of such materials, such as egg yolks, cotton ginning remnants, sawdust etc.

- The biological origin part of urban waste water and rubbish.

Biomass is a captured and stored form of solar energy and is a result of the photosynthetic activity of plant organisms. Therefore, once the biomass is formed, it can very well be used as a source of energy.

The main advantages resulting from the use of biomass for energy production are the following:

- The prevention of the greenhouse effect, which is largely due to the carbon dioxide produced by the combustion of fossil fuels. Biomass does not contribute to increasing the concentration of this pollutant in the atmosphere because, while burning it, CO2 produces significant amounts of this pollutant during production and photosynthesis.

- The avoidance of atmospheric pollution with sulfur dioxide produced during combustion of fossil fuels and contributes to the phenomenon of "acid rain". The sulfur content of biomass is practically negligible.

- The reduction of energy dependence, as a result of the import of third country fuel, with corresponding currency savings.

- Securing employment and restraining rural populations in border and other agricultural areas, biomass contributes to regional development in the country.

The disadvantages associated with the use of biomass mostly involve difficulties in its exploitation and are:

- Its large volume and its high moisture content, per unit of energy produced.

- The difficulty in collecting, processing, transporting and storing it against fossil fuels.

- The more expensive facilities and equipment needed to harness biomass compared to conventional energy sources.

- Its wide dispersion and seasonal production.

Because of the above disadvantages and for the majority of its applications, the cost of biomass remains high compared to oil. However, there are already applications where the exploitation of biomass has economic benefits. Moreover, this problem is gradually being eradicated by the rise in oil prices and, more importantly, by the improvement and development of biomass utilization technologies. Finally, the environmental benefit, which often cannot be valued, is essential for the quality of life and the future of mankind (CRES, 2018).

In general, low yield and dependence on inconsistent biomass fuels have limited the development of biomass energy systems. Technological progress in gasification however, provides a significant increase in efficiency of about 10%, in electricity generation. Higher efficiency translates into a company's ability to pay for consistent biomass fuels.

Technologies already in use or potentially usable for the production of electricity are already in use in coal-fired plants. The main techniques investigated for energy from biomass are (Erik Christian Daugherty, 2001):

- Direct combustion of biomass.
- The "co-firing" of biomass with carbon.
- Gasification of biomass
- The pyrolysis of biomass to produce "bio-slow" liquid fuels.

A small scale example of an industry that uses a biomass cogeneration plant in Greece, is a ginning plant in the region of Boeotia (CRES,2018). 40-50 kt of cotton are ginned, and this production process results annually 4 -5 kt of residues, which were burned in incinerators in the past without much control, thus creating a risk of ignition. The necessary drying of the cotton before ginning was done earlier by burning oil and exhausting the exhaust to the cotton ready to be dried until a co-generation system was installed, which exploits the ginnation residues by combustion.

The power of the biomass boiler is 4,000,000 kcal / h and the vapor produced has a pressure of 10 bar. The work produced, when the steam is vaporized on a turbine, is converted into a generator of 500 kW electric power. After being exhausted, steam is led, via pipelines, to heat exchangers, where the air is heated to a temperature of 130°C, which is then used to dry cotton in towers special for this purpose, and next in the oil mill, where it is used in steam presses for the export of cotton.

By installing the above system, all of the heat needs of the ginning plant and some of its electricity needs are covered. The savings on conventional fuels achieved annually reach 630 tons of oil. Thus, the initial investment, totaling € 0.9m, was depreciated in just two ginning periods. Finally, it is worth mentioning that similar units, only for heat production, have already been installed and operate in 17 cotton ginning plants in our country, where the use of oil and fuel oil from the gin waste was fully replaced.

It’s worth pointing out that the burning of the biomass and the products that come from thermal or biological treatment, without being further processed, does not contribute to the warming. Since the CO2 equivalents produced by the combustion are thought to have been incurred for the production, the biomass presents a zero CO2 balance and is considered a "neutral" fuel to carbon dioxide (Technical Chamber of Greece, 2018).

According to the Greek Centre for Renewable Energy Sources and Saving, the available biomass quantity suited for potential use in the region of eastern Macedonia and Thrace results in the following quantities (Regional Association of Municipalities of Eastern Macedonia and Thrace, 2018):

- Energy crops at around 1,0 – 1,3 Mton/yr
- Agricultural and livestock residues 1,75 – 2,28 Mton/yr
- Organic residues 50 – 180 kton/yr

This results in a total amount of at least 2800 kton of available biomass, an amount that could rise up to 3760 kton. Given the fact that the study area 1, NP-EMATH covers the 6,5% of the total Eastern Macedonia and Thrace Region, we could assume that the available biomass within the boundaries of NP-EMATH is around 180 – 245 kton. If this available quantity would be utilized in thermal energy production could result into a reduction of 72.000 – 98.000 tons of oil for heating. That is a scenario that includes only the available mount of biomass within the boundaries of NP-EMATH. In an even better scenario, biomass from the whole Eastern Macedonia and Thrace Region could be utilized and reduce even further the use of oil for heating.

In a symbiotic scenario this biomass power plant could be fed by biomass produced from the agricultural sector within the boundaries of study area 1 and provide energy back to the energy sector, in order to achieve a relative energy autonomy.

2.1.3 Industrial Wastewater for District Heating

The reuse of industrial waste water is a classic example of a symbiotic relationship within an industrial symbiosis. This move is an economically and attractive alternative and helps saving a significant commodity, water, for future generations. Economic use further reduces the amount of wastewater diverted to treatment facilities and further reduces the cost of treatment. Wastewater industries are investing in wastewater treatment and re-use not only to comply with environmental wastewater disposal limits, but also because product recycling and raw material recovery can multiply the benefits of a business (C. Visvanathan, Takashi Asano, 2004).

An example is the case of Kalundborg symbiosis where wastewater from the Ansaes is converted into steam and delivered as a high-energy by-product to neighboring facilities or as heat for the district heating system (Jacobsen, 2006).

As in the case of CO_2 capture and enrichment of a local greenhouse, we examine the possibility of reusing industrial wastewater from two industries located in close proximity to the boundaries of Study area 1. The first industry is the already mentioned fertilizer production plant, which produces around 100-120 m^3/h of wastewater which is currently discarded at the sea at a temperature of 40-50^{o}C. The second industry is an oil extraction company which produces wastewater at a rate of 1300 m^3/h. In both of these cases the wastewater is treated within the facilities before being discarded.

These amounts of wastewater, if viewed as waste heat, could potentially provide a valuable solution for the local district heating. A way to successfully incorporate this solution is with the installation of heat pumps that distribute the treated wastewater to the district for heating purposes. Recent studies have shown in the past decades Wastewater heat pump systems have become increasingly popular due to their advantages of relatively higher energy utilization efficiency and their environmental performance (Hepbasli et al., 2014).

To cover the heating or cooling demand of a building through the utilization of wastewater as a heat source a sufficient amount of wastewater has to be available. To recover 1MW of heating energy there is a need for 140–160 m^3/h of wastewater (ideally - depending on the temperature of the wastewater and the technical efficiency of the system) (Kiss, 2017). In the case of Study Area 1, the available quantity of wastewater through the two industrial facilities, is 1400 m^3/h, so we are looking at recovering 10 MW of heating/thermal energy. In a yearly basis we are looking at 86400 MW of thermal energy (both for heating and cooling), an amount that reduces the use of oil for heating, and that could provide an alternative solution to the thermal needs for the residence and municipal buildings of Study Area 1.

2.1.4 Agricultural based symbiotic network

As stated in BIO2CARE Deliverable 3.1 “One (1) study collecting information and producing knowledge regarding anthropogenic activities and status of nature (incl. SWOT analysis) of the areas”, the agricultural sector (agriculture and livestock farming) is a focal point of economic activity in the East Macedonia and Thrace Region, and that is the case within the boundaries of Study Area 1 as well. Due to its importance, the establishment of a new, closed loop, agricultural network, is considered necessary.

As a base for this network, Alfaro and Miller’s (2013) case study will be used, due to the similarities of the systems under examination. Most of the proposed actions is going to be assessed mainly qualitatively and not quantitatively. The proposed symbiotic actions are described in detail below.

1. Development of fishfarms/rice puddles. Rice is already a product produced in the region of Eastern Macedonia and Thrace (around 12.000 tones in 2010). The development of local fishfarms/fishpond in the area is proposed, while utilizing those areas as rice plantation areas, possibly freeing land use in the rest of the region. This action is proposed since fish could provide fertilizer to the rice while eating weeds and pests that could potentially damage the rice crops. In addition, rice stalks provide food, shade and ideal temperature for the water, hence making the environment ideal for the fish (Fernando and Halwart, 2000). Furthermore, in order to exploit further the symbiotic potential, the fishfarms could use the industrial wastewater mentioned above for heating, during the winter months.

2. Livestock residue utilization. Within the boundaries of NP-EMATH, just as in the Region of Eastern Macedonia and Thrace, livestock is an important activity. Several species of farm animals are bred (see Deliverable 3.1 for detailed listing, hence as a consequence there is a relatively big number of waste residues from this activity. This residue could potentially be utilized as fertilizer for other agricultural activities, for the new proposed greenhouse, as well as by-product for the biomass power production plant. Moreover, waste rice bran from the Rice Mill (during the rice production) could serve as food for the livestock (e.g. rabbit farms).

3. Crop residues utilization. As in the case of rice bran, residues from the wide variety of crops within the boundaries of NP-EMATH (see Deliverable 3.1 for detailed listing) could serve as food for the livestock. Furthermore, crop waste is considered biomass, so it could be utilized in the biomass power production plant. There should be further examination for the scenario of crop wastewater, after treatment, being used in the proposed heat pumps for district heating.

4. Development of a local farmers' market. A farmers' market that provide to the public meat, fish, and various agricultural products, produced within this symbiotic network. All these products will carry the BIO2CARE Symbiosis Eco-label (Deliverable 4.5). This farmers' market will be built with the target of promoting the symbiotic products, minimizing impacts from transportation of goods, while ensuring the customers of the high quality standards of the products.

The final picture of the proposed symbiotic scenario for Study Area 1 is shown in Figure 2-4, while the benefits of the proposed symbiotic actions are presented in Table 2-1. 16 symbiotic exchanges have been identified that could lead the way towards a sustainable future for the production and consumption within the boundaries of NP-EMATH.

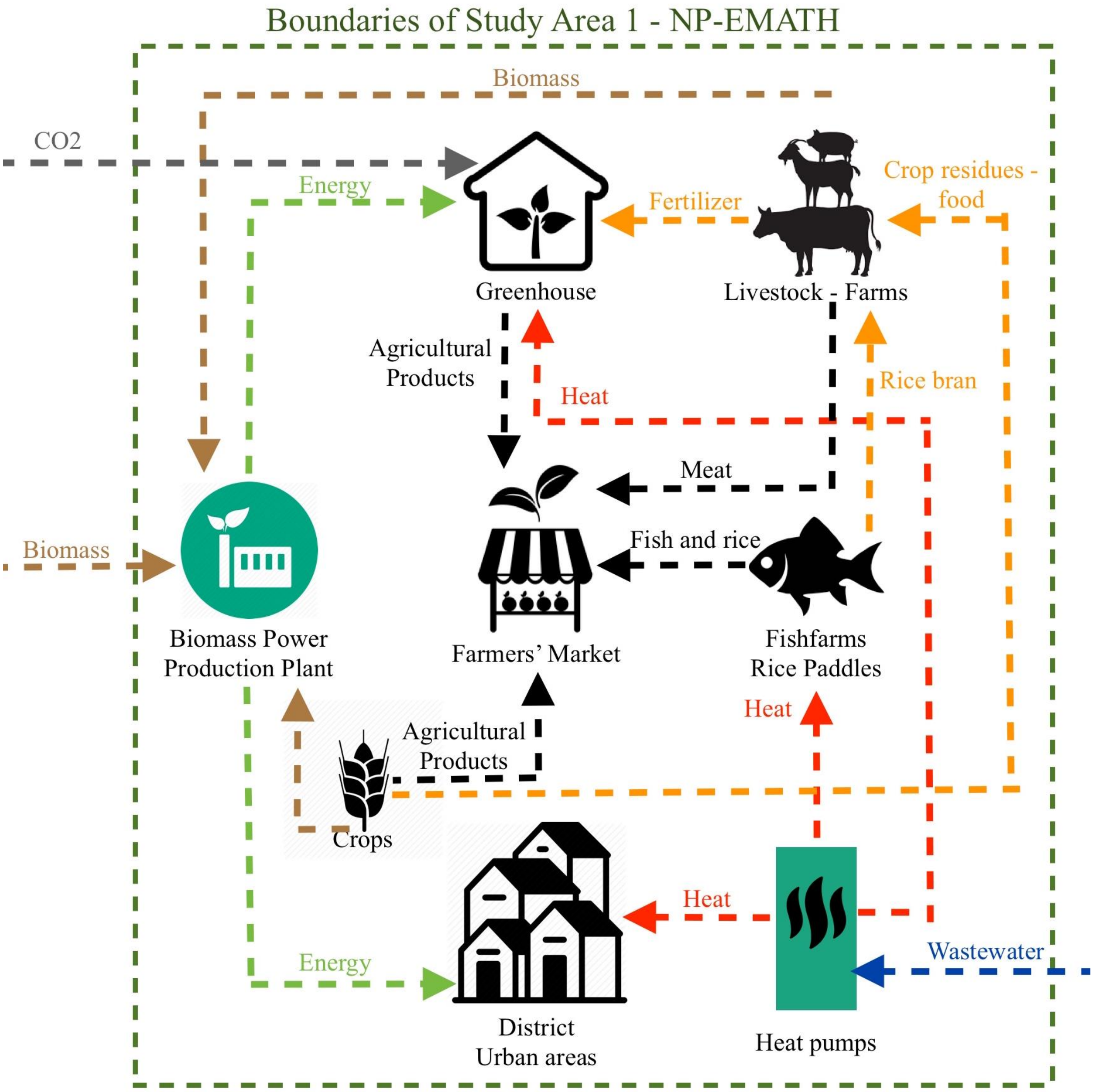


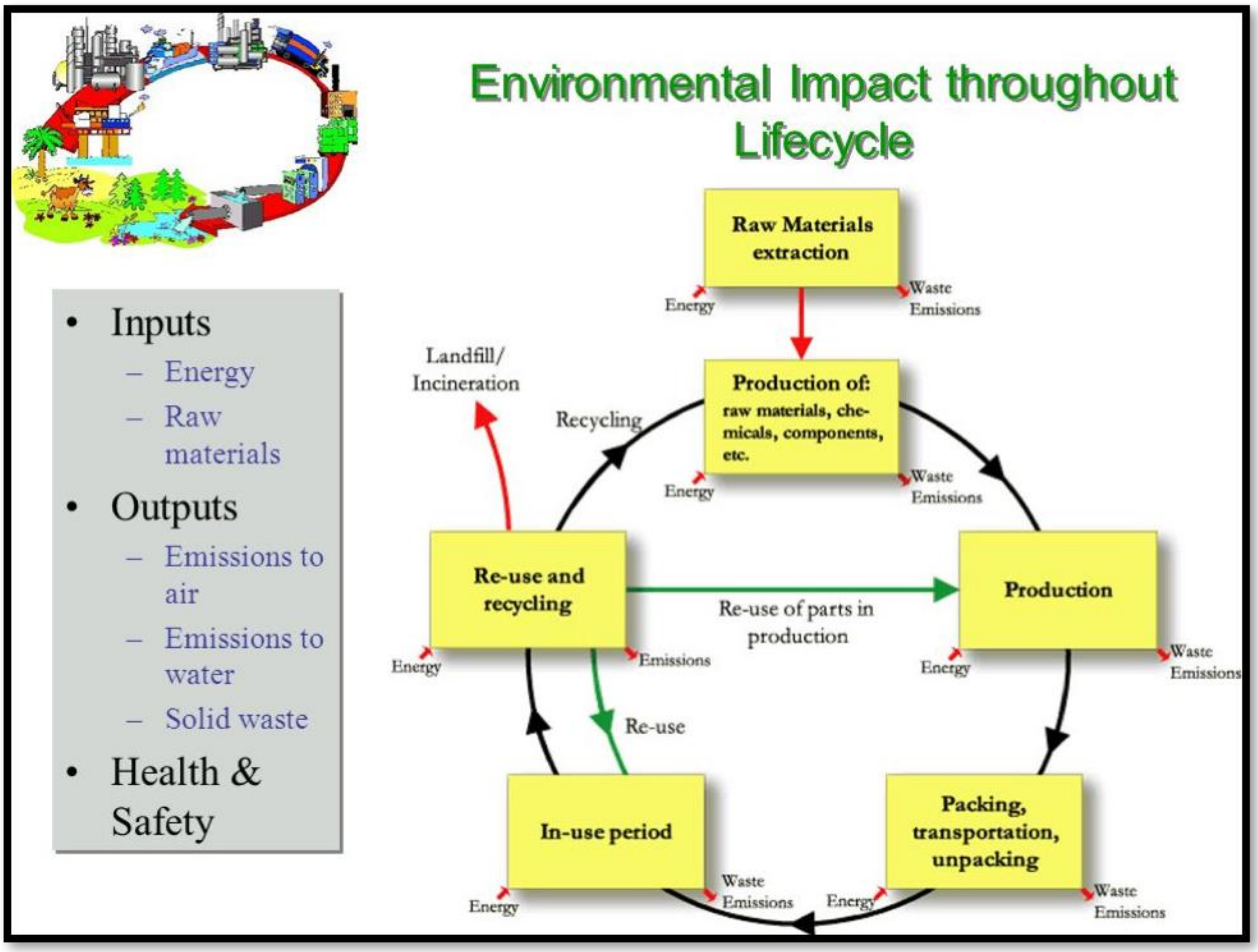
Figure 2-4: Symbiotic activities within the boundaries of Study Area 1

Table 2-1: Environmental benefits from the implementation of the proposed symbiotic activities in Study Area 1.

Proposed Symbiotic Activity		**Environmental Benefits**
CO_2 capture and reuse for the development of local Greenhouse		Reduction of 4.320 tonnes of CO_2
Development of a Biomass Power Production Plant		Reduction of 72.000 – 98.000 tons of oil
Industrial Wastewater for District Heating		Reduction of 86.400 MW of thermal energy from heating oil
Agricultural based symbiotic network	Development of fishfarms/rice puddles	Fertilizer reduction Land use
	Livestock residue utilization	Fertilizer Biomass
	Crop residues utilization	Food for livestock Biomass
	Development of a local farmers' market	Reduced transportation impacts

2.2 Identification of potential symbiotic activities in study area 2

Industrial symbiosis (IS) can be described as waste or byproduct exchange and utility-sharing networks among collocated firms (Chertow 2000). Resource consumption and costs are reduced through utilization of materials that would otherwise be classified as by-products or waste and jointly providing energy, water, and waste treatment services for associated partners (Fig. 2). Most symbioses have self-organized in order to improve economic profits and comply with stricter environmental permit requirements (Chertow 2007), but also some policy instruments can promote their development (Lehtoranta et al.2011). The practical applications of IS include expanding existing symbioses (Chertow 2007), planning new eco-industrial parks (EIPs) (Baas and Huisingh 2008; Gibbs and Deutz 2005; Heeres et al. 2004; Mirata 2004; Van Leeuwen et al. 2003; Veiga and Magrini 2009; Zhang et al. 2010), and even restructuring the whole nation into a circular economy (Geng et al. 2009; Yuan et al. 2006).



Environmental Impact throughout Lifecycle

- Inputs
  - Energy
  - Raw materials
- Outputs
  - Emissions to air
  - Emissions to water
  - Solid waste
- Health & Safety

Figure 2-5: Environmental Impact throughout the Lifecycle (source: slideplayer.com)

2.2.1 List of the existing anthropogenic and industrial activities within Study Area 2

Most of the economic activity in the project area is formed by processing industry (43%), followed by construction (21%) and transport (18%). Mining industry and education have the smallest share.

Table 2-2: Number of economic enterprises in Blagoevgrad municipality by types of economic activities (Struma Business catalogue, 2018)

Area of economic activity	Economically active companies
Forestry and agriculture	65
Extractive industry	6
Healthcare	223
Education	40
Industrial production	467
Construction, Properties	446
Transport, Communications, Automobiles	670
Trade	1974
Services for the population	438
Financial and business services	615
Hotels and restaurants	378
Total	5 322

1. **Hydroenergy Company JSC (HEC)** is the Blagoevgrad company, which “covers the world” with photovoltaics. It deals with the construction of photovoltaic parks and is probably the **most important player** in this sector for **Bulgaria** in general. It is still not very well known in our country. And there's a reason - her successful business is mostly in distant and often exotic-looking destinations like Chile. HEC can boast as a subcontractor for projects in many other parts of the world such as the United States, Jordan, Japan and, of course, Europe. In the future, the company plans to build parks in Mexico, Nigeria and Abu Dhabi. So far **1 528 MW** of **photovoltaic capacity** installed worldwide are made namely by this Blagoevgrad company, and another **232 MW** are currently under construction.

2. **State Enterprise for energy supply** "**Energosnabdyavane**" – Blagoevgrad.
   It is a successor of the Electricity Service in the Municipality of Gorna Dzhumaya (Blagoevgrad), established in 1928. Its successor in 1992 became the "NEC" JSC - branch

"Energosnabdyavane" – Blagoevgrad, for transmission, distribution of electricity; the purchase of electricity from other domestic producers; construction, repair and investment. It is subordinated to the State Agency for Energy and Energy Resources. In 2000 it was transformed into Ltd, branch of "Electricity Distribution - Sofia District". It was privatized in 2005. The owner of 67% of the company's capital since **2005** is the Czech company **CEZ GROUP**.

3. **Plant for mechanical constructions** – Blagoevgrad

   It was created by Order No. 78 of 24 February 1970 of the Committee for Economic Coordination. The plant is part of the State Economic Association "Computing and Organizational Equipment". Its main activity is the manufacture of household appliances, mechanical constructions and since 1990 also of refrigeration products. From 1989 to 1991 it had been an Electronics and Mechanics Plant. By Order No. 19 of 17 September 1991 of the Council of Ministers it was transformed into "Inkoms - Electronics and Mechanics" Ltd. - Blagoevgrad. It was privatized in 1996.

4. **Factory for Measuring Instruments and Appliances** - Blagoevgrad, 1965-1996

   It was created in 1965 with Decision No. 448 of the Council of Industry and Construction at the Council of Ministers. The factory is to State Economic Association "Factory for metal cutting machines" - Sofia with subject of activity - production of mechanical measuring instruments. It was registered in 1991 as Plant for Metal Processing Machines - Ltd. - Blagoevgrad. The company designs, manufactures and implements metal cutting, woodworking machines and measuring instruments and equipment, household goods, services and trade. In 1996 it was transformed into Plant for Measuring Instruments and Appliances "Standart " Ltd – Blagoevgrad

5. **Sole Trading Company "Incoms" - Tooling Equipment and Non-Standard Technological Equipment - Blagoevgrad**, 1980–2001

   It was created by Order No. 1875 of 6 December 1979 of the Ministry of Electronics and Electrical Engineering, as Plant for Tooling Equipment and Non-Standard Technological Equipment. In 1991 it was transformed Sole Trading Company "Incoms" - Tooling Equipment and Non-Standard Technological Equipment - Blagoevgrad. The subject of activity is development, production, service and repair of tooling equipment and non-standard technological equipment for communication equipment; goods and services for the population. Since 1999 becomes a Ltd. Privatized in 2001.

6. **Sole Proprietorship Limited Company "Metalkofrazh"** (Metal formwork) **- Blagoevgrad** 1985-2000

   It has existed since 1 January 1986 on the basis of Order No.RD-14-02-1238 of 18 December 1985, by the Ministry of Construction and Urban Development. The factory for formwork forms, mechanized tools and spare parts is a division of Scientific-Manufacturing Plant "Formwork Equipment" - Plovdiv. The successor of the plant was the State company "Metalkofrazh" established in 1991. The company is engaged in manufacturing and trading of formwork equipment, building materials and metal constructions, equipments and tools. It was transformed in 1992 into Ltd. Owner of the company since 2000 is “Moststroy” JSC – Sofia

7. **Plant for loudspeakers “Grozdan Nikolov”- Blagoevgrad**

   It is established according to Decree of the Council of Ministers No 116 of May 5, 1960, on the development of low-voltage electric power industry. The scope of activity is research, implementation and production of loudspeakers, speakers and systems, provision of household goods, trade in the country and abroad. In 1997 it was transformed into JSC "Loudspeakers" – Blagoevgrad. The plant is among the few that survived the wave of bankrupts caused by unsuccessful and thief-privatization. At the present moment it works at a good scale and continues to sell and export its production within the country and abroad.

8. **Timber industry, wood processing and furniture industry**

   Firms engaged in logging and wood-harvesting, work mainly for export (mostly for Greece and Macedonia). Wood and furniture enterprises have almost equal share in the local industry. Two of them are large, with about 300 workers. These companies provide work as subcontractors for the smaller ones in this sector.

9. **The textile and clothing industry** is **among the main and best developed** industrial sectors in Blagoevgrad Municipality. There are small, medium-sized and large companies, that work in this sector.

Leading companies, which are **big companies** within the meaning of the Law on Small and Medium-Sized Enterprises are: **“Strumateks” JSC**, **“Struma style” Ltd**, **“Prima” Ltd**, **Labor-Productive Cooperatives “TPK Rila” and "TPK Nov sviat".** The ownership of a significant number of enterprises is foreign, mainly Greek. They produce cotton yarns and fabrics, workwear and uniforms, ladies' and men's apparel, knitwear.

Medium-sized companies in the sector are: **"Valentina-Strumyana" JSC, "Milena" JSC, "Ledian" Ltd (which works mainly for the French market), "Vamos" Ltd, "Vyor-Antonov" Ltd, "Asparuh 91" Ltd**, and others. Their activity is mainly focused on the production of textile garments.

10. Brewing industry

State brewery "Pirinsko pivo" – Blagoevgrad

It was established by Decision No. 131 of 30 March 1967 of the Council of Ministers as a State Enterprise for bottling and trade in beer at DSO "Balgarsko Pivo". Since 1997 it has been transformed into "Pirinsko pivo" JSC. **Carlsberg Bulgaria JSC** (the owner of the **“Pirinsko”** brand) is the other major structuring company in the food and beverage industry. The production capacities of the “Pirinsko Pivo” plant, founded in 1967, are now part of the Carlsberg Group. Pirinsko pivo was acquired by the Danish company in 2003 and today it is emerging as the fastest growing company in the brewing industry, which ranks second in market share in beers. In 2006, modernization investments amounting to **BGN 20 million** were made at the plant. Approximately **300** people are employed in the production.

11. Production and processing of meat

The main enterprise in the industry is **"Karol Fernandez Meat" Ltd.** (KFM Ltd.), which employs nearly 130 workers and has realized investment in production for EUR 1 million (provided by the SAPARD program). Smaller companies in the sector are **"Interxim" Ltd** and **"Difil" Ltd**.

12. Wine and spirits

Several wineries are operating in the municipality of Blagoevgrad, including **“Vinprom Logodazh”, “Vini Bozhkilov”, “Vinprom Gorna Dzhumaya” Ltd, “Vinprom Taskov Distillers and Wine – Wintasproject” Ltd, “Vinex Commerce” Ltd.**, most of which are also for exporting their production abroad.

13. Tobacco industry

The main enterprise in this branch is **“Blagoevgrad-BT” JSC**, which is the **biggest** and the most modern tobacco factory in Bulgaria. The factory employs about **2000 workers** and is one of the largest employers in the municipality. The company produces nearly **half** of the cigarettes destined for the Bulgarian market. After the modernization of the plant in 1994, its capacity reaches **13-14 billion cigarettes** per year.

2.2.2 Proposed symbiotic activities based on the existing anthropogenic and industrial activities

Based on the information disclosed in the previous chapters he proposed symbiotic activities should affect positively the following three categories of the socio-environmental system in the project territory:

1. Economy: Minimizing costs and improved bottom line and competitive edge

2. Environment: Resource efficiency through reuse, recycling, and reduced intake of virgin materials

3. Innovation and development: Improved introduction and access to new technologies and R&D, job creation and regional development

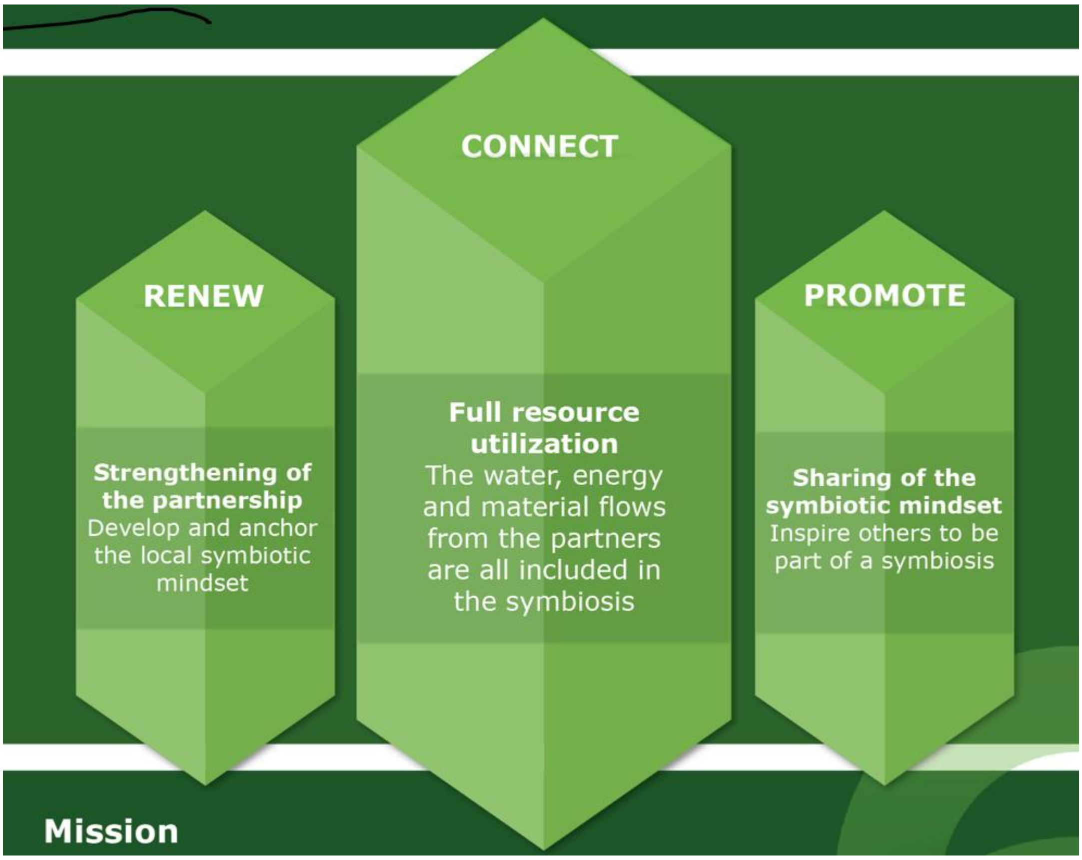


Figure 2-6: Principle scheme of symbiotic activity

The catchment area of Blagoevgradska Bistritza is a well define geographically area where due to the small territory the transport expenses to acquire the needed resources and to deliver the

production to the consumers are relatively small. Because of this the project area 2 and especially the catchment area of Blagoevgradska Bistrica is suitable for establishment of eco-industrial parks with well-developed symbiotic connections between the enterprises inside it.
In the area are possible the following symbiotic activities:

1. Waste-to-Energy Options in municipal Solid Waste Management

Inside the catchment area of Blagoevgradska Bistrica river is situated the town of Blagoevgrad which is home of more than 60000 people. These constant leaving population is source of tremendous amounts of solid and organic waste which are disposed in open landfill dump site. The landfill site is operated by the municipality of Blagoevgrad with total population of 77440 people and this technology for waste treatment is a source of considerable quantities of Methane (CH4) and other green house gasses (Table.1.).

Table 2-3: Methane generated from waste landfill site in Blagoevgrad municipality

Municipality	Population	Waste generation rate kg/person/day	Total waste generated T/Year	CH4 generated kg/year per citizen	CH4 emissions t/year
Blagoevgrad	77440	1.21	33 945	17.52	1356

The key parameter in the determination of the total methane emissions from the landfills, is the value of the degradable organic carbon and it directly depends on the different fractions of waste that is being disposed on the landfills. The values of these fractions are taken from the revised IPCC guidebooks, whereby this value is calculated and it is equal to 19,23%. The methane emissions in one year are calculated according to the equation: CH4 emitted in the year (kt/year) = [CH4 generated in the year – R(ton)] •(1-OX) Where: R – methane that has been reused, OX – oxidation factor. In these calculations, R and OX are taken with a value of 0.

Methane emissions from the waste generated in Blagoevgrad municipality have energy value of 74 580 000 Mj (heat value of methane is 50-55 Mj/kg - source: www.world-nuclear.org) which is equal to the energy stored in 3120 tons of coal (1 kg of coal can produce around 2 Kwh electricity – source: www.quora.com). Based on this calculation the methane emitted in the air can produce 6 240 000 Kwh electricity or 6240 Mwh. This amount can directly affect the carbon footprint of the project area because this will lower the footprint with 51110,56 T CO2/MWhe.

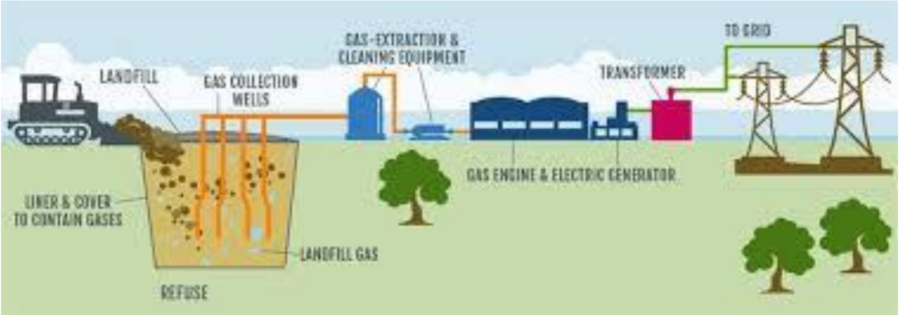


Figure 2-7: Components of landfill gas capturing system with electricity production (source: www.giz.de)

2. Waste water to Agriculture - Options in municipal Waste Water Management

The municipality of Blagoevgrad operate a residential and commercial waste water treatment facility. During the process of purification of the waste water a substantial amount of sludge are generated this waste product can have a secondary use as a fertilizer that can be used in the agricultural sector for improving the plant growing results. The produced agricultural crops then are used for feeding base for the animal sector which biological waste can be used for producing bio-gas and electricity.

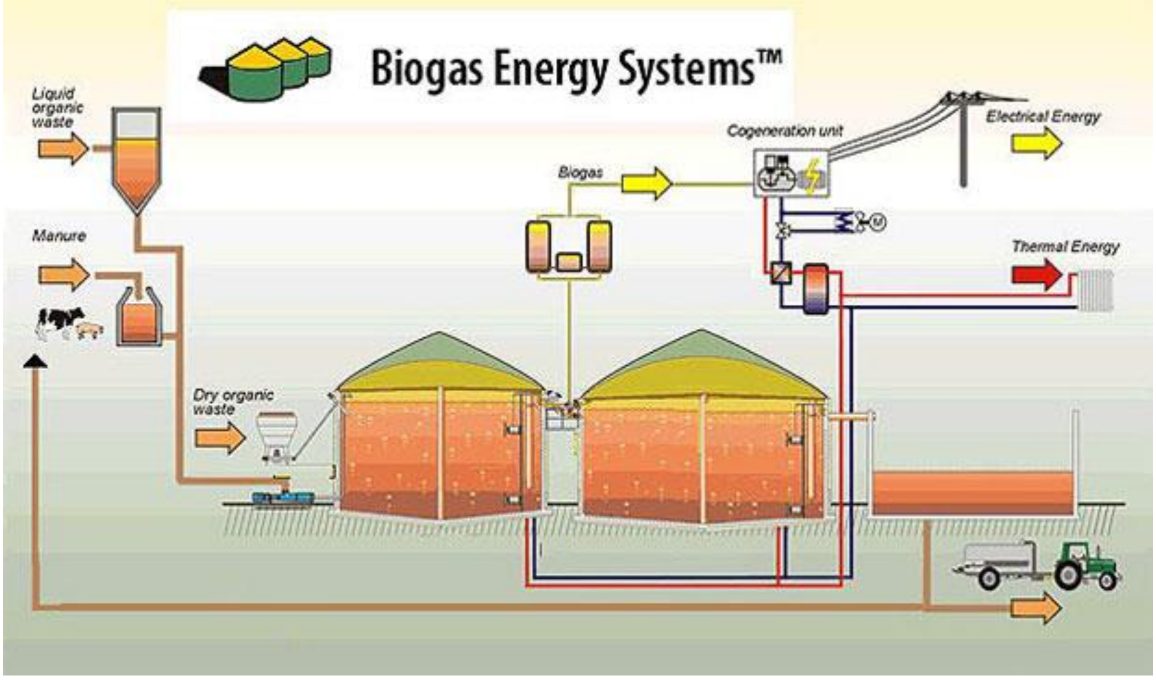


Figure 2-8. The biogas production system with liquid organic wastes and animal manure (source: www.integratedenergyindustries.com)

Table 2-4: Methane emissions from manure management in Blagoevgrad municipality

Type of animal	Emission factor for manure management	Number of animals	Methane emissions from manure management
Unit	kg/head/y	No.	(tons/y)
Dairy cattle Cows	15	n/a	
Cattle that does not produce milk	8	3639	29.11
Sheep	0.19	7113	1.4
Goats	0.13	2632	0.34
Horses	1.56	76	0.1
Mules and donkeys	0.76	n/a	n/a
Pigs	3	388	1.2
Poultry	0.03	n/a	n/a
		Total emmisions:	32,15

Methane emissions from manure management in Blagoevgrad municipality have energy value of 1768250 Mj (heat value of methane is 50-55 Mj/kg - source: www.world-nuclear.org) which is equal to the energy stored in 74 tons of coal (1 kg of coal can produce around 2 Kwh electricity – source: www.quora.com). Based on this calculation the methane emitted in the air from the manure can produce 148000 Kwh electricity or 148 Mwh. This amount can directly affect the carbon footprint of the project area because this will lower the footprint with 121,21 T CO2/MWhe.

3. Forestry - Timber production - Producing Furniture – Wood pallets

The total area covered by forest in the territorial scope of project area 2, but outside the boundaries of Rila National Park is 12 648 ha .

Table 2-5: Statistical data on the area of the forest fund and its distribution by type of territory in the catchment area of Blagoevgrad Bistritsa river in ha

Forestry section	Total area	Wood-productive area			Non-wood-productive area
		Wooded area	Barrens	Total	
1	2	3	4	5	6
„Dobro pole“	5829.3	5467.5	205.6	5673.1	156.2
„Blagoevgrad“	7309.2	6846.8	128.3	6975.1	334.1
Total	13138.5	12314.3	333.9	12648.2	490.3

The area of forests in the catchment area of Blagoevgrad Bistritsa river, which are managed by Blagoevgrad state forestry is 12 314.3 ha (97.4% of the wood-producing area). The two forest sections differ in area by 1 379.3 ha (20.1%), despite almost double the larger geographical area on the left bank of the Blagoevgrad Bistritsa river. The reason for this is the large fragmentation of the forest cover with agricultural areas - fields, meadows, pastures, etc.

The wooded area in the catchment of the Blagoevgrad Bistritsa river is divided into forests with economic functions and forests with protective and special functions. Their ratio is respectively 4 272.1 ha (34.7%) compared to 8 042.2 ha (65.3%). The proportion of forests with a limited degree of use is almost twice as large and this ensures good prospects for the development of forest ecosystems. The reason for this increase is the introduction of new protected forests and the inclusion of large areas in NATURA 2000 protected areas under the Protected Areas Act.

The main economic activity, generally in the forests as well as in the survey area, is tree felling for the extraction of firewood materials (also called primarily use). The distribution of the planned by project wood mass for felling (without branches) during the decade in the catchment area of Blagoevgrad Bistritsa river is indicated in Table 4. The total quantity envisaged represents 10.6% of the total stock - 2 289 662 cubic meters.

Table 2-6: Scheduled ten-year use by types of felling in the catchment area of Blagoevgrad Bistritsa river in cubic meters (Blagoevgrad state forestry, 2011)

Types of felling	"Dobro Pole" forestry section	"Blagoevgrad" forestry section	Total
Renewal	19825	36370	56195
Cultivating	101890	83860	185750
Sanitary	680	-	680
Total	**122395**	**120230**	**242625**

At the last inventory (2015) on the territory of Rila National Park the measured area of the forest fund is 56 005.5 ha. This makes a share of the total area (78 040.6 ha) of the National Park amounting to 71.76%. Large part of this area falls into four reserves – Parangalitsa, Central Rila Reserve, Skakavitsa and Ibar, which are protected areas with a strict security regime. Their total area is 16 232.5 ha, of which 9 825.8 ha are wooded area with a wood stock of 1 122 115 cubic meters. Despite the big inventory of forest in the Rila National Park their economical use is limited because of the legislation restrictions and strict regime of protection.

Based on the information disclosed above the research area possess substantial resources for development of timber industry which can have a symbiotic relation with the furniture producing companies and production facilities for wooden pallets. The last can use the waste products of the timber and furniture industry and can be used for heating of commercial or private properties reducing the use of electricity and carbon fuels that purposes. The heating systems on wood pallets are much more efficient than these that used wood or coals. Because of that the use of that the use of pellets for heating will have a direct impact on the carbon footprint and on the quality of the breathing air in town of Blagoevgrad. The air quality in the town of Blagoevgrad due to the geographical position and the broad use of coal and wood for heating in the winter months despite the proximity of Rila National Park is very poor. Often the town of Blagoevgrad during the winter months is on the leading position in the chart of the leaving places with bad quality of the breathing air.

2.2.3 Principal scheme of the symbiotic activities in the catchment area of Blagoevgradska Bistrica catchment area

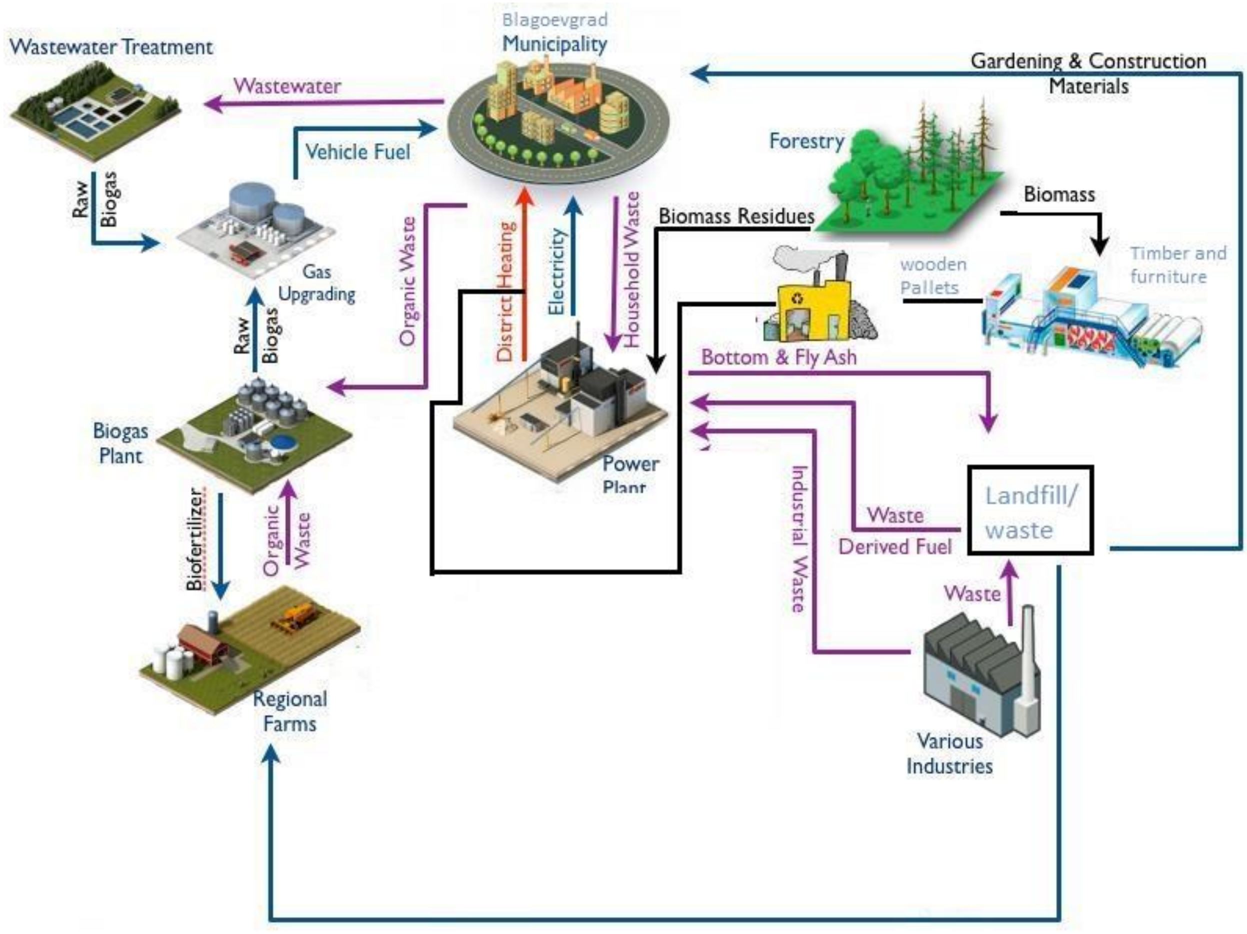


Figure 2-9: Proposed symbiotic activities in Project area 2

In the territorial scope of the project area in Bulgaria there are no big industrial enterprises that can be group in a single eco industrial park. However, there are suitable conditions to combine the existing social and commercial entities in symbiotic relations. These relations are mainly associated with the waste management of solid and organic waste disposed at the landfill site and the bio- waste products from the agriculture sector. At the moment there is a new landfill site under construction in the municipality of Blagoevgrad that will be operational soon. This site contains an installation for landfill gas which can be used for production of heat or electricity.

The bio-waste from the agriculture also can be used in biogas plant for production of bio-gas and subsequent use of this gas for energy production. This can be profitable enterprise, because the energy produced by bio-gas is heavily subsidize on national level.

Rila National Park is a territory with high level of protection and any economic activity is prohibited in side the park except the tourist visits. That is why the possibilities to develop strong symbiotic relations between anthropogenic activities are very limited. But beside this limited use of the natural resource of the park their substantial loss of wood biomass in the park due to natural or main made activities expected loss for 12-year period is 302 744 m^3 and more over the planned wood extraction for the sanitary maintenance activities in the forest areas of Rila National Park for the period 2005-2015 are 46568 m^3. The primary use of this wood mass is for heat generation by wood burning in private houses which has a catastrophic effect on the air quality in the winter months. Because of that a better management of these resource is required and they can be redirected for use in the timber and furniture industries and the produced waste can be used for production of wooden pallets. The heating installations that work on pallets are much more effective than the one that used burning wood mass and they also generate far less waste and air pollution.

2.2.4 Conclusions

At present, Blagoevgrad is in a transition period from a classic industrial center with local and regional importance to a modern economic center of innovative and educational initiatives. At this stage a number of classical industrial branches in the city are in decline and suffer a greatly reduced number of employees, or completely closed. Because of that the territory of the catchment area of Blagoevgrdska Bistritza River is suitable for establishment of new enterprises grouped in eco-industrial Park with strong symbiotic relations between them. These symbiotic activities that are based on the life cycle approach must take in consideration the social and natural resources that are available in the area in order to sustain the balance between planned anthropogenic activities and the preservation of the natural eco-systems. Research centers established and funded under the initiative of South-West University "Neofit Rilski" and the American University in Bulgaria that operating in the city can be used for scientific accelerator to achieve a sustainable development of the area.

As a result of these processes, Blagoevgrad will increasingly become the center of scientific, research and development activities which combinned with the strategic geographic location and proximity of the Rila Natural Park will continue to have a strong impact on the structure and the sustainability of the local economy.

The proposed local symbiotic activities are the first stage of a broader process which final result will be establishment of cross-border eco industrial clusters with the neighboring Republic of North Macedonia and the Republic of Greece.

2.3 Identified symbiotic activities and their impacts on biodiversity

2.3.1 Study Area 1

Biodiversity throughout the world is decreasing and our increasing needs for food and energy are the main causes. From bees that pollinate our crops, to forests and wetlands that contain flood waters, people degrade biodiversity elements that support our societies and overturn the balances that regulate life. The five factors of change with the greatest global impact are, in descending order: land use changes, species exploitation, climate change, pollution and invasive alien species.

As described in the previous chapters, the National Park of Eastern Macedonia and Thrace (NP-EMATH), is a designated area under a multitude of protection instruments. It is a large Delta and consists of agricultural land with few freshwater lagoons separated from the sea by narrow sandy strips. Only a relict area of the previously extended riverine forest (Kotza Orman wood) remains along the river course near the river mouth and the poplar plantation. Another important habitat type except the above, is reeds along the river beds and especially those along the canals. Most of the area of Nestos river is embanked by retaining dykes so that to be separated from the cultivated land. The Keramoti lagoons are a complex of coastal saltwater lagoons, situated at the western extreme of Nestos Delta in the west of Keramoti town. The most important habitat types are large coastal dunes, saltmarshes, reed beds, and especially beds of marine vegetation-communities of vascular plants (Zostera, Posidonia e.t.c.). Its designation status according to Greek legislation is differentiated according to a zoning system. It is a Ramsar wetland, occupying a large area rich in habitats. It is a valuable part of a wetland chain included between Axios river and Delta of Evros of north Greece. From the point of fish, the wider part of the river mouth is important spawning and nursery ground for several commercially, intensively used species (Seabream, Seabass, Mullet, Eel, e.t.c.). Keramotis lagoons is an important site from ornithological and ichthyological point of view. Some heron colonies are also found there. An important site for breeding, passage and wintering waterbirds, raptors and passerines associated with reed-beds.

The implementation of circular economy and industrial symbiosis practices for this study area is considered a desirable step towards a more sustainable production and consumption behavior. In this context, biodiversity components should always be taken into consideration when practices, that may have environmental, economic and social impacts are proposed and further planned.

With regard to CO2 capture and reuse for the development of local greenhouse, a critical component that has to be taken into consideration, with regard to biodiversity impacts, is the location of the proposed greenhouses; a designated agricultural area seems to be compatible with the nature of the proposed development, whereas, natural and semi-natural habitats have to be avoided. Moreover, circular economy principles have to be adopted in order to minimize waste production, and impact on water bodies of significance.

With regard to a symbiotic scenario, a biomass power plant can be constructed; it could be fed by biomass produced from the agricultural sector and provide energy back to the energy sector, in order to achieve a relative energy autonomy. However, it is noted that a power plant, although environmental friendly, in the sense that it is fed by biomass, is still an industrial plant and as such, it’s siting need to be carefully selected. Organized and designated industrial areas seem to suit for these types of power plants.

With regard to the reuse of industrial waste water for heating, it is a classic example of a symbiotic relationship within an industrial symbiosis. This move is an economically and attractive alternative and helps saving a significant commodity, water, for future generations. Economic use further reduces the amount of wastewater diverted to treatment facilities and further reduces the cost of treatment. Wastewater industries are investing in wastewater treatment and re-use not only to comply with environmental wastewater disposal limits, but also because product recycling and raw material recovery can multiply the benefits of a business. This seems to improve the quality of life for residents of towns in the surrounding area of the national park, if located appropriately, at the residential districts.

Furthermore, the identification and planning of an agricultural symbiotic network, seems to promote circular economy principles and reduce, in theory, wastes and impacts on biodiversity. With regard to fish farms, since lagoons are considered a priority habitat of European interest, an extra careful consideration on biodiversity impacts should be given, when further planning for this activity.

In general, and as a conclusion, symbiotic activities must take in consideration the social and natural resources of the study area, in order to sustain the balance between planned anthropogenic activities and the preservation of biodiversity and natural ecosystems.

2.3.2 Study area 2

A number of economic activities take place in the wider area. Most of the economic activity is formed by processing industry (43%), followed by construction (21%) and transport (18%). Mining industry and education have the smallest share. An extensive list is given in chapter 2.2.1. With regard to the environmental criteria for the identification of symbiotic activities, these are resource efficiency through reuse, recycling, and reduced intake of raw materials. In principle, there may be opportunities to combine existing social and commercial entities in symbiotic relations. These relations are mainly associated with the waste management of solid and organic waste disposed at the landfill site and the bio- waste products from the agriculture sector.

In Rila National Park is a territory with high level of protection and any economic activity is prohibited inside the park except the tourist visits. That is why the possibilities to develop strong symbiotic relations between anthropogenic activities are very limited. With regard to forest logging, a better management can be redirected for use in the timber and furniture industries and the produced waste can be used for production of wooden pallets.

In general, and as a conclusion, symbiotic activities must take in consideration social and natural resources of the study area, in order to sustain the balance between planned anthropogenic activities and the preservation of biodiversity and natural ecosystems.

Chapter 3 - Life Cycle Assessment of the existing situation

3.1 LCA inventory for study area 1

As already mentioned in Section 1.5, to develop a LCA model, it is necessary to collect data for each material and process within the system boundaries. The data needed is a combination of inputs and outputs in each process included within the system boundaries. Data collection is the most resource and time-consuming stage in an LCA. In this case relevant data have been extracted from Deliverables 3.1 and 3.3 of WP3 of the Project BIO2CARE (also available in the site of the Project (www.bio2care.eu). Before presenting the data needed to perform the LCA of the protected areas, it is necessary to clarify a number of key assumptions adopted for the implementation:

Definition of the objectives (Goal): The goal of the specific LCA is to examine the environmental impact of current anthropogenic activities within the boundaries of Study Area 1 (GR), with a view to compare it with future symbiotic activities under the circular economy framework.
Functional Unit: The functional unit set is the satisfaction of the energy needs (serving as a key indicator of anthropogenic activity in the area) of the residents and visitors of Study Area 1 for one year.
Boundaries of the system under examination (Scope):
Setting the boundaries of the system determines which processes should be included in the LCA study. In this case a variety of anthropogenic activities within the boundaries of study areas (as described in D3.1) in GR and BG will be included in the LCA. Taking into account: a) that one of the key goals of EU and National Policies and Strategies is the reduction of GHG emissions and energy efficiency, b) the fact that impacts related to land use and product consumption have been extensively analysed and can be assessed using the methodological framework developed in Del. 3.2 of WP3 (Carrying Capacity and Ecological Footprint Estimation), LCA model will focus on the energy needs of the residents and visitors of Study Area 1. Under this framework, the boundaries of the study will include: a) energy consumption of building sector including the analytical energy consumption per energy source (electricity, heating oil) in residential buildings and tertiary buildings (incl. offices/commercial, hotels, schools, health care buildings), b) energy consumption of transportation sector (incl. air transportation, highway/National/local roads, , transportation by ship/train) and c) energy consumption of public lighting and tourism. This approach will also enable the comparison of the results with similar carbon footprint assessment frameworks like the Covenant of Mayors Initiative to develop relevant Sustainable Energy Action Plans. Serving the above mentioned goals and scope, the following data have been identified that need to be quantified to develop the LCA model for Study Area 1.

Households

	Value	Unit
Total electricity consumption	41,187,497	kWh
Total heating oil consumption	140,771,259	kWh

Tertiary Buildings

	Value	Unit
Total electricity consumption	27,889,270	kWh
Total heating oil consumption	39,453,936	kWh

Municipal Buildings

	Value	Unit
Total electricity consumption	2,902,548	kWh
Total heating oil consumption	5,818,704	kWh

Public Lighting

	Value	Unit
Total electricity consumption	2,866,590	kWh

Transportation *(in this case consumption of energy is estimated indirectly based on the available LCA modules)*

	Value	Unit
Private Transportation		
Operation of scooters	31,485,000	km
Operation of heavy duty vehicles	35,540,764	km
Operation of passenger cars (diesel)	19,179,543	km
Operation of passenger cars (petrol)	93,641,299	km
Public Transportation		
Operation of scooters	52,500	km
Operation of heavy duty vehicles	937,500	km
Operation of passenger cars (diesel)	91,800	km
Operation of passenger cars (petrol)	448,200	km
Operation of buses	924,662	km
Operation of regional train	1,533,000	personkm
Operation of small ships	2,152,673	tkm
Operation of large ships/tankers	358,730	tkm
Operation of passenger aircraft	4,851,199	personkm
Operation of freight aircraft	7,260	tkm

Tourism

	Value	Unit
Total electricity consumption	5,977,360	kWh
Total heating oil consumption	7,609,920	kWh

3.2 LCA inventory for study area 2

The life cycle inventory analysis step consists of itemizing all inputs (materials and energy resources) and outputs (emissions and wastes to the environment) to and from the product system or process undergoing study (Zaimes G., V. Khanna, 2015). Input and output data are collected and documented for each process contained in the system boundary, including flows of raw materials, energy, products, co-products, wastes, and emissions to air, soil, and water (Zaimes G., V. Khanna, 2015). For that purpose, the real situation has to be translated into a model so that the assessed parameters can be quantified in the most realistic way, taking the defined frame conditions into consideration (Wulf C., K. Kaltschmitt). Data collection can be particularly time-intensive and resource-intensive because it must include all upstream processes (resources extraction, production, and transport) as well as downstream processes (product use and disposal) (Zaimes G., V. Khanna, 2015). Once the data are compiled, aggregate resource use and pollutant emissions can be calculated to determine environmental loads and material/energy flows per functional unit.

To reduce the complexity of this assessment and to allow the inventory analysis to be handled within the given time constraints, the real situation has to be translated into a model so that the assessed parameters can be quantified in the most realistic way. Based on the defined frame conditions into the process chain is traced back only to the point that the neglecting of additional chain components would lead to a mistake within the overall result of a maximum of a defined percentage (Zaimes G., V. Khanna, 2015).

The life cycle inventory analysis consists of itemizing all inputs as materials, energy and resources and outputs as emissions and wastes to the environment and it is build based on the methodological framework and the date from del. 3.3.

The main object of the BIO2CARE project is to reinforce the capacity of the protected areas based on new methodology that examine the energy balance of the protected areas. This energy driven approach convert in comparable units (Gha), what is consumed as materials, goods and energy inside the project area and the available bio resources (bio capacity). The Bulgarian part of the project area is complex conglomerate of Rila National Park and the catchment area of Blagoevgradska Bistritza River. In the first due to the high level of protection economic activity different from walking tourism is prohibited, but in the second one the anthropogenic load is much more complex and there are variety of industries and large number of permanent living population inside it. Usually the LCA models are product oriented and they calculate the environmental impact on every stage of the live cycle of the single product. Although, the LCA refer the life span from extracting the materials, production and disposal of the single product in some cases, to prepare the Life Cycle Inventory can be a challenging job due to the large number of materials that can be used in a single product. On Figure 3-1 is shown the complicity of the conceptual model of LCI for a product.

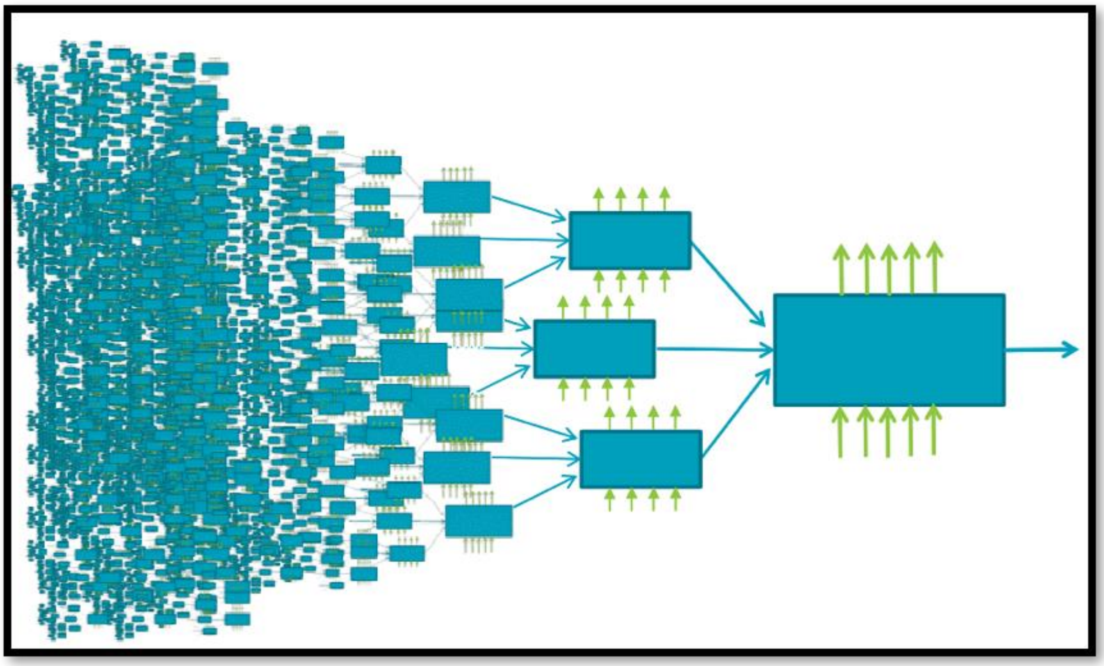


Figure 3-1: Life Cycle Inventory (after Lesage P., 2015)

It was stated above that even though the Rila National Park is a territory with limited anthropogenic load, in the catchment area of Blagoevgradska Bistritza River are situated numerous industries with different type of production and to build a product based life cycle inventory for the Bulgarian part of the project area are complex and even impossible task. Because of that a different approach is needed to build a life cycle inventories for an area or defined territory based on consumption or community approach.

At Figure 3-2 is represent the general model for LCA of product system which can be modified for Life Cycle Inventories based on community approach as it is represented on Figure 3-3.

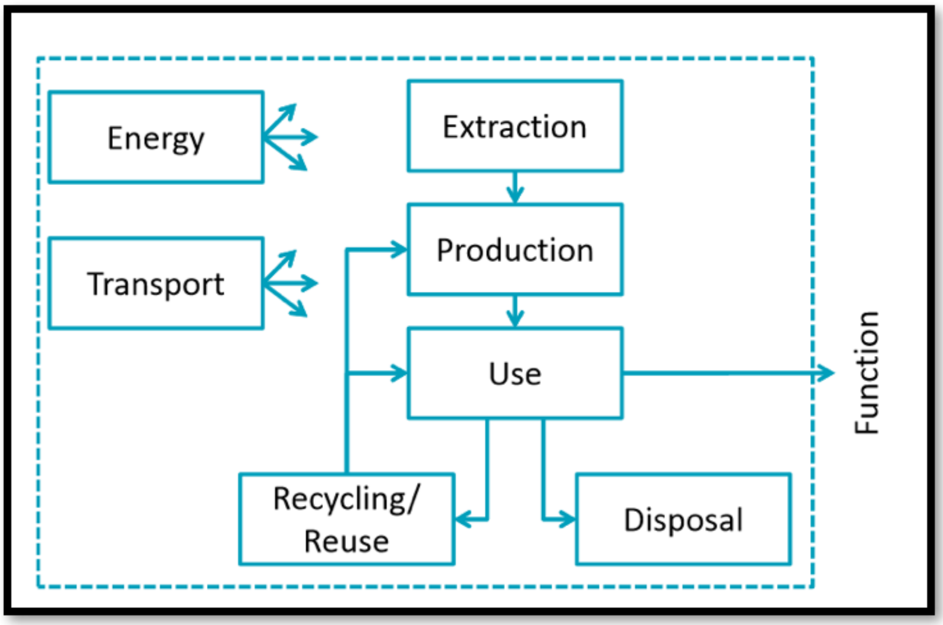


Figure 3-2: General model for product system (after Lesage P., 2015)

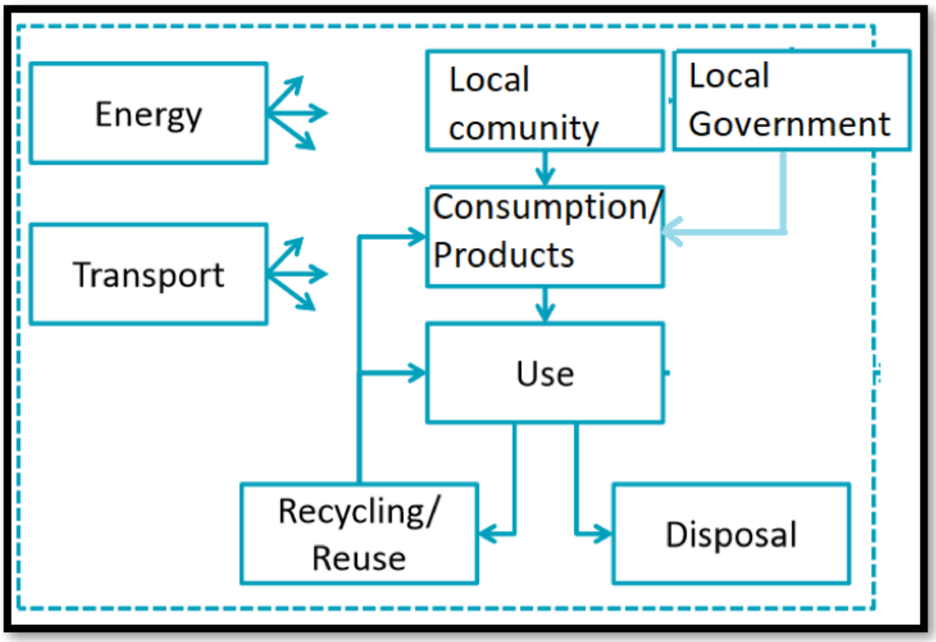


Figure 3-3: General model of LCI for geographically defined area.

As in the case of Study Area 1, before presenting the data needed to perform the LCA, it is necessary to clarify a number of key assumptions adopted for the implementation:

Definition of the objectives (Goal): The goal of the specific LCA is to examine the environmental impact of current anthropogenic activities within the boundaries of Study Area 2 (BG), with a view to compare it with future symbiotic activities under the circular economy framework.

Functional Unit: The functional unit set is the satisfaction of the energy needs (serving as a key indicator of anthropogenic activity in the area) of the residents and visitors of Study Area 2 for one year.

Boundaries of the system under examination (Scope): An attempt was made to develop the LCA model with a view to be as much comparable as possible between the two study areas. Due to the complexity of the in-flow and out-flow materials in the territorial scope of the Bulgarian side of the project area, the only reliable balance that can be made is the one that regards the electricity and fuel use. Obviously due to the disproportional anthropogenic load in the Rila National Park and the catchment area of Blagoevgradska Bistritza River the majority of that consumption is distributed in the last. The following data have been identified that need to be quantified to develop the LCA model for Study Area 1.

Households

	Value	Unit
Total electricity consumption	7,438,607	kWh
Total heating oil consumption	23,614,450	kWh

The data about the electricity consumption in the household and tertiary sector are generalized due to the lack of accurate information. Because of that this inventory line cannot be divided in more sub-inventory lines except on electricity consumption and thermal energy consumption.

Tertiary Buildings

	Value	Unit
Total electricity consumption	57,194,847	kWh
Total heating oil consumption	80,927,154	kWh

Municipal Buildings

	Value	Unit
Total electricity consumption	325,534	kWh
Total heating oil consumption	819,252	kWh

Due to the anthropogenic load the main contributor to this inventory line is the catchment area of Blagoevgradska Bistritza River and especially the town of Blagoevgrad. Even though the municipality of Blagoevgrad implemented couple of projects that regards the use of more energy efficient light bulbs still great amount of electricity is used for public lightening.

Public Lighting

	Value	Unit
Total electricity consumption	1,000,000	kWh

Depending on its anthropogenic load and its transport absorption and accessibility, the conditional catchment of Blagoevgrad Bistritsa can be divided into three zones:

The first zone covers the lower part of the catchment area of Blagoevgrad Bistritsa with the river Struma. It is best transported due to the character of the relief. There is a valley extension, where the district and municipal center of Blagoevgrad is located with the districts Strumsko, Izgrev, Elenovo and the village of Byalo pole. There is a connection between them via asphalted roads and streets, as well as through the railway line on which there is one station in Blagoevgrad and 2 stops in Byalo pole and Strumsko. Here, the density of road infrastructure is the highest and the communication with the water basin is realized from here. This area is also the most anthropogenic. The transport service of the municipality is presented in table № 1 according to the category of road from the national road network, presence of a railway station, stop and border checkpoints.

There are no data about the distribution of the transport activity along the three zones because of that it is presented on two combine tables. The first one represent the km passed by the private transport vehicles and the second one the km passed by the different types of public transport.

Transportation *(in this case consumption of energy is estimated indirectly based on the available LCA modules)*

	Value	Unit
Private Transportation		
Operation of scooters	-	km
Operation of heavy duty vehicles	163,761,260	km
Operation of passenger cars (diesel)	193,783,800	km
Operation of passenger cars (petrol)	256,876,200	km
Public Transportation		
Operation of scooters	-	km
Operation of heavy duty vehicles	-	km
Operation of passenger cars (diesel)	1,542,427	km

Operation of passenger cars (petrol)	2,044,613	km
Operation of buses	286,200	km
Operation of regional train	-	personkm
Operation of small ships	-	tkm
Operation of large ships/tankers	-	tkm
Operation of passenger aircraft	-	personkm
Operation of freight aircraft	-	tkm

Tourism

	Value	Unit
Total electricity consumption	3,538,946	kWh
Total heating oil consumption	4,676,790	kWh

Inside the catchment area of Blagoevgradska Bistrica river is situated the town of Blagoevgrad which is home of 69589 people. This constant leaving population is source of tremendous amounts of solid and organic waste which are disposed in open landfill dump site. The landfill site is operated by the municipality of Blagoevgrad with total population of 77440 people and this technology for waste treatment is a source of considerable quantities of Methane (CH_4) and other greenhouse gasses.

Study Area 2 (BG) represents a complex conglomerate of two different types of territories - Rila National Park and the catchment area of Blagoevgradska Bistritza River. The first one is a territory with high protection, very limited economic activity and no constantly living population inside it. The second one opposite to the first one possess high anthropogenic load and it is home of more than 69000 people. Generally, the life cycle inventory analysis consists of itemizing all materials and energy resources and emissions and wastes to the environment to and from the product system or process. Due to the complexity of the in-flow and out-flow materials in the project area Life Cycle Inventory analyze of that territory is a complex and challenging task which due to the lack of reliable information is restricted only to the used fuel, electricity, thermal energy and the deposited waste.

3.3 LCA Model

LCA methodology is based on the creation of a model, which is developed by the user trying to describe a system as realistically as possible. In this case, the model was developed following the four distinct steps and specifications of ISO 14040 described in Section 1.4 and by utilizing the SimaPro LCA software (Professional Version). The model was built upon seven main general assemblies – categories (in accordance with Deliverable 3.2): Households, Tertiary Buildings, Municipal Buildings, Public Lighting, Transportation (separated in Private and Public) and Tourism. For every assembly relevant subassemblies have been developed (if deemed necessary to strengthen apprehension) that include the key processes-material of the model. In other words, the processes per assembly/subassembly are the components included in the life cycle inventory corresponding to a specific process-material included in SimaPro databases. Great attention was given to select those modules that better reflect the geographical, temporal and technological characteristics of the study areas. Following this process, the LCA model structure is provided below:

LCA Model Structure for Study Area 1 (GR)

1st Level: Materials/Assemblies: Households (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	41,187,497	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	140,771,259	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Tertiary Buildings (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	27,889,270	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	39,453,936	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Municipal Buildings (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	2,902,548	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	5,818,704	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Public Lighting (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	2,866,590	kWh	Ecoinvent

1st Level: Materials/Assemblies: Transporation (1p)

2nd Level: Sub-Assembly: Private Transportation (1p)

Processes Utilized	Value	Unit	Database
Operation, scooter/CH S	31,485,000	km	Ecoinvent
Operation, lorry >16t, fleet average/RER S	35,540,764	km	Ecoinvent
Operation, passenger car, diesel, fleet average/RER S	19,179,543	km	Ecoinvent
Operation, passenger car, petrol, fleet average 2010/RER S	93,641,299	km	Ecoinvent

2nd Level: Sub-Assembly: Public Transportation (1p)

Processes Utilized	Value	Unit	Database
Operation, scooter/CH S	52,500	km	Ecoinvent
Operation, lorry >16t, fleet average/RER S	937,500	km	Ecoinvent
Operation, passenger car, diesel, fleet average/RER S	91,800	km	Ecoinvent
Operation, passenger car, petrol, fleet average 2010/RER S	448,200	km	Ecoinvent
Operation, regular bus/CH S	924,662	km	Ecoinvent
Operation, regional train, SBB mix/CH S	1,533,000	personkm	Ecoinvent
Operation, barge/RER S	2,152,673	tkm	Ecoinvent
Operation, barge tanker/RER S	358,730	tkm	Ecoinvent
Operation, aircraft, passenger, Europe/RER S	4,851,199	personkm	Ecoinvent
Operation, aircraft, freight, Europe/RER S	7,260	tkm	Ecoinvent

1st Level: Materials/Assemblies: Tourism (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	5,977,360	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	7,609,920	kWh	ETH-ESU 96

LCA Model Structure for Study Area 2 (BG)

1st Level: Materials/Assemblies: Households (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	7,438,607	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	23,614,450	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Tertiary Buildings (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	57,194,847	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	80,927,154	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Municipal Buildings (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	325,534	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	819,252	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Public Lighting (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	1,000,000	kWh	Ecoinvent

1st Level: Materials/Assemblies: Transporation (1p)

2nd Level: Sub-Assembly: Private Transportation (1p)

Processes Utilized	Value	Unit	Database
Operation, scooter/CH S	-	km	Ecoinvent
Operation, lorry >16t, fleet average/RER S	163,761,260	km	Ecoinvent
Operation, passenger car, diesel, fleet average/RER S	193,783,800	km	Ecoinvent
Operation, passenger car, petrol, fleet average 2010/RER S	256,876,200	km	Ecoinvent

2nd Level: Sub-Assembly: Public Transportation (1p)

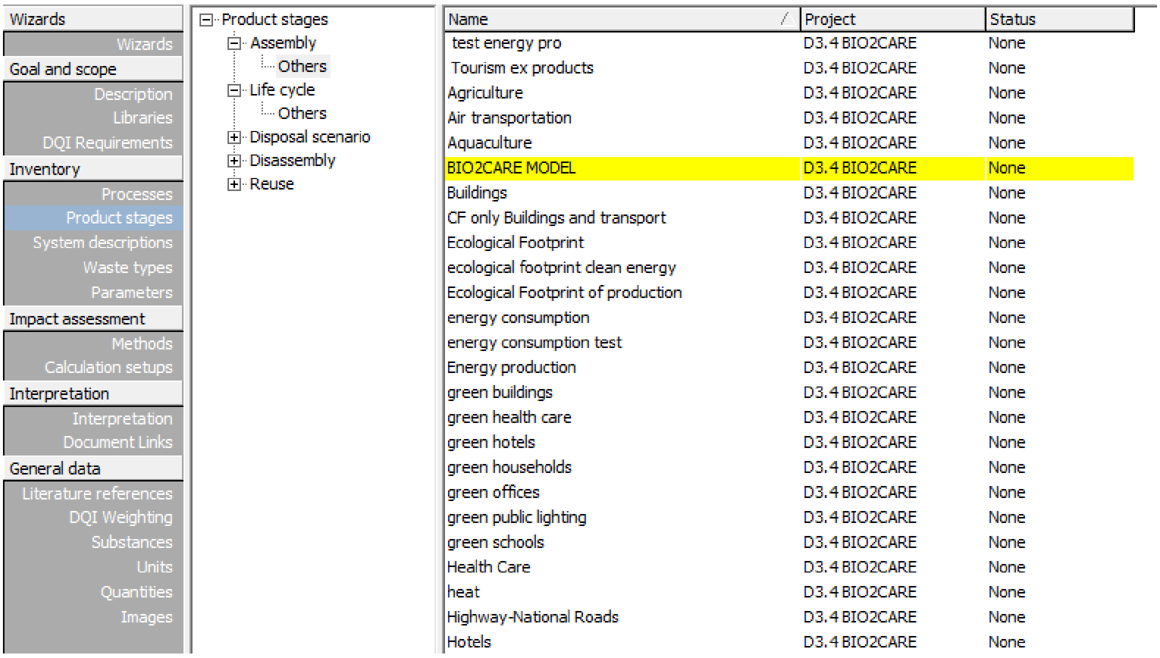
Processes Utilized	Value	Unit	Database

Operation, scooter/CH S	-	km	Ecoinvent
Operation, lorry >16t, fleet average/RER S	-	km	Ecoinvent
Operation, passenger car, diesel, fleet average/RER S	1,542,427	km	Ecoinvent
Operation, passenger car, petrol, fleet average 2010/RER S	2,044,613	km	Ecoinvent
Operation, regular bus/CH S	286,200	km	Ecoinvent
Operation, regional train, SBB mix/CH S	-	personkm	Ecoinvent
Operation, barge/RER S	-	tkm	Ecoinvent
Operation, barge tanker/RER S	-	tkm	Ecoinvent
Operation, aircraft, passenger, Europe/RER S	-	personkm	Ecoinvent
Operation, aircraft, freight, Europe/RER S	-	tkm	Ecoinvent

1st Level: Materials/Assemblies: Tourism (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	3,538,946	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	4,676,790	kWh	ETH-ESU 96

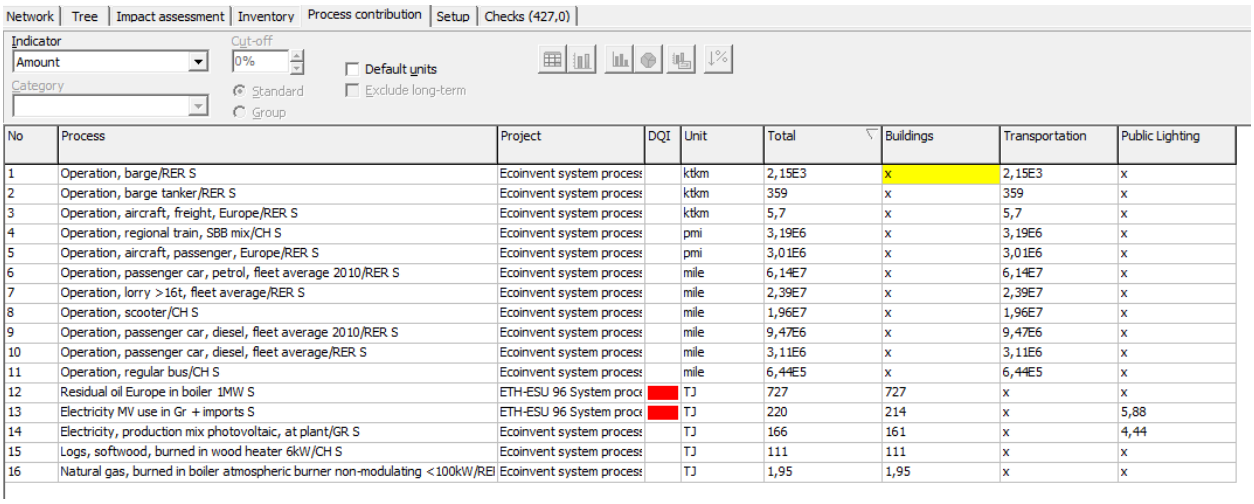
Building on the data presented above, a model has been developed that can be utilized to assess various impacts categories for the existing situation in Study Area 1 (GR) and Study Area 2 (BG) with the application of the impact categories included in SimaPro.



Name	Project	Status
test energy pro	D3.4 BIO2CARE	None
Tourism ex products	D3.4 BIO2CARE	None
Agriculture	D3.4 BIO2CARE	None
Air transportation	D3.4 BIO2CARE	None
Aquaculture	D3.4 BIO2CARE	None
BIO2CARE MODEL	D3.4 BIO2CARE	None
Buildings	D3.4 BIO2CARE	None
CF only Buildings and transport	D3.4 BIO2CARE	None
Ecological Footprint	D3.4 BIO2CARE	None
ecological footprint clean energy	D3.4 BIO2CARE	None
Ecological Footprint of production	D3.4 BIO2CARE	None
energy consumption	D3.4 BIO2CARE	None
energy consumption test	D3.4 BIO2CARE	None
Energy production	D3.4 BIO2CARE	None
green buildings	D3.4 BIO2CARE	None
green health care	D3.4 BIO2CARE	None
green hotels	D3.4 BIO2CARE	None
green households	D3.4 BIO2CARE	None
green offices	D3.4 BIO2CARE	None
green public lighting	D3.4 BIO2CARE	None
green schools	D3.4 BIO2CARE	None
Health Care	D3.4 BIO2CARE	None
heat	D3.4 BIO2CARE	None
Highway-National Roads	D3.4 BIO2CARE	None
Hotels	D3.4 BIO2CARE	None

Figure 3-4: Model developed in SimaPro.

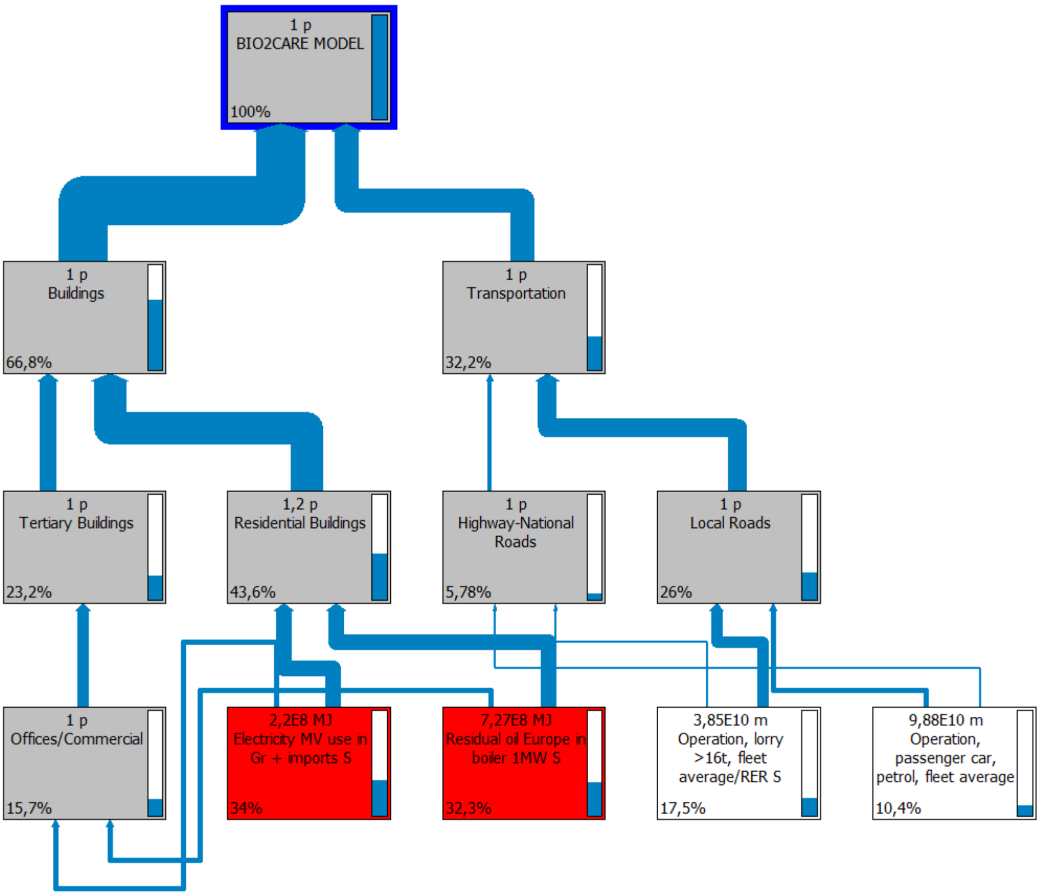
The following snapshots present an overview of the results that can be developed using the SimaPro Software and the ReCiPe impact category (see Section 3.4 for detailed results).

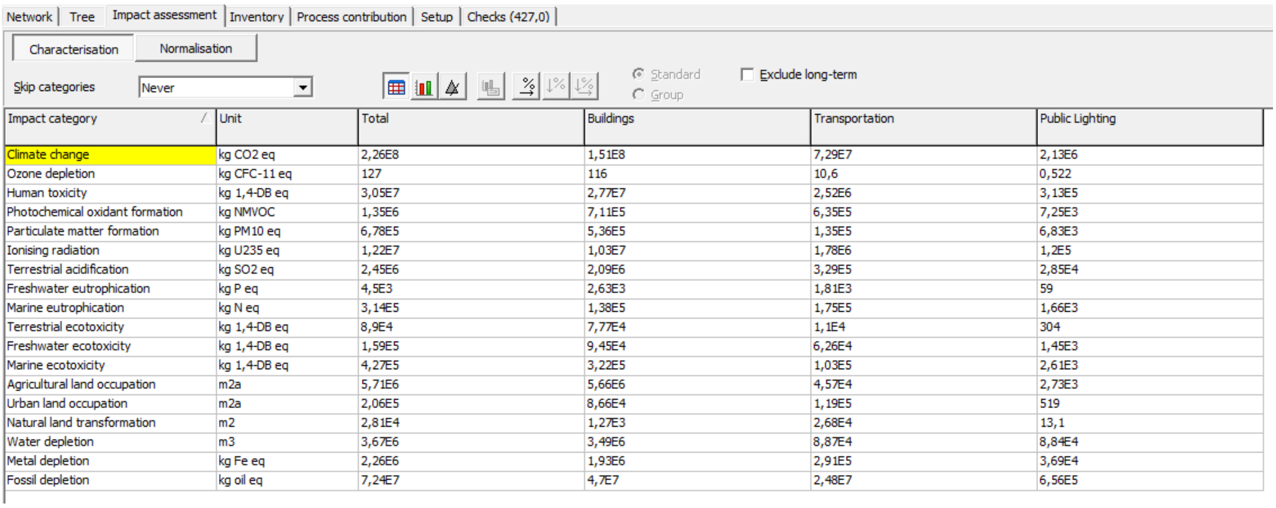


Indicator: Amount

☐ Default units

No	Process	Project	DQI	Unit	Total	Buildings	Transportation	Public Lighting
1	Operation, barge/RER S	Ecoinvent system process		ktkm	2,15E3	x	2,15E3	x
2	Operation, barge tanker/RER S	Ecoinvent system process		ktkm	359	x	359	x
3	Operation, aircraft, freight, Europe/RER S	Ecoinvent system process		ktkm	5,7	x	5,7	x
4	Operation, regional train, SBB mix/CH S	Ecoinvent system process		pmi	3,19E6	x	3,19E6	x
5	Operation, aircraft, passenger, Europe/RER S	Ecoinvent system process		pmi	3,01E6	x	3,01E6	x
6	Operation, passenger car, petrol, fleet average 2010/RER S	Ecoinvent system process		mile	6,14E7	x	6,14E7	x
7	Operation, lorry >16t, fleet average/RER S	Ecoinvent system process		mile	2,39E7	x	2,39E7	x
8	Operation, scooter/CH S	Ecoinvent system process		mile	1,96E7	x	1,96E7	x
9	Operation, passenger car, diesel, fleet average 2010/RER S	Ecoinvent system process		mile	9,47E6	x	9,47E6	x
10	Operation, passenger car, diesel, fleet average/RER S	Ecoinvent system process		mile	3,11E6	x	3,11E6	x
11	Operation, regular bus/CH S	Ecoinvent system process		mile	6,44E5	x	6,44E5	x
12	Residual oil Europe in boiler 1MW S	ETH-ESU 96 System proce	🟥	TJ	727	727	x	x
13	Electricity MV use in Gr + imports S	ETH-ESU 96 System proce	🟥	TJ	220	214	x	5,88
14	Electricity, production mix photovoltaic, at plant/GR S	Ecoinvent system process		TJ	166	161	x	4,44
15	Logs, softwood, burned in wood heater 6kW/CH S	Ecoinvent system process		TJ	111	111	x	x
16	Natural gas, burned in boiler atmospheric burner non-modulating <100kW/REI	Ecoinvent system process		TJ	1,95	1,95	x	x



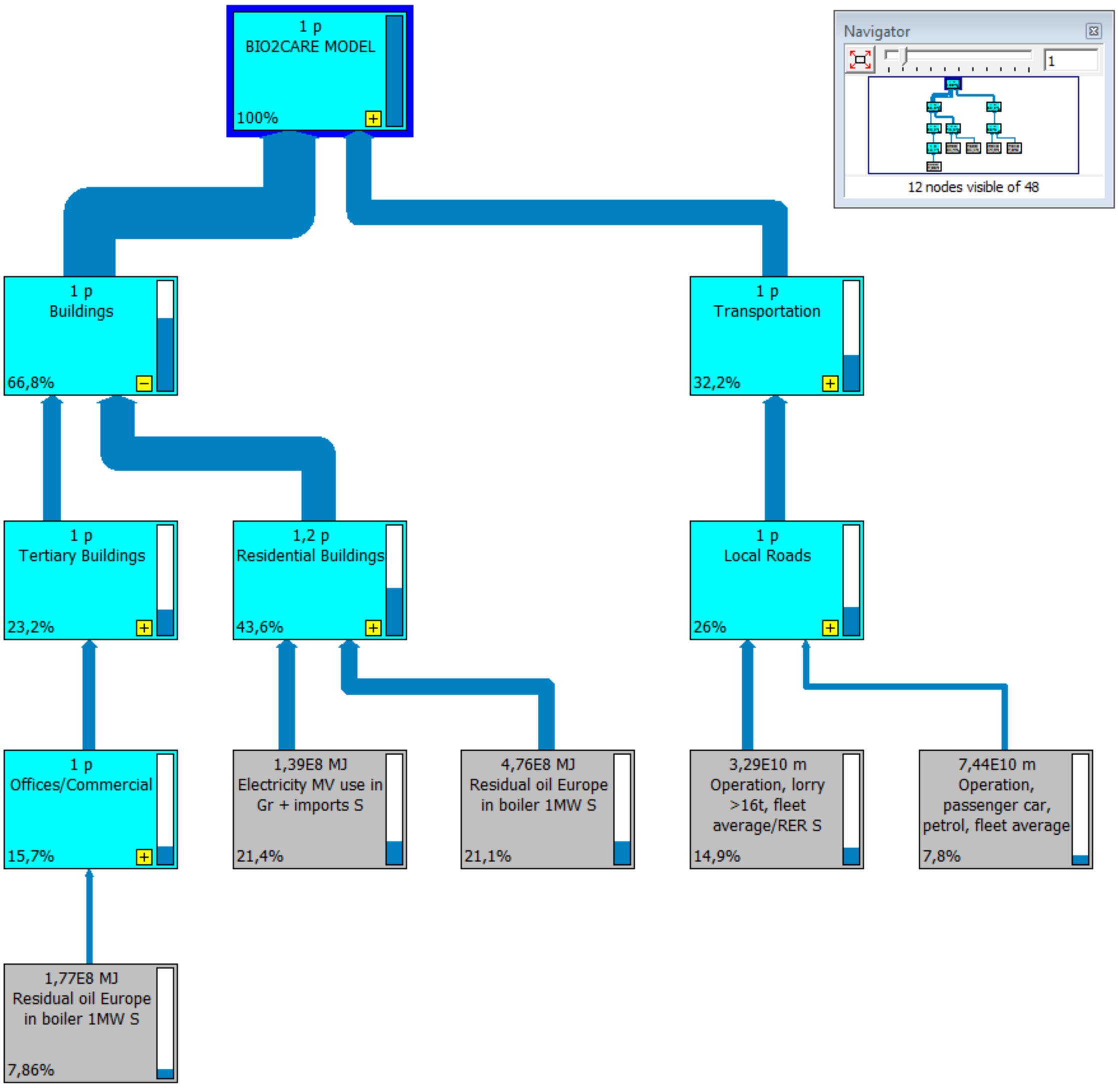


Skip categories: Never

● Standard
○ Group

☐ Exclude long-term

Impact category	Unit	Total	Buildings	Transportation	Public Lighting
Climate change	kg CO2 eq	2,26E8	1,51E8	7,29E7	2,13E6
Ozone depletion	kg CFC-11 eq	127	116	10,6	0,522
Human toxicity	kg 1,4-DB eq	3,05E7	2,77E7	2,52E6	3,13E5
Photochemical oxidant formation	kg NMVOC	1,35E6	7,11E5	6,35E5	7,25E3
Particulate matter formation	kg PM10 eq	6,78E5	5,36E5	1,35E5	6,83E3
Ionising radiation	kg U235 eq	1,22E7	1,03E7	1,78E6	1,2E5
Terrestrial acidification	kg SO2 eq	2,45E6	2,09E6	3,29E5	2,85E4
Freshwater eutrophication	kg P eq	4,5E3	2,63E3	1,81E3	59
Marine eutrophication	kg N eq	3,14E5	1,38E5	1,75E5	1,66E3
Terrestrial ecotoxicity	kg 1,4-DB eq	8,9E4	7,77E4	1,1E4	304
Freshwater ecotoxicity	kg 1,4-DB eq	1,59E5	9,45E4	6,26E4	1,45E3
Marine ecotoxicity	kg 1,4-DB eq	4,27E5	3,22E5	1,03E5	2,61E3
Agricultural land occupation	m2a	5,71E6	5,66E6	4,57E4	2,73E3
Urban land occupation	m2a	2,06E5	8,66E4	1,19E5	519
Natural land transformation	m2	2,81E4	1,27E3	2,68E4	13,1
Water depletion	m3	3,67E6	3,49E6	8,87E4	8,84E4
Metal depletion	kg Fe eq	2,26E6	1,93E6	2,91E5	3,69E4
Fossil depletion	kg oil eq	7,24E7	4,7E7	2,48E7	6,56E5



The assessment of the existing and symbiotic situation in study area 1 (GR) and study area 2 (BG) will be carried out using the ReCiPe and Eco-Indicator 99 methods (described in more detail in section 1.6). The results are analytically provided and discussed in the following section.

3.4 Interpretation of the results

3.4.1 The ReCiPe method (Midpoint evaluation)

The application of the ReCiPe method led to the quantification of a number of important environmental indicators which are described in detail in Tables 3-1 and 3-2 for Study Areas 1 and 2 respectively. These results were extracted by utilizing the inventory and models presented in Sections 3.1, 3.2 and 3.3. The carbon footprint of the two Study Areas according to the LCA principles and the ReCiPe impact assessment method amounts to 221,000 and 359,000 tons of CO_2 eq. respectively. The results are in close proximity with the estimations performed using the methodological framework developed in D.3.2, further validating its applicability.

Table 3-1: LCA results for Study Area 1 (GR) using the ReCiPe method.

Impact category indicator	Unit	Value
Climate change	kg CO_2 eq.	$2,21\times10^{8}$
Ozone depletion	kg CFC-11 eq.	$1,05\times10^{2}$
Terrestrial Acidification	kg SO_2 eq.	$1,77\times10^{6}$
Freshwater eutrophication	kg P eq.	$2,21\times10^{5}$
Marine eutrophication	kg N eq.	$3,24\times10^{5}$
Human Toxicity	kg 1,4-DB eq.	$1,48\times10^{8}$
Photochemical oxidant formation	kg NMVOC	$1,17\times10^{6}$
Particulate matter formation	kg PM_{10} eq.	$5,42\times10^{5}$
Terrestrial ecotoxicity	kg 1,4-DB eq.	$4,00\times10^{3}$
Freshwater ecotoxicity	kg 1,4-DB eq.	$3,14\times10^{6}$
Marine ecotoxicity	kg 1,4-DB eq.	$3,28\times10^{6}$
Ionising radiation	kg U235 eq.	$1,07\times10^{7}$
Agricultural land occupation	m^2×yr	$1,52\times10^{5}$
Urban land occupation	m^2×yr	$2,51\times10^{5}$
Natural land transformation	m^2	$3,43\times10^{4}$
Water Depletion	m^3	$8,25\times10^{5}$
Mineral resource depletion	kg Fe eq.	$1,17\times10^{6}$
Fossil resource depletion	kg oil eq.	$7,47\times10^{7}$

Table 3-2: LCA results for Study Area 2 (BG) using the ReCiPe method.

Impact category indicator	Unit	Value
Climate change	kg CO_2 eq.	$3,59\times10^{8}$
Ozone depletion	kg CFC-11 eq.	$9,47\times10^{1}$
Terrestrial Acidification	kg SO_2 eq.	$2,08\times10^{6}$
Freshwater eutrophication	kg P eq.	$7,82\times10^{4}$
Marine eutrophication	kg N eq.	$8,12\times10^{5}$
Human Toxicity	kg 1,4-DB eq.	$6,17\times10^{7}$
Photochemical oxidant formation	kg NMVOC	$2,52\times10^{6}$
Particulate matter formation	kg PM_{10} eq.	$7,60\times10^{5}$
Terrestrial ecotoxicity	kg 1,4-DB eq.	$5,83\times10^{4}$
Freshwater ecotoxicity	kg 1,4-DB eq.	$1,26\times10^{6}$

Marine ecotoxicity	kg 1,4-DB eq.	$1{,}50\times10^{6}$
Ionising radiation	kg U235 eq.	$4{,}39\times10^{7}$
Agricultural land occupation	$m^{2}\times yr$	$4{,}70\times10^{5}$
Urban land occupation	$m^{2}\times yr$	$5{,}33\times10^{5}$
Natural land transformation	m^{2}	$1{,}02\times10^{5}$
Water Depletion	m^{3}	$8{,}80\times10^{5}$
Mineral resource depletion	kg Fe eq.	$1{,}74\times10^{6}$
Fossil resource depletion	kg oil eq.	$1{,}17\times10^{8}$

Table 3-3 presents the key processes / sectors contributing to the carbon footprint of the Study Areas according to the ReCiPe LCA method. Regarding Study Area 1 (GR), electricity consumption is the most contributing process (37%) to total carbon footprint, followed by heating oil consumption (32%) and heavy duty vehicles (17%). Therefore, there is a need to target the reduction of the electricity consumption (or change of the energy mix) for the substantial improvement of the carbon footprint. Regarding Study Area 2 (BG) the results are significantly differentiated. Heavy duty vehicles is the most contributing process (46%) to total carbon footprint, followed by the operation of passenger cars (petrol - 17%, diesel – 13%). Heating and electricity present a much lower (23% combined) contribution to the total carbon footprint in comparison with Study Area 1. In that aspect, there is a need for Study Area 2 (BG) to find ways to reduce the impact of transportation. The absence of alternative ways of public transportation within the boundaries of Study Area 2 (e.g. train, airplane etc.) is further contributing to these results, whereas there are too many private heavy duty vehicles operating or passing by the area.

Table 3-3: Key processes/sectors contributing to the carbon footprint of the two Study Areas according to ReCiPe LCA model.

Study Area 1 (GR)			
S/N	**Process**	**Unit kg CO_2 eq.**	**Pecentage (%)**
1	Electricity MV at grid	$8{,}10\times10^{7}$	37
2	Heating Oil	$7{,}01\times10^{7}$	32
3	Operation, lorry	$3{,}74\times10^{7}$	17
4	Operation, passenger car, petrol	$2{,}25\times10^{7}$	10
5	Operation, passenger car, diesel	$4{,}48\times10^{6}$	2
6	Rest of the processes	-	2
	Total Carbon footrpint	$2{,}21\times10^{8}$	100

Study Area 2 (BG)			
S/N	**Process**	**Unit** **kg CO_2 eq.**	**Pecentage (%)**
1	Operation, lorry	$1{,}68\times10^{8}$	46
2	Operation, passenger car, petrol	$6{,}18\times10^{7}$	17
3	Operation, passenger car, diesel	$4{,}54\times10^{7}$	13
4	Electricity MV at grid	$4{,}32\times10^{7}$	12
5	Heating Oil	$3{,}98\times10^{7}$	11
6	Rest of the processes	-	<1
	Total Carbon footrpint	$3{,}59\times10^{8}$	100

The percentage contribution of the individual elements-processes included in the LCA model for all environmental indicators is presented in Figures 3-4 to 3-22 as network trees.

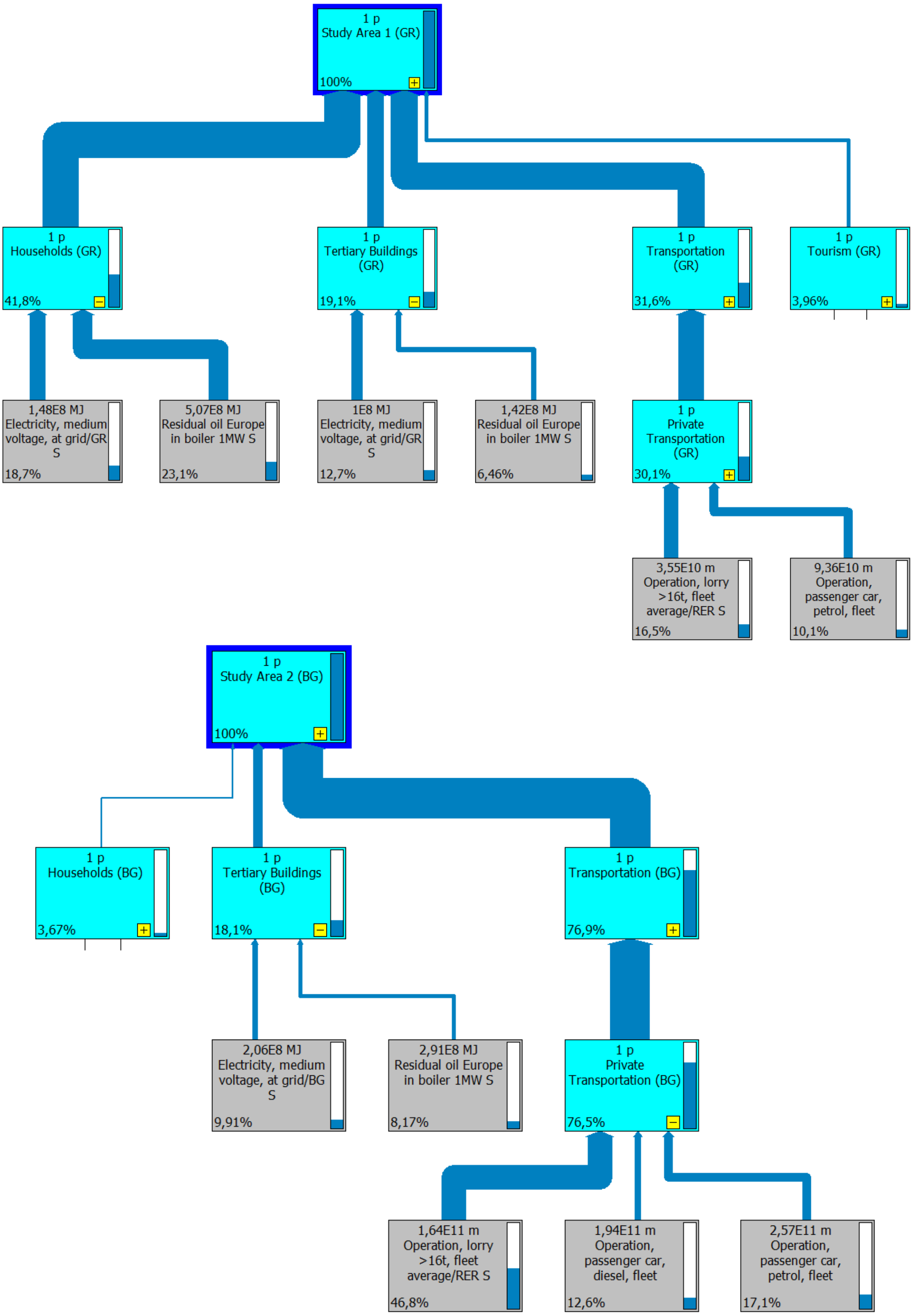


Figure 3-5: Contribution (%) of individual elements to the environmental indicator «Climate Change» (Study Area 1 – up; Study Area 2 – down).

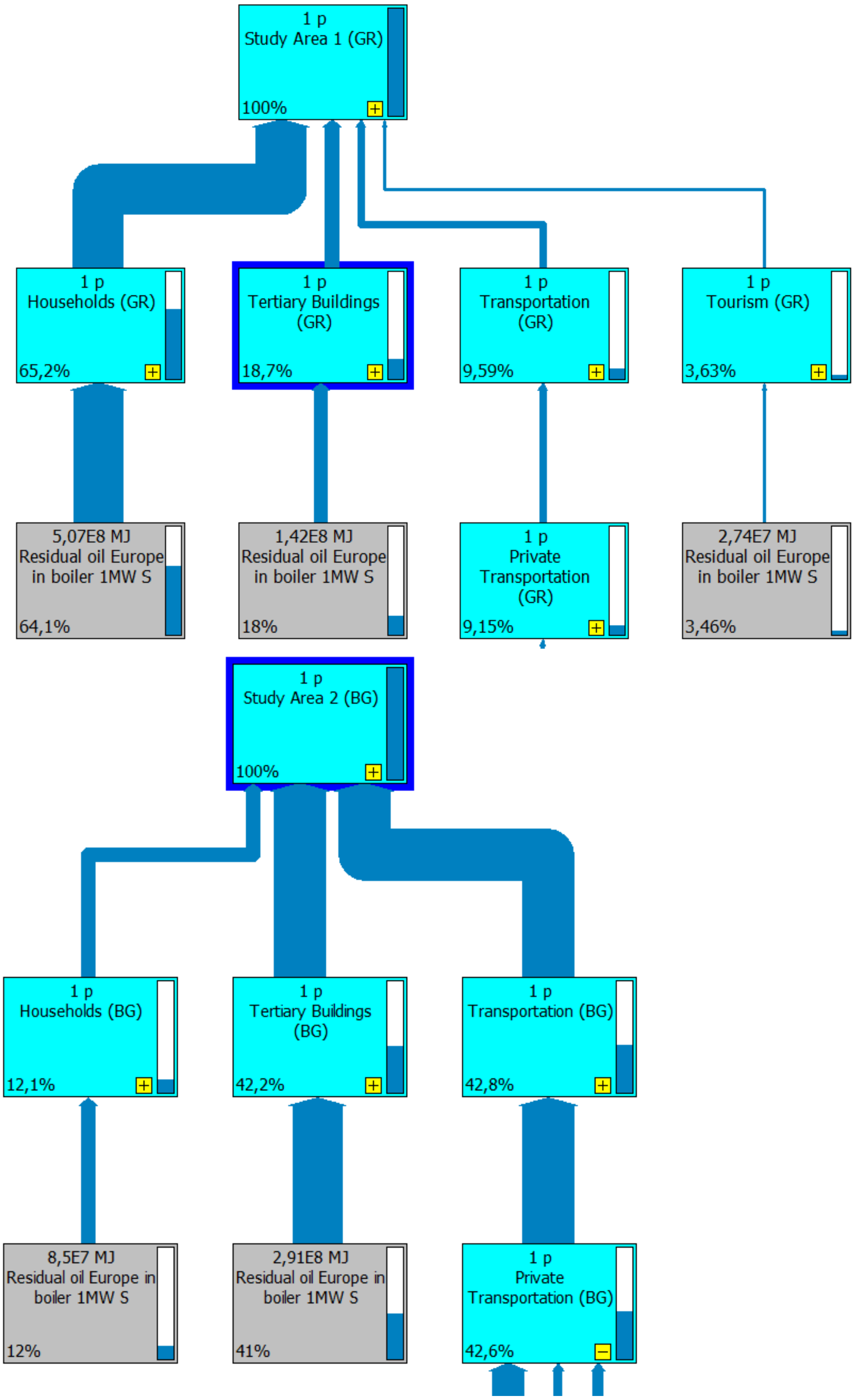


Figure 3-6: Contribution (%) of individual elements to the environmental indicator «Ozone Depletion» (Study Area 1 – up; Study Area 2 – down).

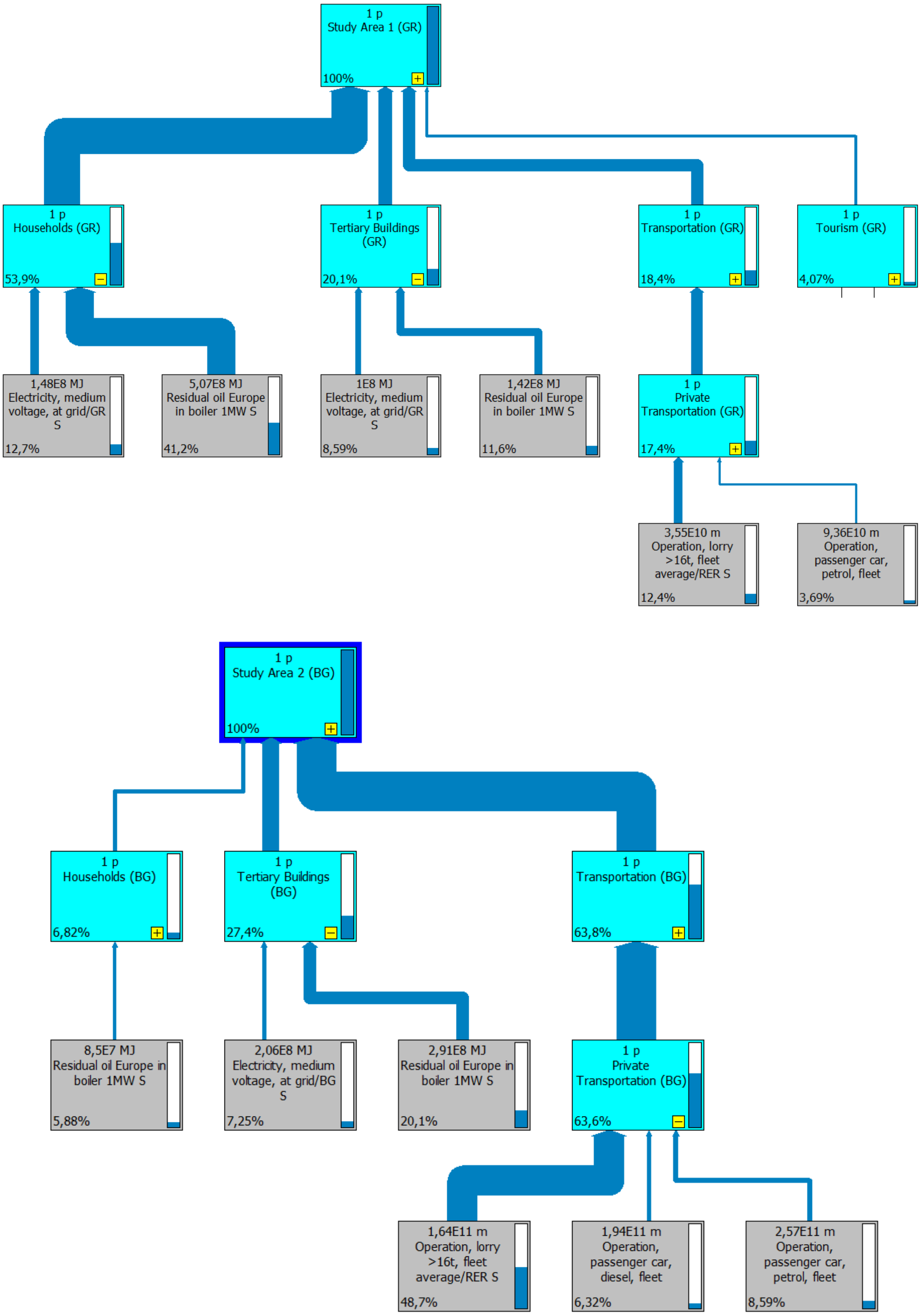


Figure 3-7: Contribution (%) of individual elements to the environmental indicator «Terrestrial Acidification» (Study Area 1 – up; Study Area 2 – down).

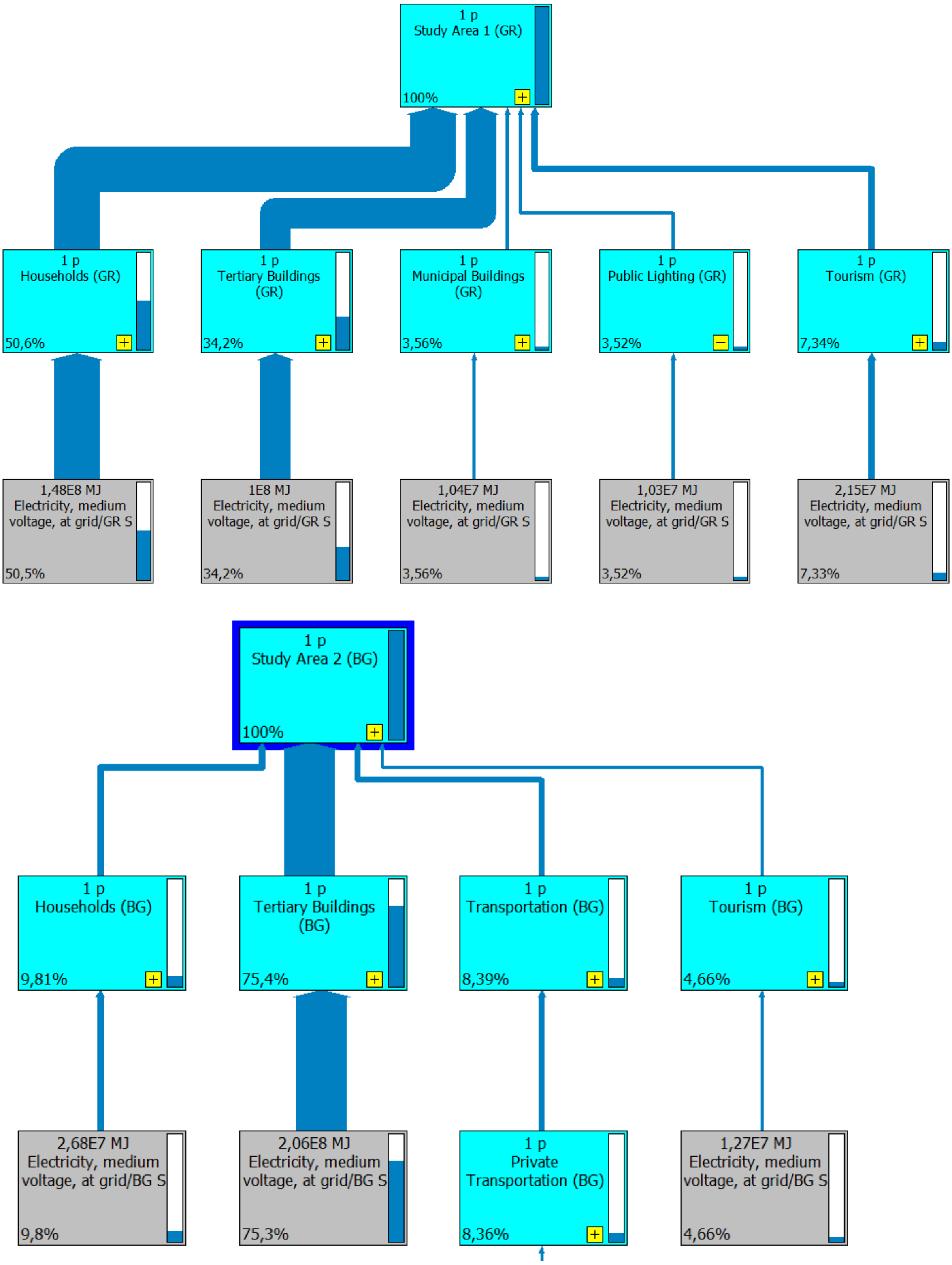


Figure 3-8: Contribution (%) of individual elements to the environmental indicator «Freshwater Eutrophication» (Study Area 1 – up; Study Area 2 – down).

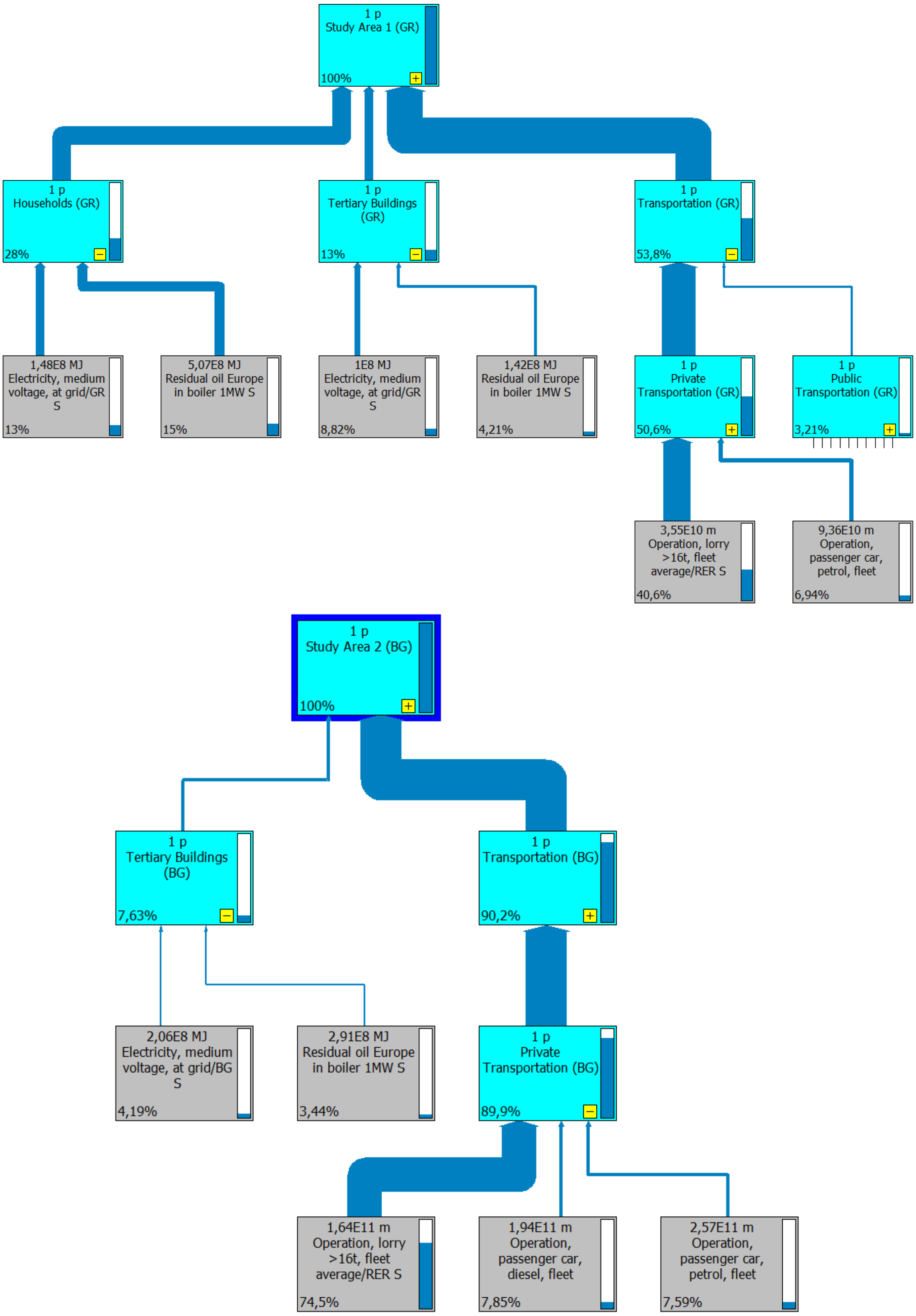


Figure 3-9: Contribution (%) of individual elements to the environmental indicator «Marine Eutrophication» (Study Area 1 – up; Study Area 2 – down).

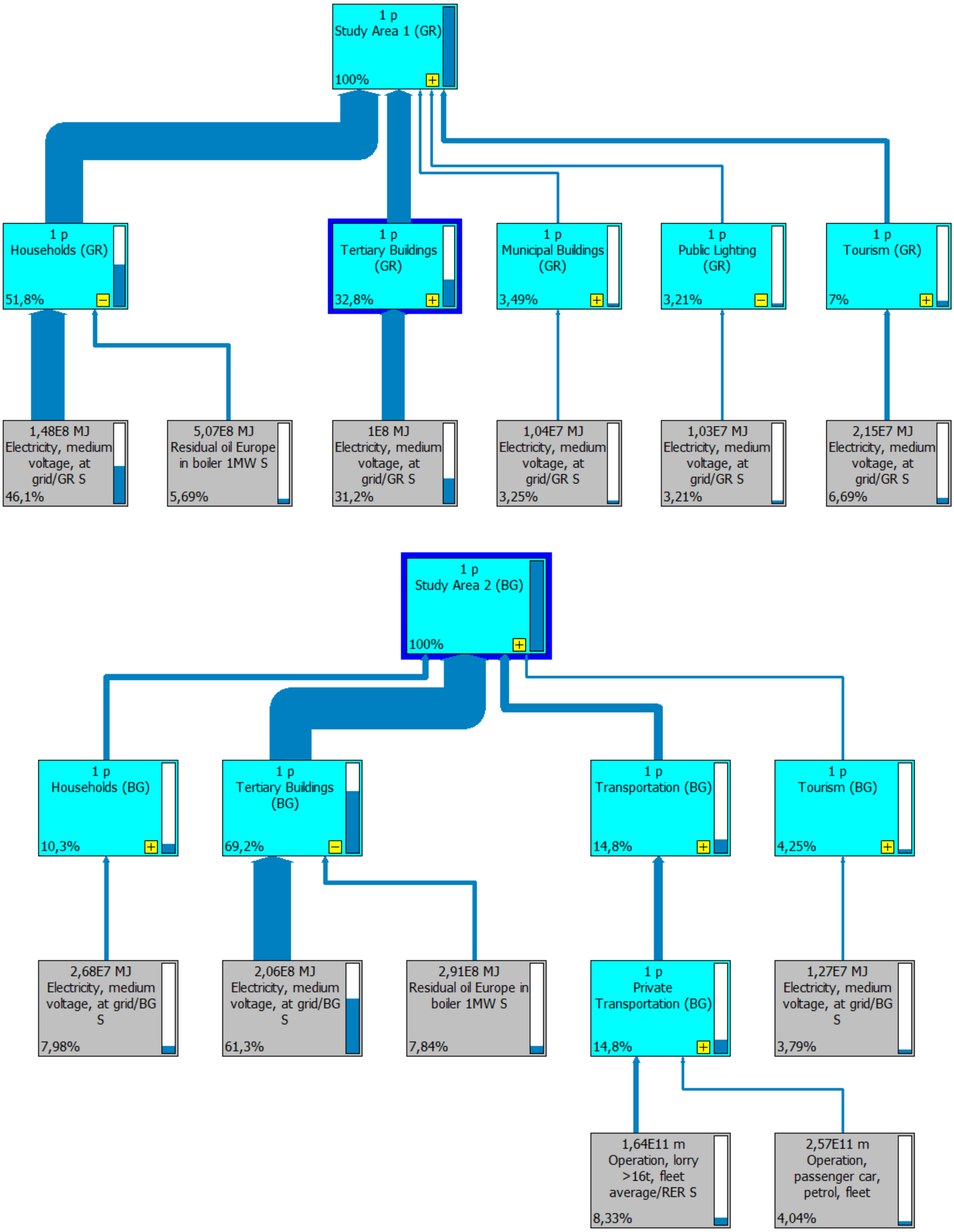


Figure 3-10: Contribution (%) of individual elements to the environmental indicator «Human Toxicity» (Study Area 1 – up; Study Area 2 – down).

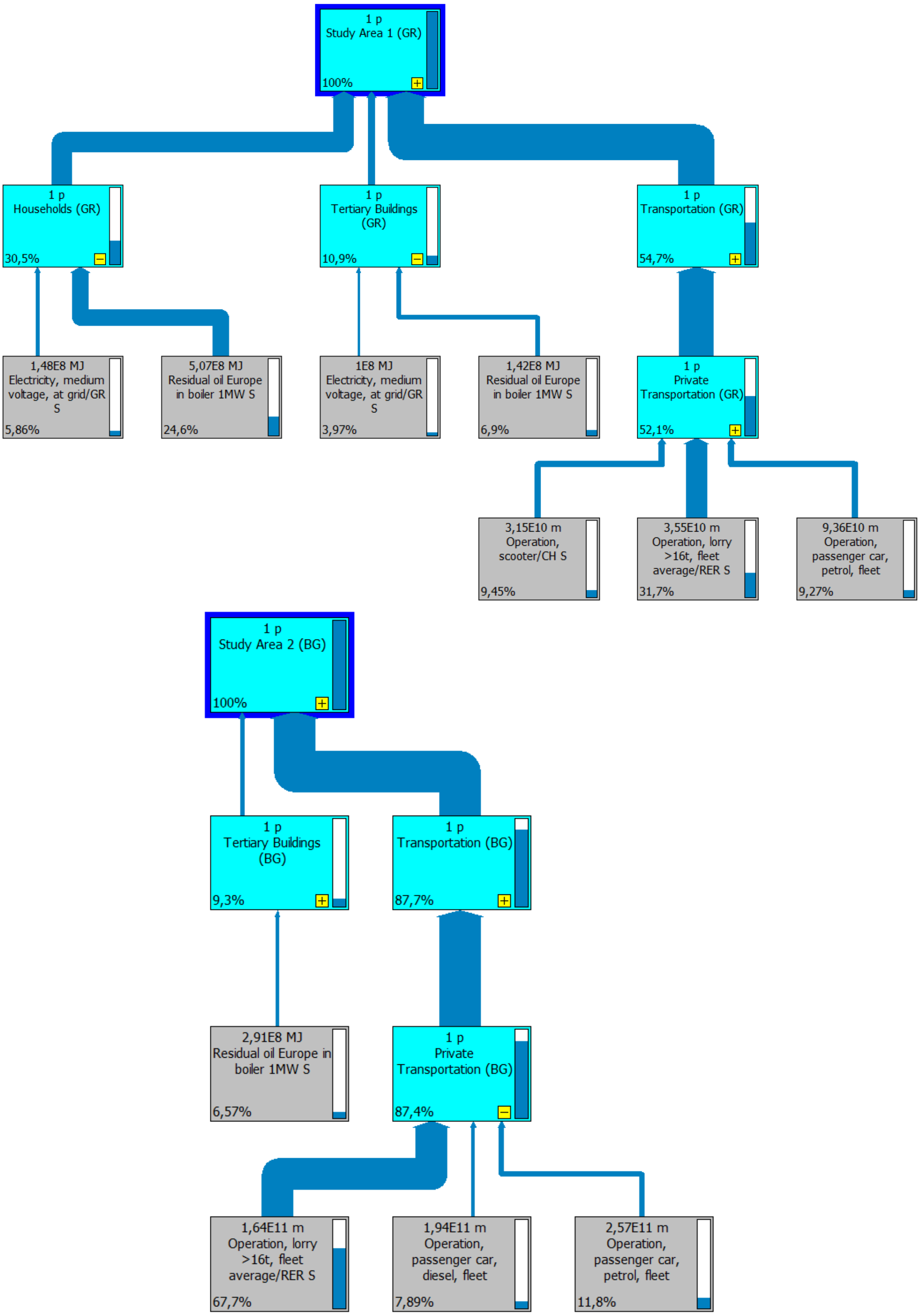


Figure 3-11: Contribution (%) of individual elements to the environmental indicator «Photochemical Oxidant Formation» (Study Area 1 – up; Study Area 2 – down).

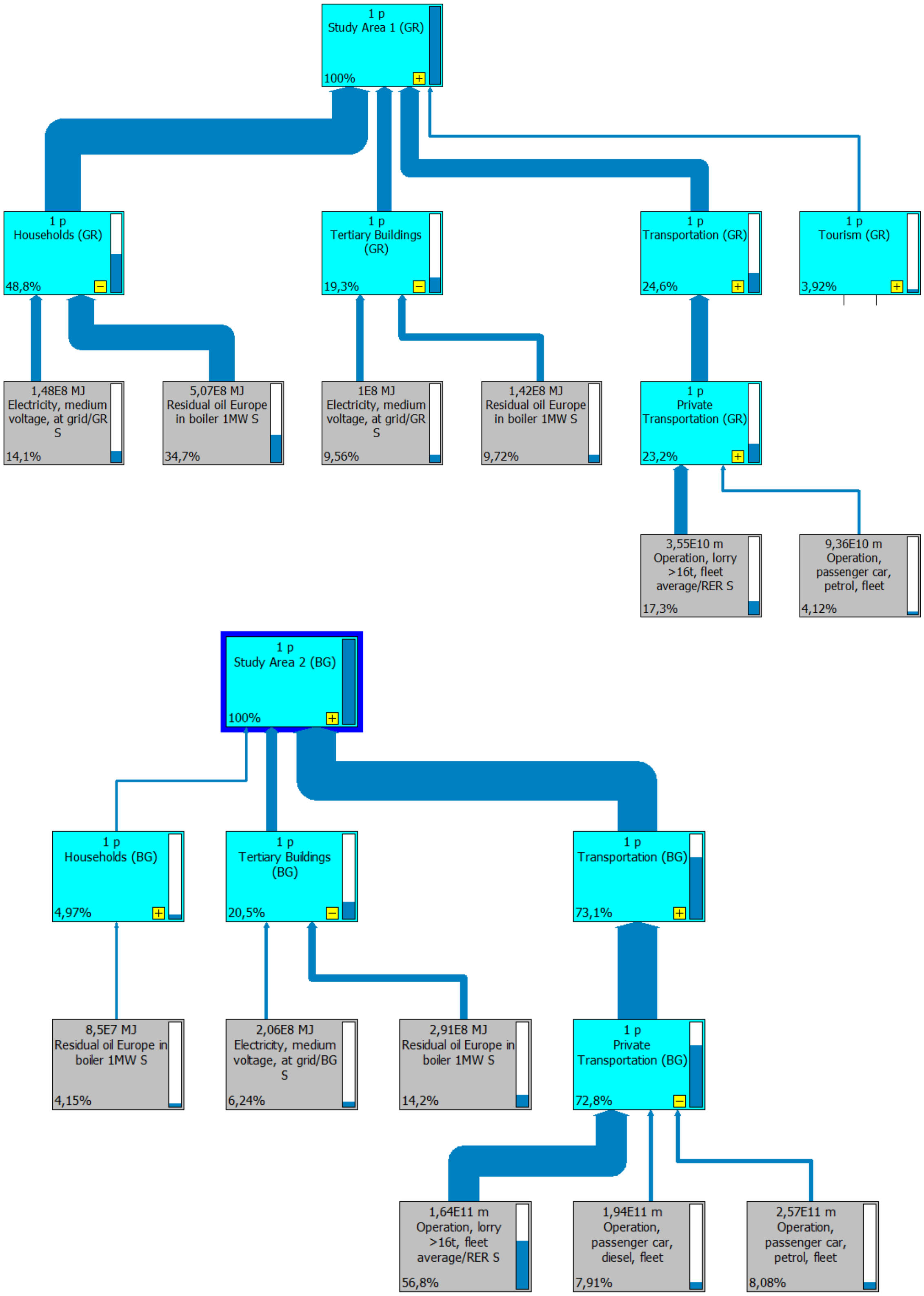


Figure 3-12: Contribution (%) of individual elements to the environmental indicator «Particulate Matter Formation» (Study Area 1 – up; Study Area 2 – down).

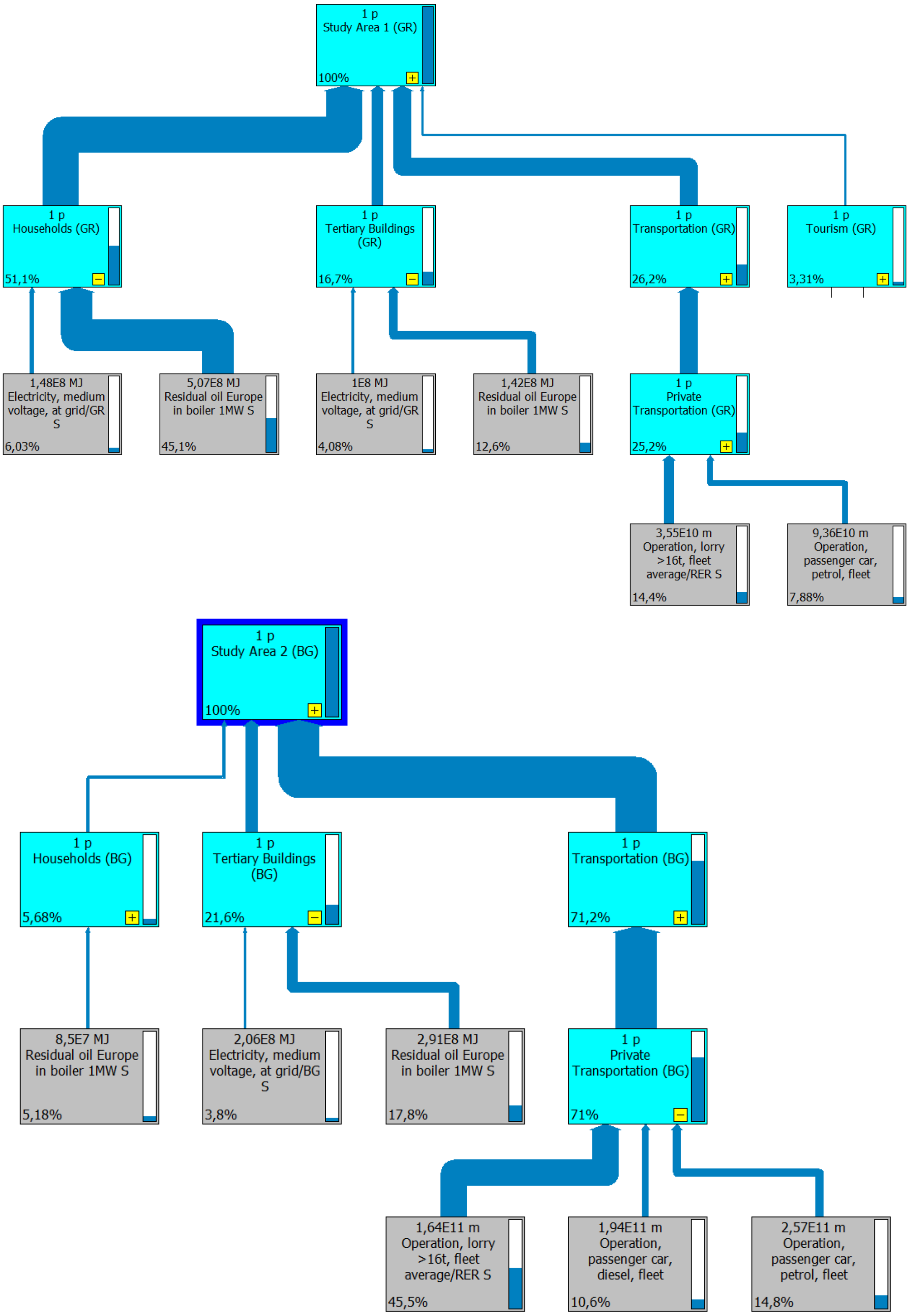


Figure 3-13: Contribution (%) of individual elements to the environmental indicator «Terrestrial Ecotoxicity» (Study Area 1 – up; Study Area 2 – down).

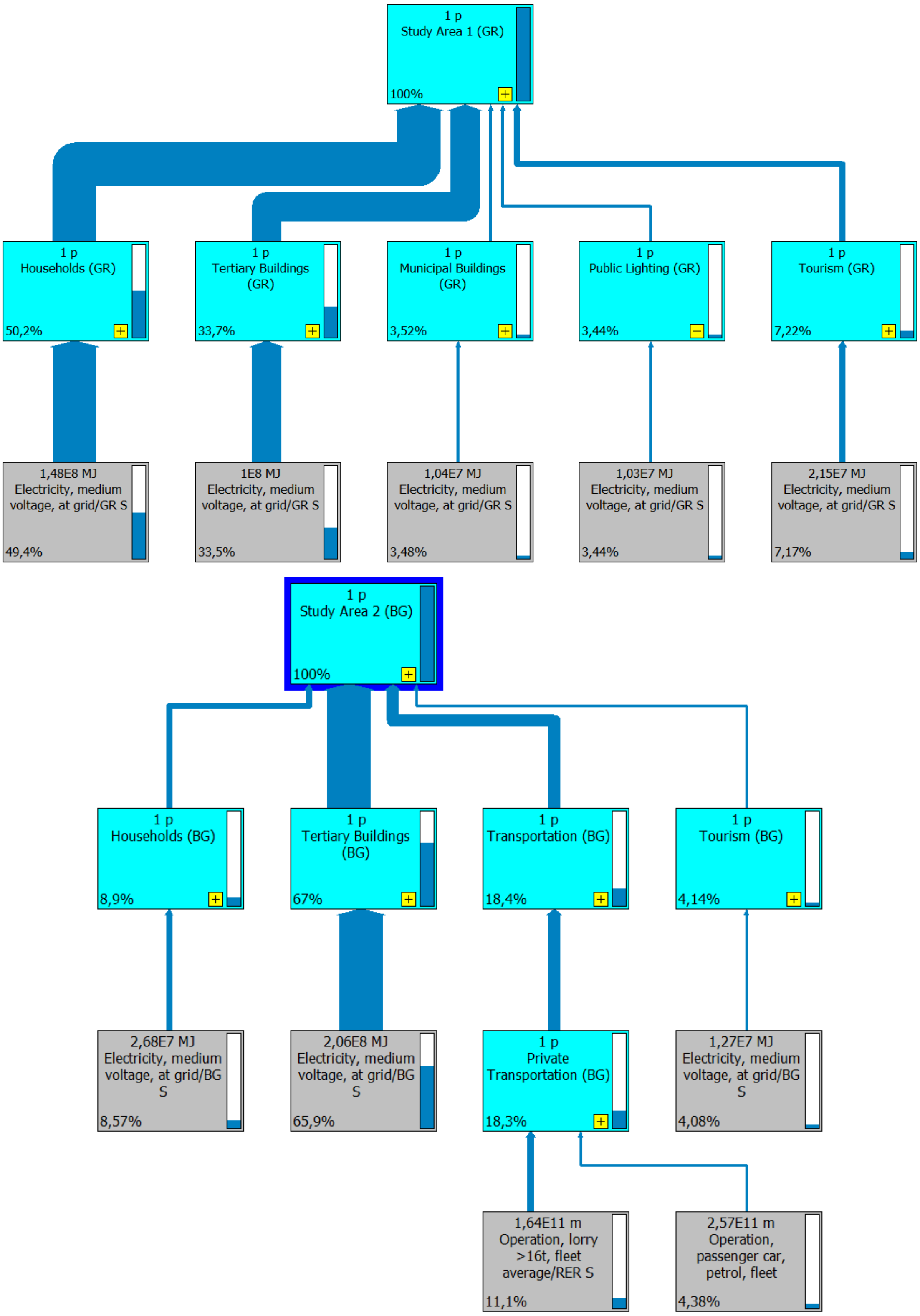


Figure 3-14: Contribution (%) of individual elements to the environmental indicator «Freshwater Ecotoxicity» (Study Area 1 – up; Study Area 2 – down).

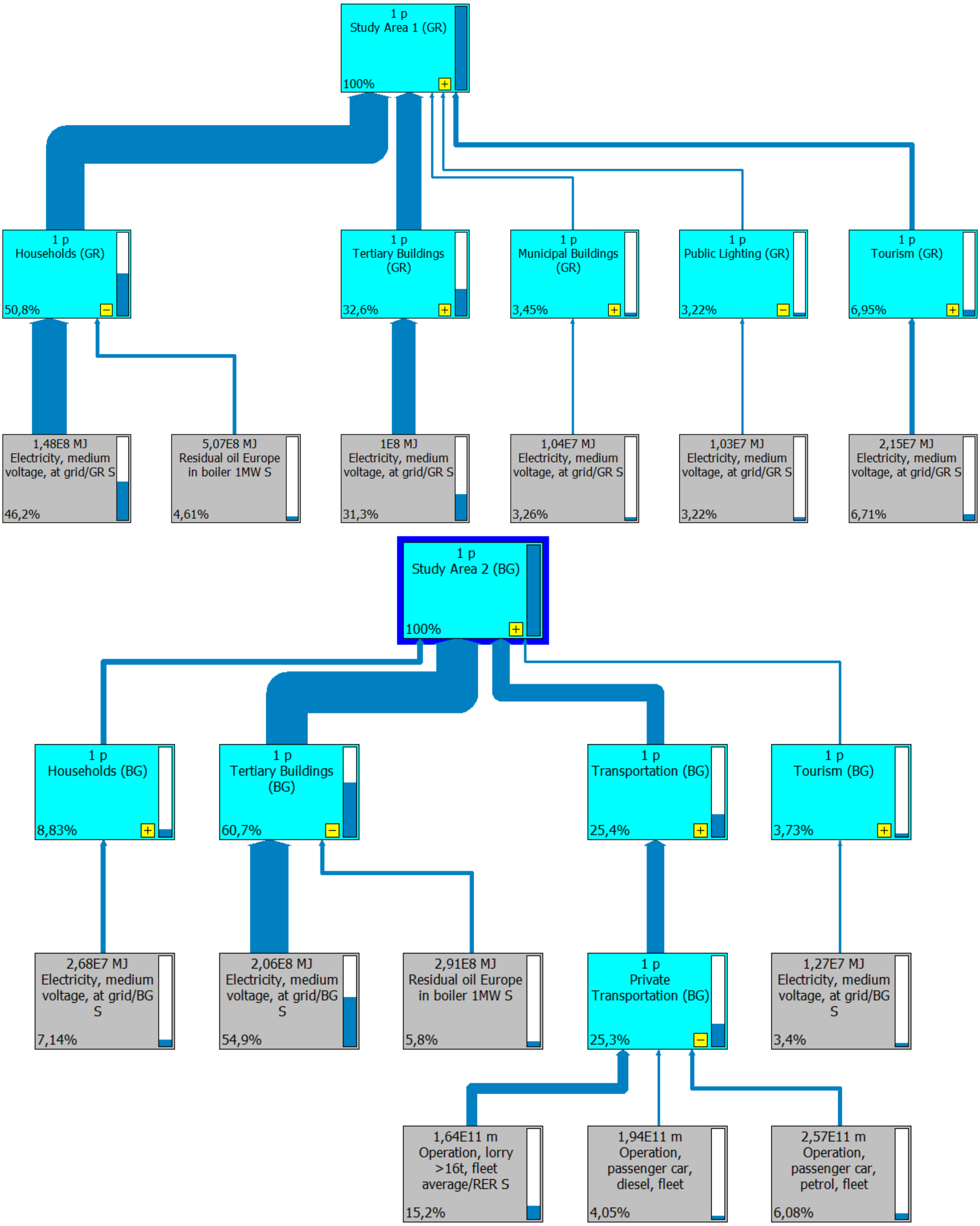


Figure 3-15: Contribution (%) of individual elements to the environmental indicator «Marine Ecotoxicity» (Study Area 1 – up; Study Area 2 – down).

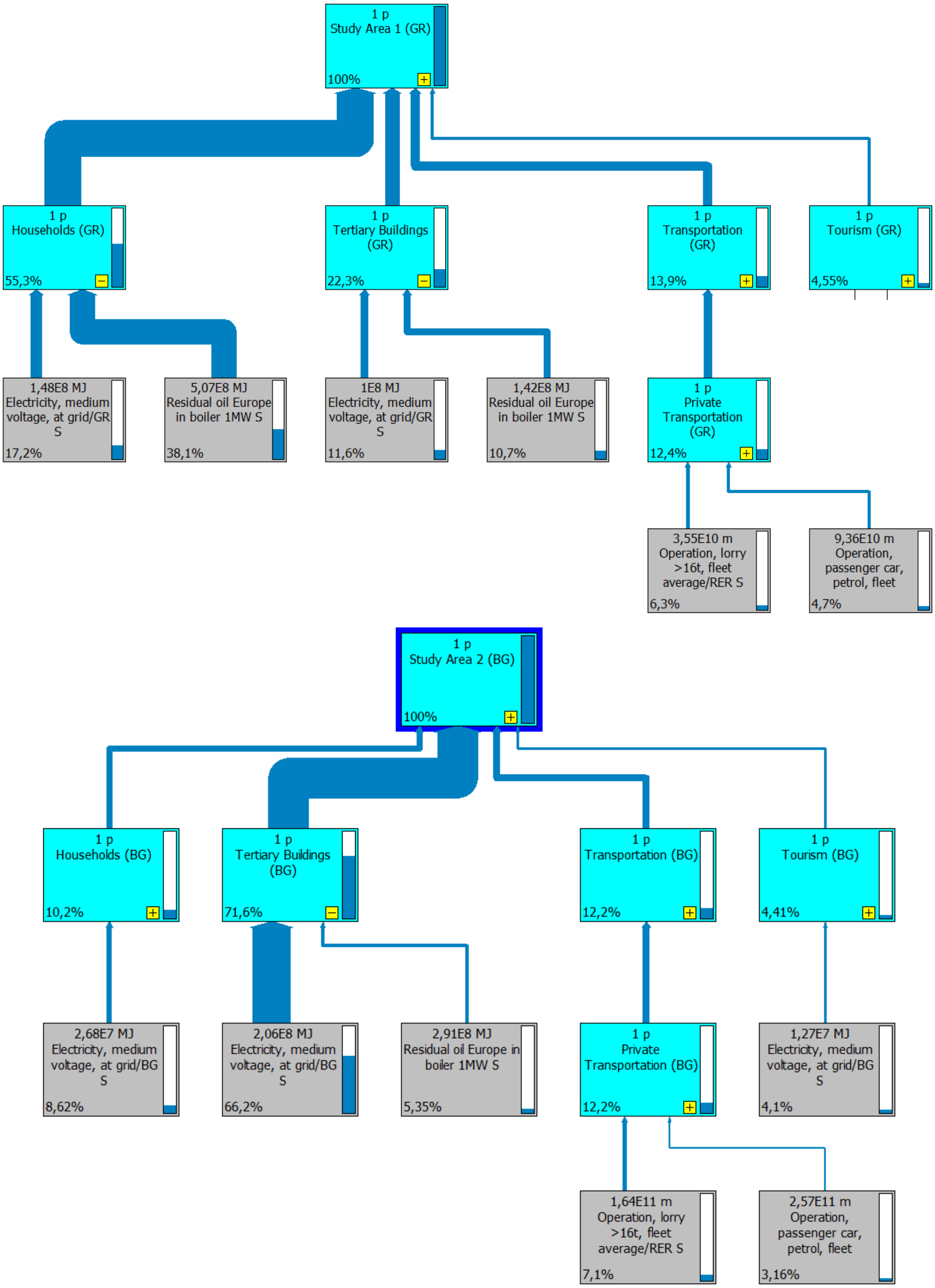


Figure 3-16: Contribution (%) of individual elements to the environmental indicator «Ionising Radiation» (Study Area 1 – up; Study Area 2 – down).

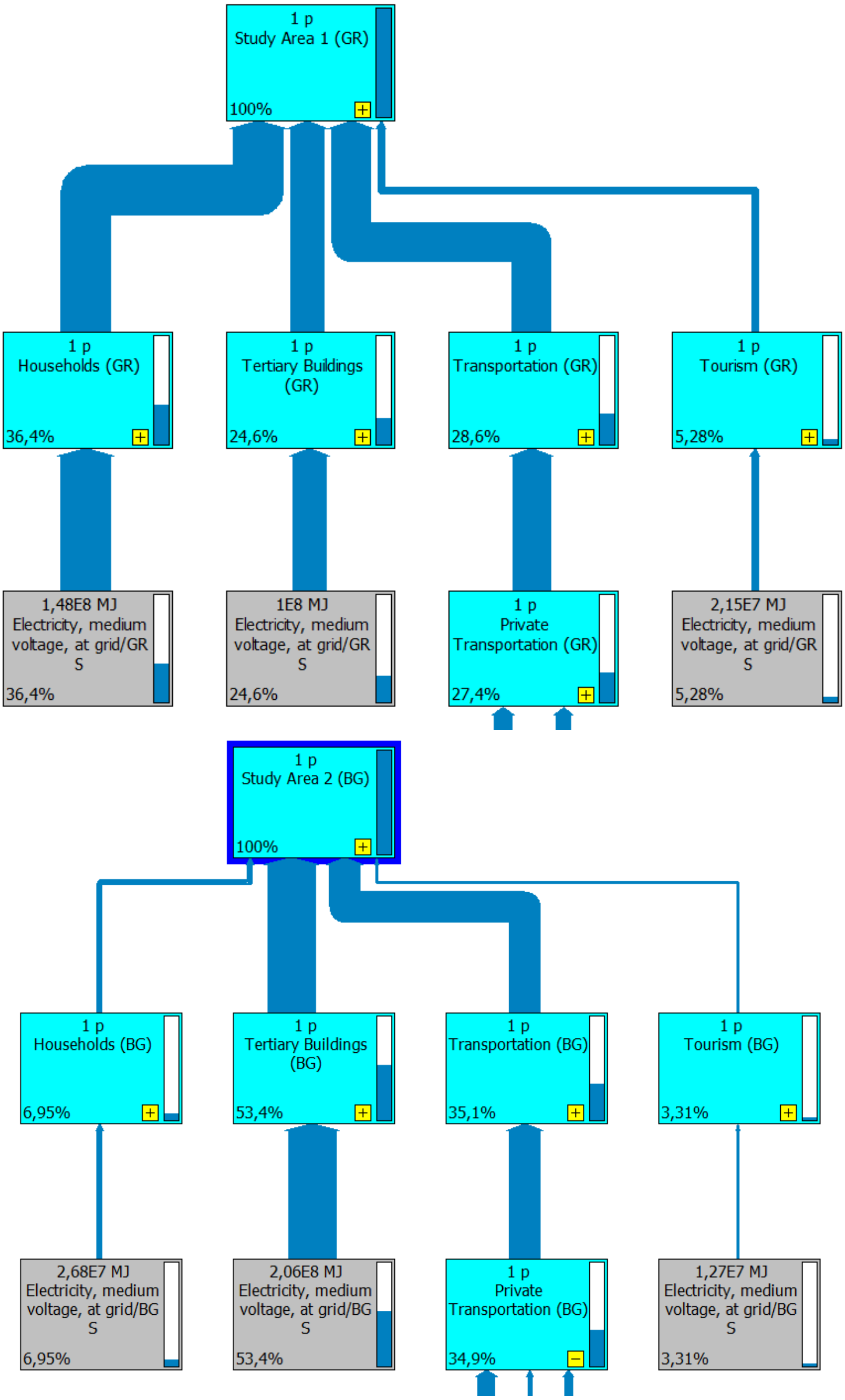


Figure 3-17: Contribution (%) of individual elements to the environmental indicator «Agricultural Land Occupation» (Study Area 1 – up; Study Area 2 – down).

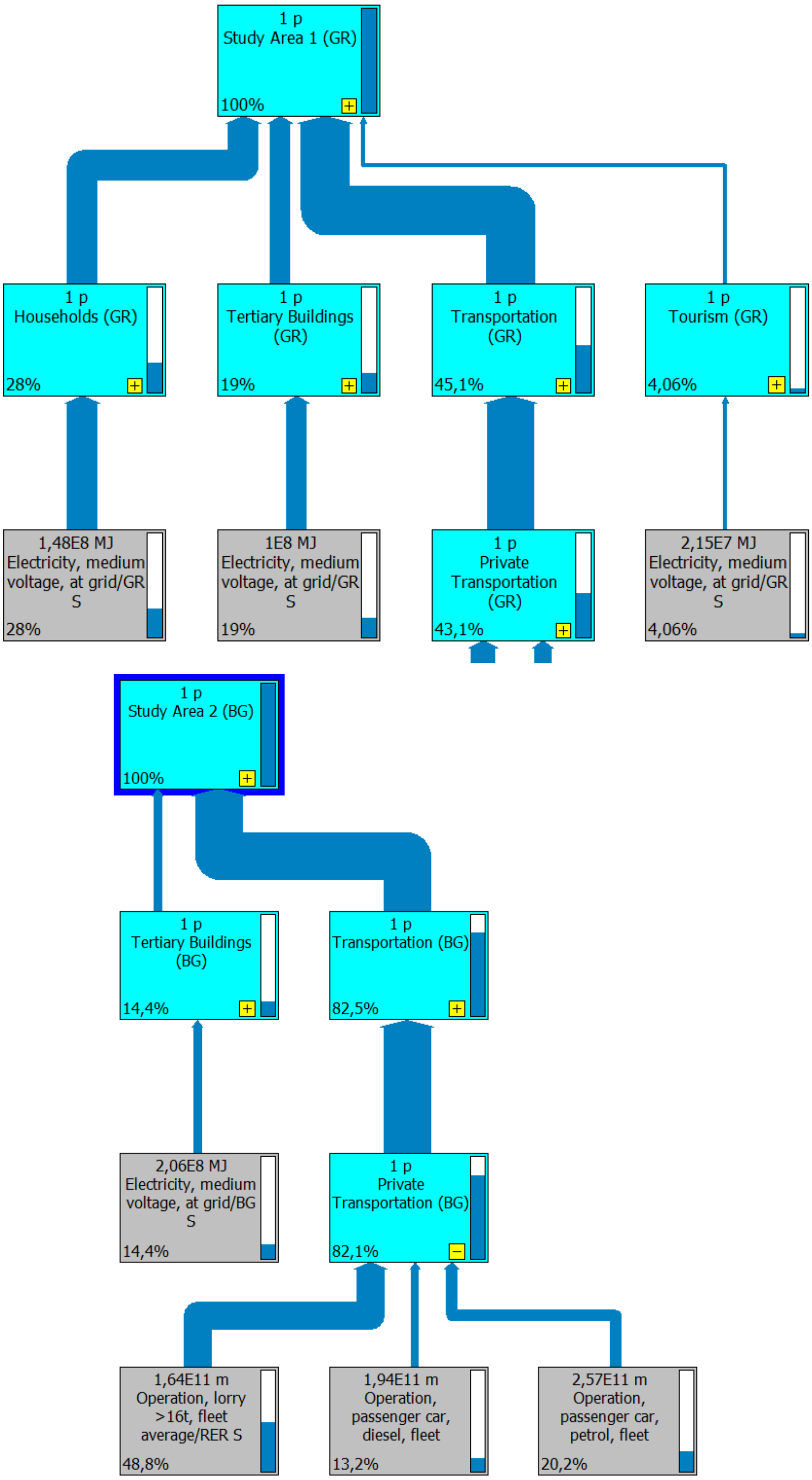


Figure 3-18: Contribution (%) of individual elements to the environmental indicator «Urban Land Occupation» (Study Area 1 – up; Study Area 2 – down).

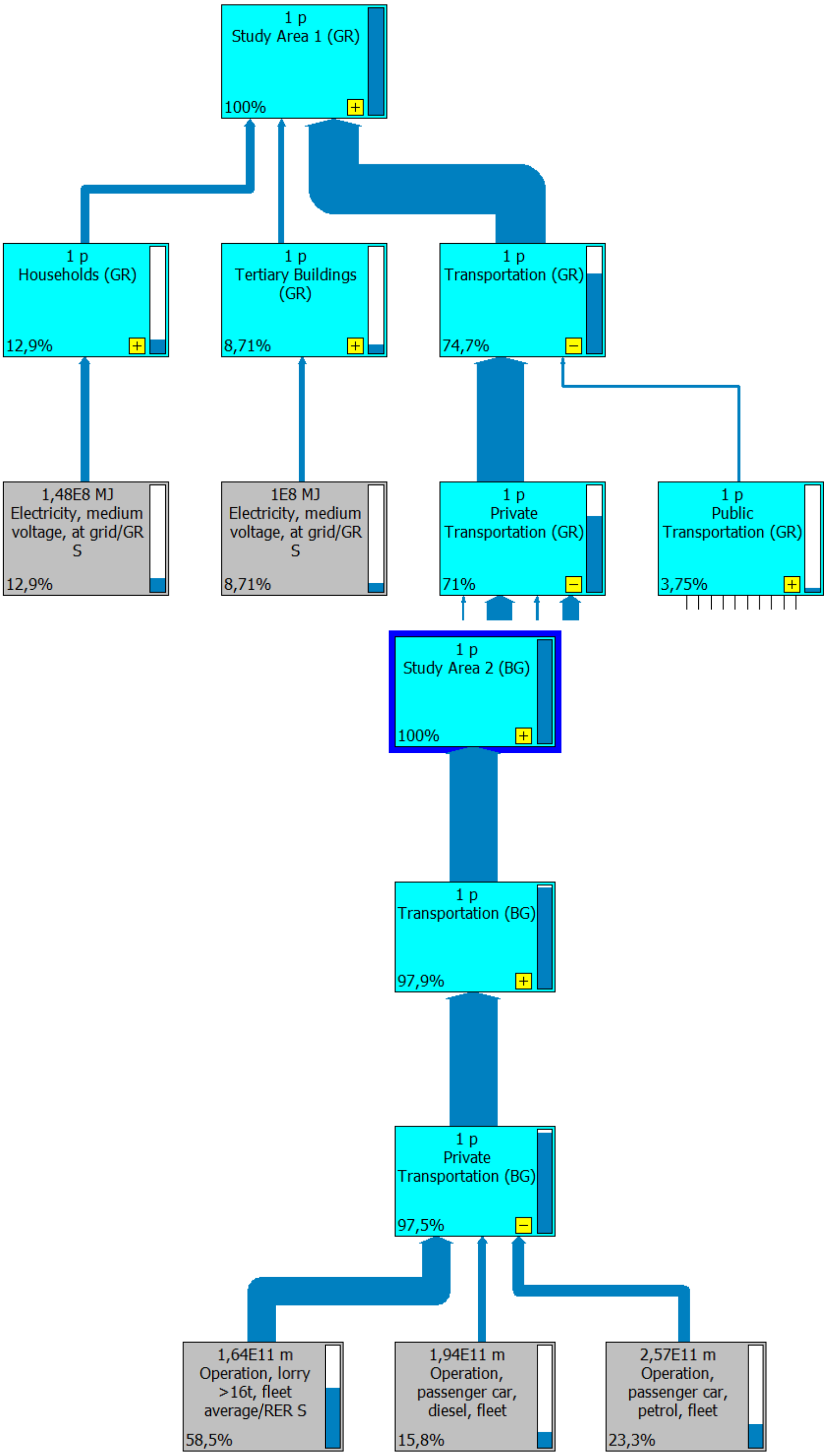


Figure 3-19: Contribution (%) of individual elements to the environmental indicator «Natural Land Occupation» (Study Area 1 – up; Study Area 2 – down).

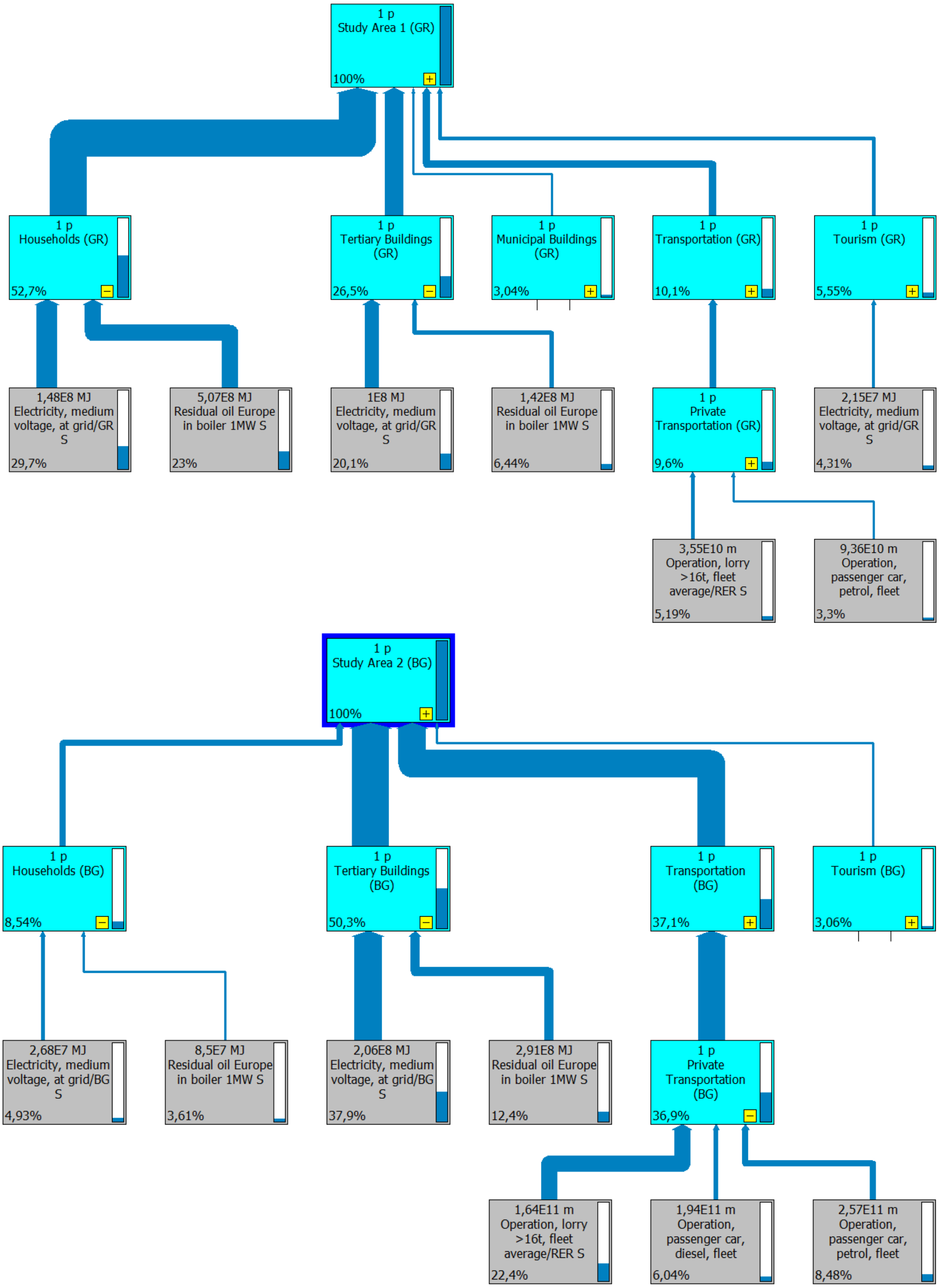


Figure 3-20: Contribution (%) of individual elements to the environmental indicator «Water Depletion» (Study Area 1 – up; Study Area 2 – down).

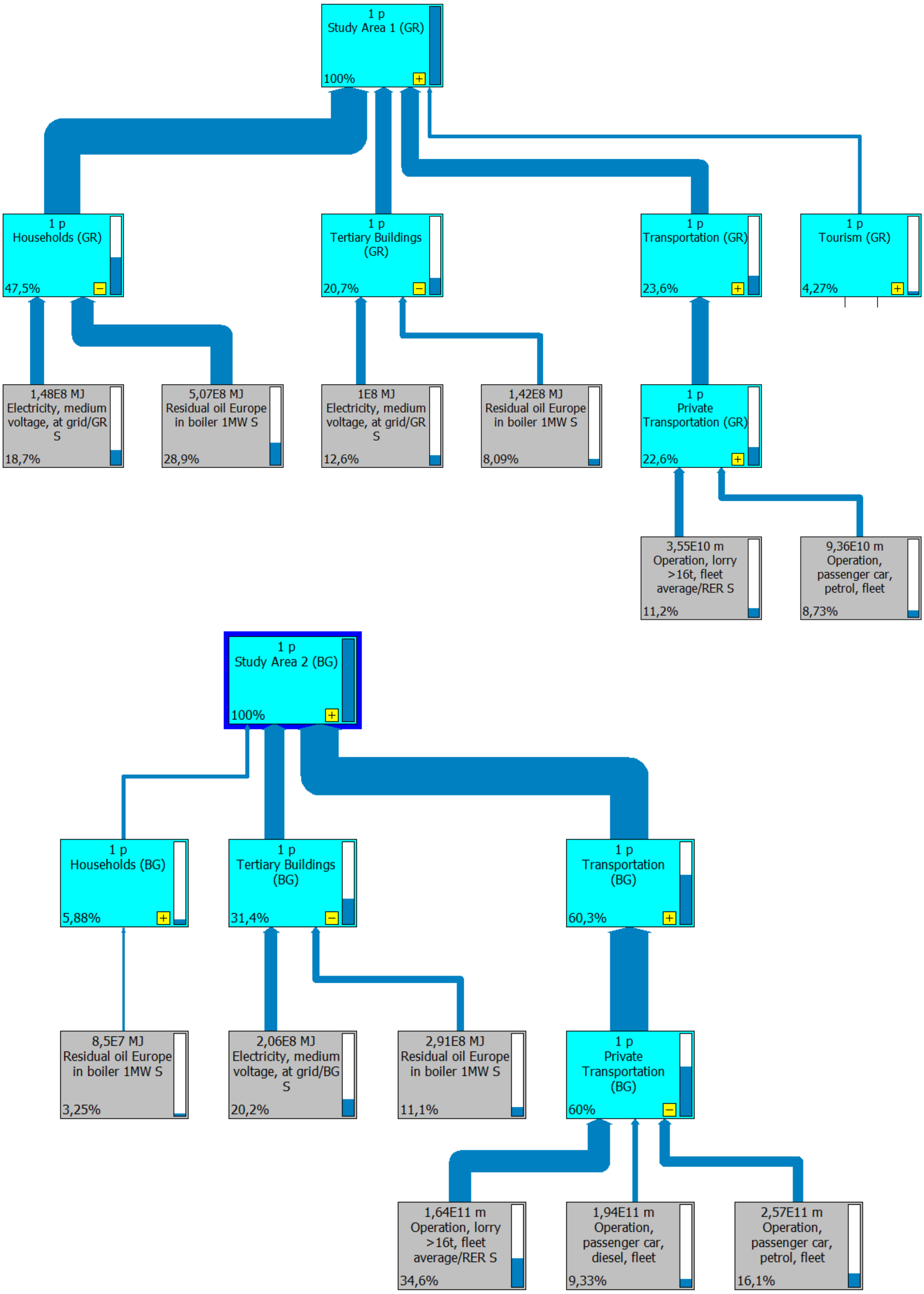


Figure 3-21: Contribution (%) of individual elements to the environmental indicator «Mineral Resource Depletion» (Study Area 1 – up; Study Area 2 – down).

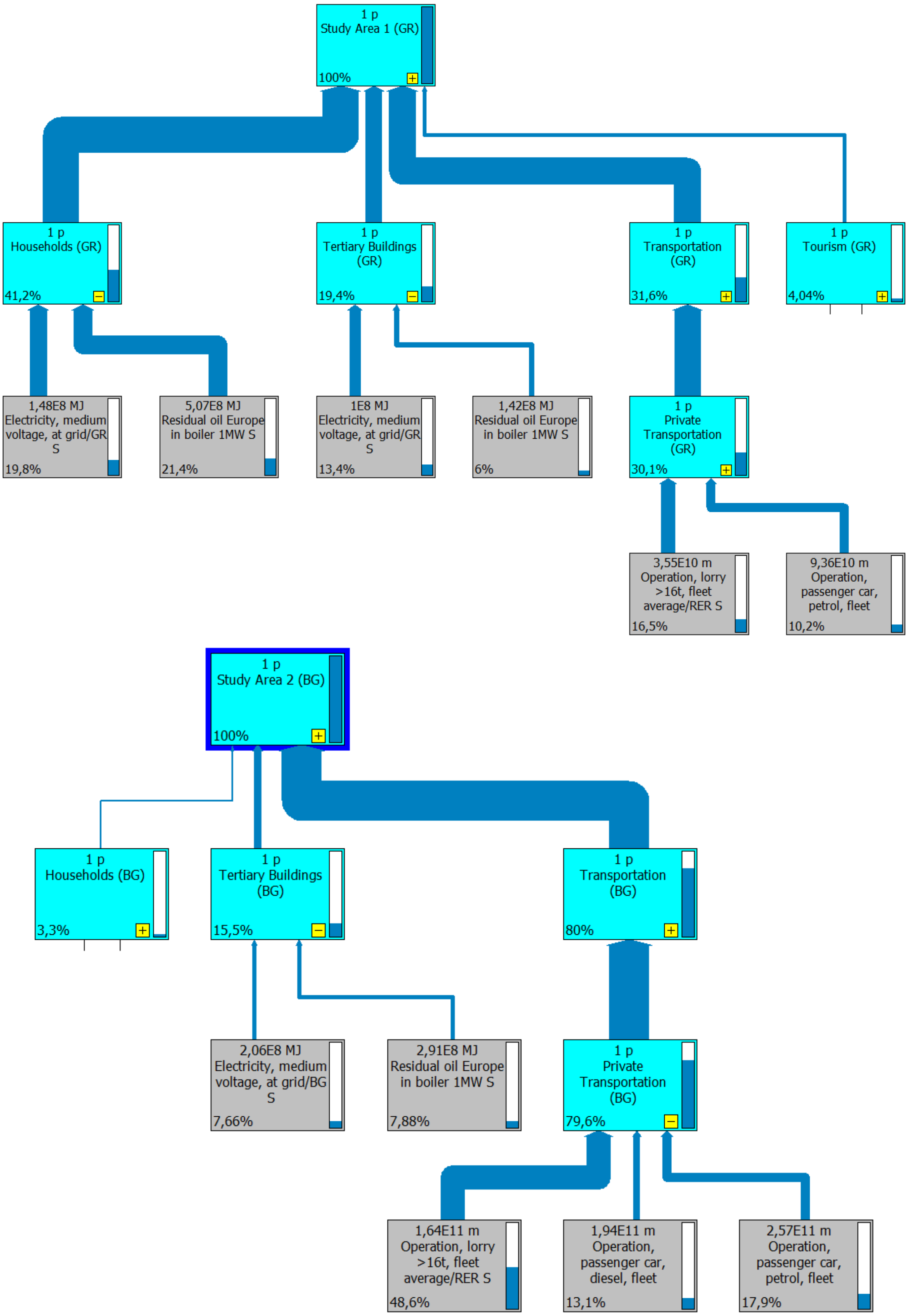


Figure 3-22: Contribution (%) of individual elements to the environmental indicator «Fossil Resource Depletion» (Study Area 1 – up; Study Area 2 – down).

Regarding Study Area 1 (GR) in most impact categories, Households contribute to more than 40% to the environmental indicators assessed. However, the contribution of the transport sector to the categories of marine eutrophication, photochemical oxidant formation, urban land occupation and natural land occupation is particularly high. The contribution of Tourism ranges between 3-7% in most impact categories indicating a noticeable but not alarming impact to the area. For the case of Study Area 2 (BG), Transporation is dominating most impact categories with a contribution of over 70%. Tertiary buildings are also exhibiting a significant impact in several categories, and especially freshwater eutrohication, human toxicity, freshwater ecotoxicity, marine ecotoxicity, ionizing radiation, agricultural land occupation and water depletion, where a contribution of >60% is observed. The contribution of Households and Tourism ranges from 3-13% depending on the impact assessment category. The two study areas, present a much differentiated profile and different targeted interventions are needed for each case to increase the environmental performance (with Study Area 1 focusing on residential households and Study Area 2 focusing on private transporation and tertiary buildings).

3.4.2 The Eco-Indicator 99 method (Endpoint evaluation)

The Eco-Indicator 99 method aims to capture the damage caused by environmental impacts. The results of the data inventory are captured in eleven categories of impacts and are analytically described in Tables 3-4 and 3-5 for Study Areas 1 and 2 respectively.

Table 3-4: LCA results for Study Area 1 (GR) using the Eco-Indicator 99 method.

s/n	Impact Category	Unit	Value
1	Carcinogens	DALY	$6{,}65\times10^{1}$
2	Resp. organics	DALY	$4{,}52\times10^{-1}$
3	Resp. inorganics	DALY	$2{,}00\times10^{2}$
4	Climate change	DALY	$4{,}64\times10^{1}$
5	Radiation	DALY	$2{,}25\times10^{-1}$
6	Ozone layer	DALY	$1{,}11\times10^{-1}$
7	Ecotoxicity	PAF×m^2×yr	$9{,}85\times10^{7}$
8	Acidification / Eutrophication	PDF×m^2×yr	$5{,}50\times10^{6}$
9	Land use	PDF×m^2×yr	$1{,}19\times10^{6}$
10	Minerals	MJ surplus	$5{,}93\times10^{5}$
11	Fossil fuels	MJ surplus	$2{,}93\times10^{8}$

Table 3-5: LCA results for Study Area 2 (BG) using the Eco-Indicator 99 method.

s/n	Impact Category	Unit	Value
1	Carcinogens	DALY	$2{,}96\times10^{1}$
2	Resp. organics	DALY	$5{,}08\times10^{-1}$
3	Resp. inorganics	DALY	$3{,}04\times10^{2}$
4	Climate change	DALY	$7{,}53\times10^{1}$
5	Radiation	DALY	$9{,}22\times10^{-1}$
6	Ozone layer	DALY	$9{,}94\times10^{-2}$
7	Ecotoxicity	PAF×m^{2}×yr	$9{,}92\times10^{7}$
8	Acidification / Eutrophication	PDF×m^{2}×yr	$1{,}27\times10^{7}$
9	Land use	PDF×m^{2}×yr	$2{,}49\times10^{6}$
10	Minerals	MJ surplus	$7{,}61\times10^{5}$
11	Fossil fuels	MJ surplus	$6{,}06\times10^{8}$

According to the Eco-Indicator 99 methodology, the environmental impacts examined are divided into eleven sub-indices. These indicators can be normalized to be directly comparable to each other and can be summed to a final single index. The normalization of the indicators is done by using a non-metric unit the “Eco-points” unit (Eco Pts). In particular, 1000 Eco-points are equivalent to the annual environmental impact of an average European citizen. Data normalization and weighting for this study were performed in accordance with the proposed LCA specific software guidelines and the application of the hierarchical template. The results from the normalization of the data are given in Tables 3-6 and 3-7 for Study Areas 1and 2 respectively, while in Figures 3-23 and 3-24 the cumulative percentage contribution (in Ecos Pts) per Study Area is presented.

Table 3-6: LCA results for Study Area 1 (GR) using the Eco-Indicator 99 method (in Eco-Pts).

s/n	Impact Category	Unit	%
1	Carcinogens	$1{,}73\times10^{6}$	10,5
2	Resp. organics	$1{,}18\times10^{4}$	<1
3	Resp. inorganics	$5{,}20\times10^{6}$	32
4	Climate change	$1{,}21\times10^{6}$	7
5	Radiation	$5{,}85\times10^{3}$	<1
6	Ozone layer	$2{,}88\times10^{3}$	<1
7	Ecotoxicity	$7{,}68\times10^{5}$	4,5
8	Acidification / Eutrophication	$4{,}29\times10^{5}$	2,5
9	Land use	$9{,}28\times10^{4}$	<1
10	Minerals	$1{,}41\times10^{4}$	<1

11	Fossil fuels	$6{,}97\times10^{6}$	42
	Total Score	$1{,}64\times10^{7}$	100,0

Table 3-7: LCA results for Study Area 2 (BG) using the Eco-Indicator 99 method (in Eco-Pts).

s/n	Impact Category	Unit	%
1	Carcinogens	$7{,}70\times10^{5}$	3
2	Resp. organics	$1{,}32\times10^{4}$	<1
3	Resp. inorganics	$7{,}93\times10^{6}$	29
4	Climate change	$1{,}96\times10^{6}$	7
5	Radiation	$2{,}40\times10^{4}$	<1
6	Ozone layer	$2{,}59\times10^{3}$	<1
7	Ecotoxicity	$7{,}74\times10^{5}$	3
8	Acidification / Eutrophication	$9{,}94\times10^{5}$	3,5
9	Land use	$1{,}94\times10^{5}$	<1
10	Minerals	$1{,}81\times10^{4}$	<1
11	Fossil fuels	$1{,}44\times10^{7}$	53
	Total Score	$2{,}71\times10^{7}$	100,0

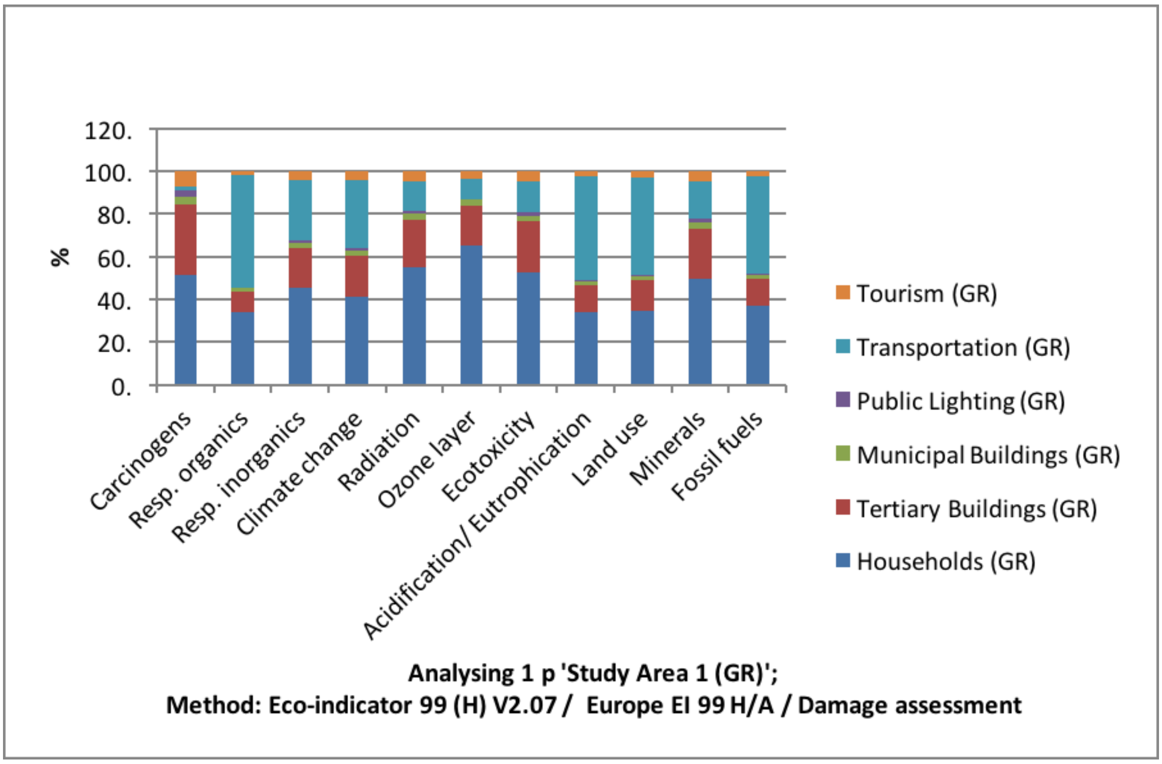


Figure 3-23: Contribution (%) to the final overall environmental impact of Study Area 1 (GR) according to the Eco-Indicator 99 method.

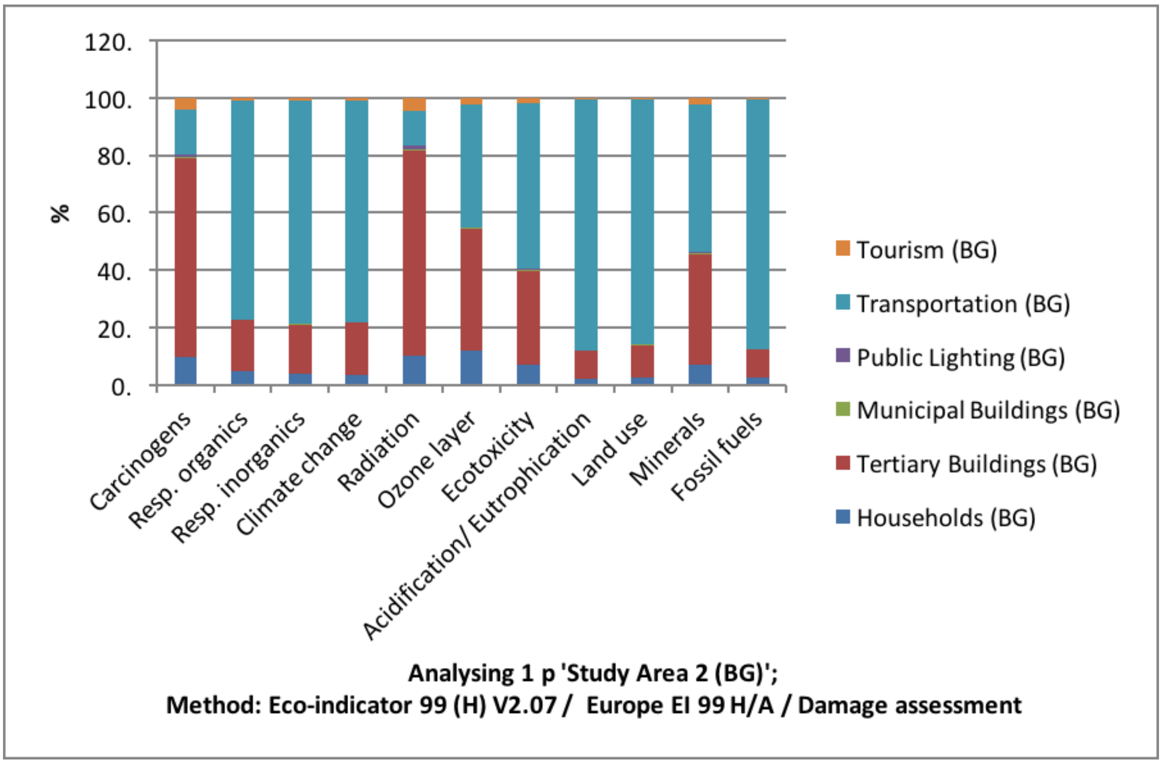


Figure 3-24: Contribution (%) to the final overall environmental impact of Study Area 2 (BG) according to the Eco-Indicator 99 method.

The annual environmental impact of the two Study Areas resulting from the consumption of electricity and fuel for the specific anthropogenic activities included in the analysis amounts to 16,400,000 Eco Pts or 560 Eco Pts / inhabitant for Study Area 1 and 27,100,000 Eco Pts or 390 Eco Pts / inhabitant for Study Area 2. Assuming that the average resident of the two Study Areas has a similar environmental impact to the average European citizen, i.e. 1,000 Eco Pts, this means that of the total annual environmental impact of an average inhabitant of the Study Areas (1,000 Eco Pts), about half is due to the satisfaction of of its needs for electricity, heating and transport, while the remainder is due to needs of clothing, food, cleaning, purchase of materials, etc. The use of a single score makes it possible to find the environmental impact indicators most affected by the processes examined. In the case of this study, the satisfaction of the energy needs of the Study Areas mainly affects the categories Carcinogens, Respirable Inorganics, Climate Change and Fossil fuels (Figures 3-25 and 3-26). This means that emissions of inorganic aerosol particles emitted within the Study Areas, which are responsible for various respiratory problems, should be taken into particular account with the existing profile of activities and emissions of pollutants in environmental media (atmosphere, hydrosphere, soil).

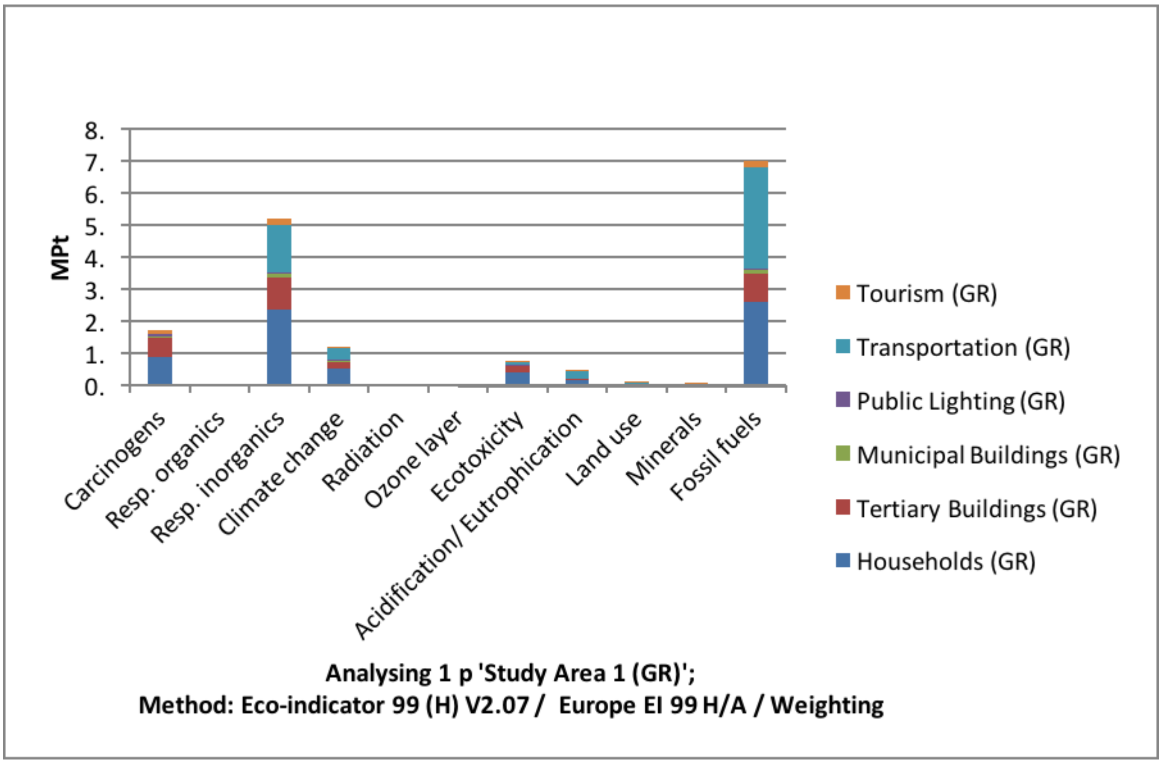


Figure 3-25: Normalization of Data with the utilization of Eco-Indicator 99 (Study Area 1).

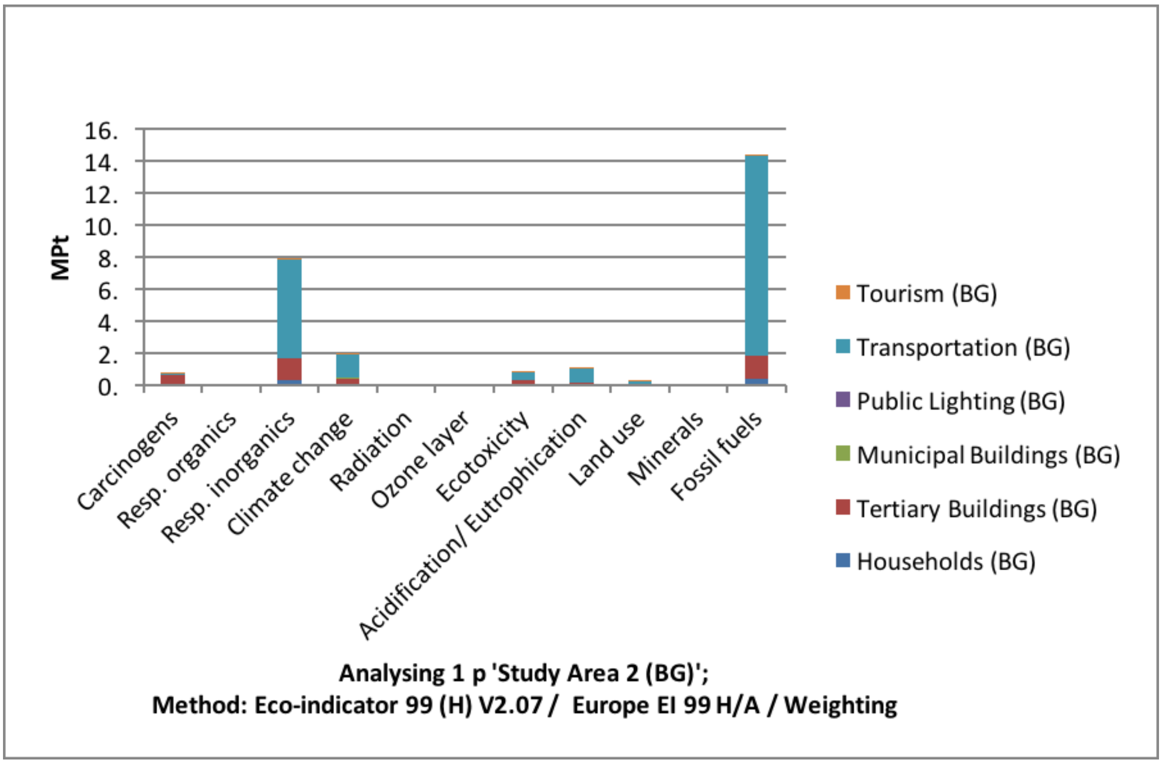


Figure 3-26: Normalization of Data with the utilization of Eco-Indicator 99 (Study Area 2).

3.5 Social LCA of the existing situation

Introduction

The ultimate goal of sustainable development is human well-being, contributing to the needs of current and future generations. Each and every operationalization through the policy instruments or an enterprise strategy, supported by methodologies, techniques and tools, which can contribute to this objective, is highly recommended. Because of that United Nations Environment Program developed the guidelines for Social Life Cycle Assessment of products.

The UNEP Guidelines for Social Life Cycle Assessment of Products provides a road map, for stakeholders responsible for the assessment of social and socio-economic impacts of products life cycle (UNEP, guidelines, 2009).

The map is important because it provides the key concepts and describe which tools and techniques will be used and their scope in the proposed social LCA models. It is one of the main step towards Sustainable Development and also shared concerns about the state and sustainability of environmental, economic and social dimensions of today’s and tomorrow’s. The move towards sustainability is based on sustainable production and consumption. Beside sustained economic profitability the sustainability is firmly connected with the social responsibility of organizations and their ultimate goal to improve social and environmental performances (UNEP, guidelines, 2009). Because the Socio-Economic relations are tight together in complex holistic system, Life Cycle Assessment is the preferred tool when it comes to access information about potential and real impacts of products life cycle (UNEP, guidelines, 2009).

Life cycles of products involve material, energy and economic flows, but the social LCA guidelines are also related to the impacts that production and consumption have on the workers and the local communities. Farther more, the S-LCA Guidelines provides the key elements to consider and provide guidance for the goal and scope, inventory, impact assessment and interpretation phases of a social life cycle assessment (UNEP, guidelines, 2009). Third, the *S-LCA Guidelines* provide information about the highlight areas where further research is needed.

Social Life Cycle Assessment is a technique available to account for stories and inform systematically on impacts that otherwise would be lost in the vast and fast moving sea of the modern world ((UNEP, guidelines, 2009). It help stakeholders to effectively and efficiently engage to improve social and socio-economic conditions of production and consumption.

Socio-economic LCA

The discussion about the social and socio-economic involvement in Life Cycle Assessment started about fifteen years ago, with the publication of the SETAC Workshop Report:
"A Conceptual Framework for Life Cycle Impact Assessment" (Fava J. et al., 1993). In this report a "social welfare impact category" was proposed by stating that, *"… the primary emphasis should be on environmental impacts that arise directly or indirectly from other social impacts …." (UNEP, guidelines, 2009)*
The proposed social impact category helped begin a more comprehensive discussion among LCA methodology developers.

During the second half of the nineties, researchers discussed – sometimes in a multidisciplinary environment in which social scientists were working together with (applied) natural scientists – if "life cycle assessment" of a product or a service taking into account social criteria is different from the usual environmental LCA. Several problems were raised:

- What about the system boundaries?
- Are there issues raised by translating criteria into impacts?
- Does a LCA really need to limit itself to social (and economic) impacts directly or indirectly influencing other environmental impacts?
- Shouldn't the social criteria be linked to international agreements?
- What about the interdependency between the environmental, social and economic criteria when assessing a product or a service?

At the beginning of this century, some research groups presented their methodologies for cradle to grave assessment of goods and services with social criteria. Some of these methodologies were branded as "S-LCA" studies. In some of the methodologies the "s" was indeed referring to "social," while others were going a step further by presenting a "sustainability LCA"(UNEP, Guidelines, 2009).
At the same time, similar exercises were being undertaken in parallel with the "LCA world's" research. As a result, several social assessment tools were developed.

Other authors, already envisioned the need to address the social dimension in life cycle tools to be developed (Brent A. and Labuschagne C., 2006; Jørgensen A, et. al., 2008; Hunkeler R,et.

al., 2005; Hutchins and Sutherland, 2008; Dreyer L, et. al., 2006; Brent A, et al., 2006; Klöpffer W., 2003; O'Brian M, et. al., 1996).

By the end of 2003, the UNEP/SETAC Life Cycle Initiative recognized the need of integration of social criteria into LCA and try to find a workable solution on the major conflict between the economical growth and the sustainable development. There were two major problems that had to be solved:

1. LCA can be considered to be 'anti-development'-orientated because it provides only apicture of negative environmental consequences, but does not reflect any of the positive aspects of development, i.e. social and economic benefits (UNEP, guidelines, 2009).
2. Even if the value of LCA is appreciated, a justification for the high costs is lacking since it does not address the developing countries' most significant concerns, i.e. poverty eradication together with other social aspects such as employment rates, wages, accidents, working conditions and human rights (UNEP, guidelines, 2009).

Two propose a workable solution UNEP/SETAC Life Cycle Initiative developed the guidelines to convert the existing environmental LCA tools into a triple-bottom-line sustainable development tool and to establish a framework for the inclusion of socio-economic benefits into LCA.

Socio-economic aspects of the existing situation in project area 2

Assessment framework

Subcategories are the basis of a S-LCA assessment because they are the items on which justification of inclusion or exclusion needs to be provided. The subcategories are socially significant themes or attributes. Subcategories are classified according to stakeholder and impact categories and are assessed by the use of inventory indicators, measured by unit of measurement (UNEP, guidelines, 2009).

Social/socio-economic subcategories may be first classified by stakeholder categories and second by Impact categories (UNEP, guidelines, 2009). Below is presented a general assessment reference framework.

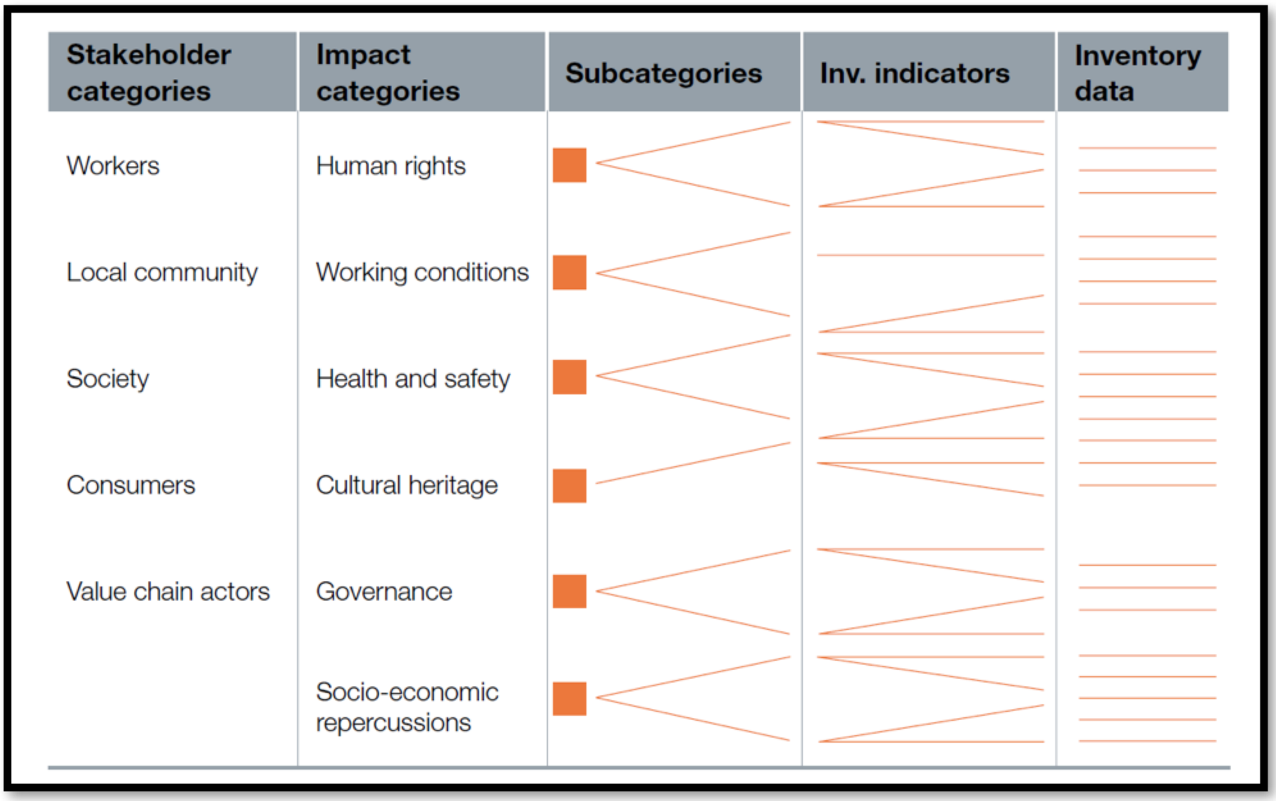


Fig. 1. Assessment system from categories to unit of measurement (Adapted from Benoit et al., 2007).

Municipality and Directorate of Rila National Park as stake holder

Based on the above in project area 2 is developed similar assessment frame work to assess the s-LCA. The framework has been divided in to similar categories plus two categories are added to the stakeholders categories municipality of Blagoevgrad and the Directorate of Rila National Park. Both are multidimensional stakeholder playing several roles and have a crucial regulatory

Role. The municipality control the economic development and the organization of the economic activities on it's territory and also controls the some of the living stages of the products as final deposition, recycling or re-sued of the products. The directorate of Rila National Park on the other side has control function that regards the economic activity inside the national park's territory and the biodiversity preservation.

Stakeholder categories	**Subcategories**
Stakeholder municipality and the directorate of Rila National Park	
Stakeholder "worker"	• Freedom of Association and Collective

	Bargaining • Child Labour • Fair Salary • Working Hours • Forced Labour • Equal opportunities/Discrimination • Health and Safety • Social Benefits/Social Security
Stakeholder "consumer"	• Health & Safety • Feedback Mechanism • Consumer Privacy • Transparency • End of life responsibility
Stakeholder "local comunity"	• Access to material resources • Access to immaterial resources • Delocalization and Migration • Cultural Heritage • Safe & healthy living conditions • Respect of indigenous rights • Community engagement • Local employment • Secure living conditions
Stakeholder "Society "	• Public commitments to sustainability issues • Contribution to economic development • Prevention & mitigation of armed conflicts • Technology development • Corruption

Fig. 2. Assessment categories for S-lCA of project area 2

Workers as a stakeholder

In the municipality of Blagoevgrad, more than 800 companies work in the industrial sector, and most of the companies are operating in the trade sector. Despite the variety of economic activities, several industrial sectors can be outlined as leading sectors in Blagoevgrad municipality: food industry, productions of beverages and tobacco processing**.**

In the period 2011-2015 the number of employees remained almost unchanged with a slight decrease in the core and a small growth in the periphery. Almost all employees (91%) work in the core and only 7% - in Simitli. By 2015, the distribution of sectoral employment was relatively even, with a slight prevalence of processing industry (22%) and trade (14%). The sectors: "Extractive Industries" and "Real Estate Operations" are almost absent. The large share of education is impressed - it accounts for 11% of all employees in Blagoevgrad compared to 7% on average for the country. In 2016, the **unemployment rate** in Blagoevgrad is **7.38%** as presented on Figure 3. These levels remain relatively stable throughout the 2011-2016 period, with a peak in 2012-2013

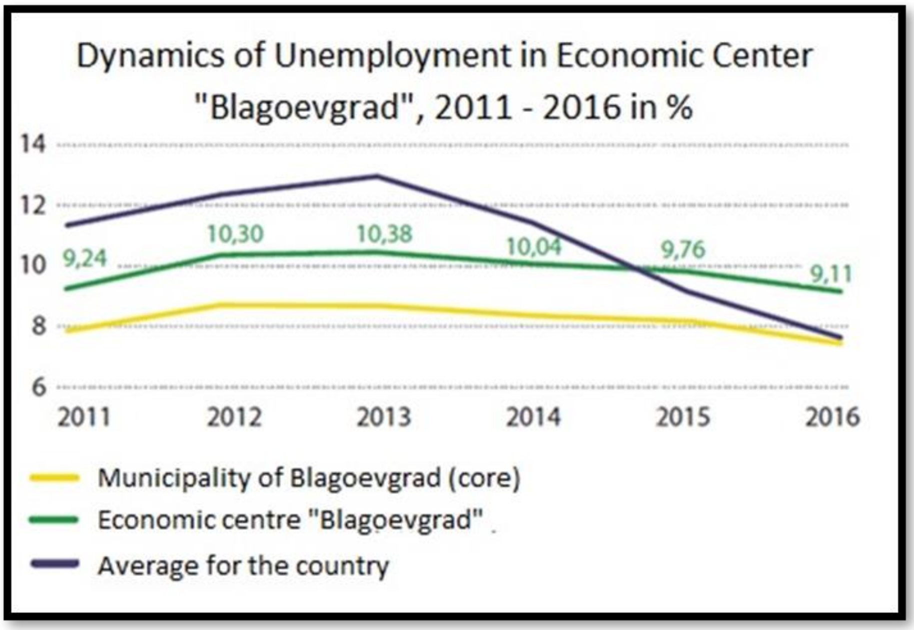


Fig. 3. Unemployment rate changes in the Economic Center "Blagoevgrad", 2011 - 2016 in %

Generally the working force in the project area 2 have well defined civil rights as freedom of association – there is two major working syndicates (KT Podkrepa and The confederation of the independence syndicates) that observing and protecting the rights of the workers. The child labor as well as the force labor is forbidden on the territory of the country. The rules of the Equal opportunities and not discrimination are strictly observed as they are guarantee by the constitution of the country. There is a well-developed network of health care providing institutions including municipality hospital, emergency center, private hospital and specialized hospital for treatment of cancer diseases. The average monthly salary in the project area is below the average monthly salary of the country and it need to be revised upwards (fig.4.). All workers has social benefits and state guarantee social security.

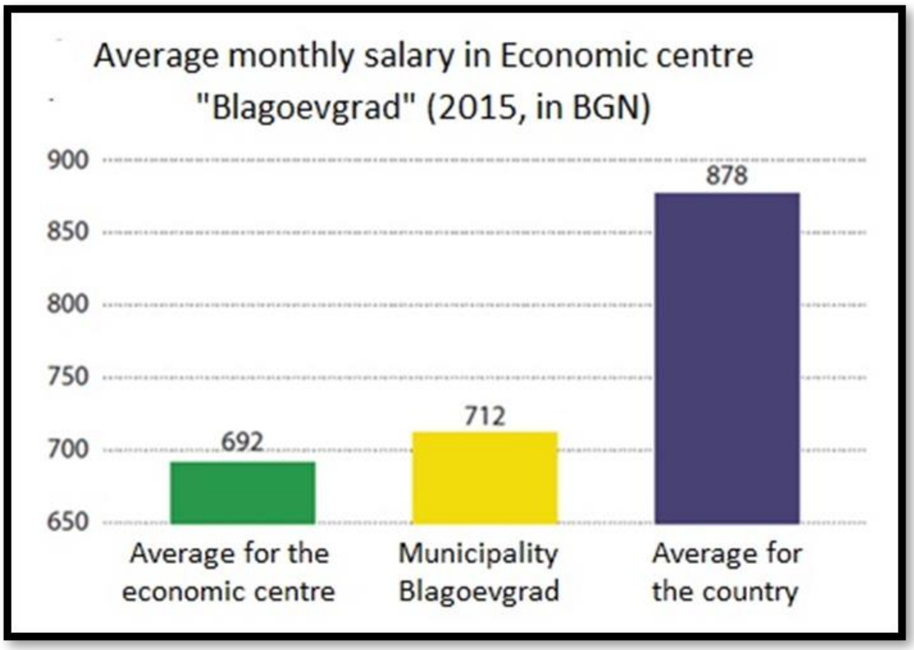


Fig. 4. The average gross monthly salary in Blagoevgrad municipality for 2015 is BGN 712.

Consumers as a stake holder

There is a well-developed government mechanisms for control of the health and safety of the consumers in the project area by supervising the quality of consumed products. The responsibilities of this control function lies with the authorities of Regional Health Inspection, Regional Directorate for Food Safety, Regional Inspectorate for Natural and Water protection. For protection of the consumers rights is responsible the local branch of the Commission for consumer protection. The consumers are responsible for end of the life disposal of some products as they have an opportunity separate disposal of waste as plastic, glass, iron and hazardous products as Battery for example.

Local community as a stakeholder

Because of the geographical position and natural characteristics of the area as the proximity of Rila, Pirin, Vlahina mountains and the agricultural lands in the vicinity of Struma river valley the local community in Blagoevrdatzka Bistritza River catchment area is well supplied with material resources. More over the town of Blagoevgrad with its economic, cultural and educational resources contribute to the well-being of the local community. The proximity of Rila National Park and numerous cultural heritage sites are the needed preconditions for well develop tourist industry and recreation industry. The local community can rely on secure living conditions and well-developed network of health care providing institutions including municipality hospital, emergency center, private hospital and specialized hospital for treatment of cancer diseases.

The economic situation and low average salary is the main reason the commitment of the local community to the sustainability not to be on the needed high level and additional political and economic measures are required to raise the level of commitment. The primary use of natural resources is still main contribution to the economic development, because of that more investment are needed to achieve a technological advanced and sustainable local economy.

Conclusions

Socio-economic situation in the research area possess complex and multi-layer features. On one side the local communities are provided with sufficient amount of social services which combined with the environmental and economic features of the area are the founding preconditions for establishing a good standard of living. On the other hand, the well-being of the local community is jeopardize by the relatively low income and the level of the average salary that is lower than the average in the country.

Additional political and economic measures have to be adopt in order to rise the commitment to sustainability of the local society, more over the constantly increasing environmental standards and the contemporary realities of the economic scene will further exacerbate the crisis in the traditional industrial sectors in the area.

The project area has to transform from a typical center of traditional industry for the region into a center of science, innovation, services and environment-friendly productions. The presence of specialists in the application and implementation of projects funded by the EU will facilitate the attraction of investments for sustainable economic initiatives. An increasingly important role towards the circular economy and sustainable use of the natural resources can be played by the academic institution in the area.

Chapter 4 - Life Cycle Assessment of the symbiotic scenario

4.1 New inventory for study area 1

In Chapter 2.1, a detailed analysis of symbiotic activities, based on the principles of Circular Economy for Study Area 1 is presented. The identification and selection of the appropriate symbiotic activities was based on literature review of successful practices, aiming to potential environmental, economic and social benefits, while taking into account the specific features of study area 1 and its reach to biodiversity. The proposed activities (see Chapter 2.1 for more details) can lead to an estimated reduction of 4,320 tonnes CO_2 and 87,250MWh of oil for heating (which corresponds to about 45% reduction of current consumption). The specific savings lead to a new inventory and a new LCA model that can be re-evaluated in order to compare the new findings with the current situation of the area (assessed in detail in Chapter 3), thus examining the potential benefits of the proposed symbiotic scenario. It should be mentioned that several more symbiotic activities are proposed in Chapter 2.1, which cannot be directly quantified and modeled using LCA. These activities are expected to significantly contribute to regional development and social cohesion and will result in additional environmental, economical and social benefits in the future. In that aspect the results-benefits presented in this Chapter, are considered under-estimated. The same approach followed in Chapter 3 to assess the current situation of Study Area 1, is adopted also in this case to perform the LCA of the symbiotic scenario:

Definition of the objectives (Goal): The goal of the specific LCA is to compare the potential reduction of the environmental impact of current anthropogenic activities within the boundaries of Study Area 1 (GR), with a proposed symbiotic scenario under the circular economy framework.

Functional Unit: The functional unit set is the satisfaction of the energy needs (serving as a key indicator of anthropogenic activity in the area) of the residents and visitors of Study Area 1 for one year (cuurent vs symbiotic scenario).

Boundaries of the system under examination (Scope): The same boundaries with the analysis performed in Chapter 3 are adopted to support comparability of the results. The following data have been identified that need to be quantified to develop the symbiotic LCA model for Study Area 1 (in bold font the values that have changed in comparison with the current situation are indicated).

Households

	Value	Unit
Total electricity consumption	41,187,497	kWh
Total heating oil consumption	**77,424,192**	kWh

Tertiary Buildings

	Value	Unit
Total electricity consumption	27,889,270	kWh
Total heating oil consumption	**21,699,665**	kWh

Municipal Buildings

	Value	Unit
Total electricity consumption	2,902,548	kWh
Total heating oil consumption	**3,200,287**	kWh

Public Lighting

	Value	Unit
Total electricity consumption	2,866,590	kWh

Transportation *(in this case consumption of energy is estimated indirectly based on the available LCA modules)*

	Value	Unit
Private Transportation		
Operation of scooters	31,485,000	km
Operation of heavy duty vehicles	35,540,764	km
Operation of passenger cars (diesel)	19,179,543	km
Operation of passenger cars (petrol)	93,641,299	km
Public Transportation		
Operation of scooters	52,500	km
Operation of heavy duty vehicles	937,500	km
Operation of passenger cars (diesel)	91,800	km
Operation of passenger cars (petrol)	448,200	km
Operation of buses	924,662	km
Operation of regional train	1,533,000	personkm
Operation of small ships	2,152,673	tkm
Operation of large ships/tankers	358,730	tkm
Operation of passenger aircraft	4,851,199	personkm
Operation of freight aircraft	7,260	tkm

Tourism

	Value	Unit
Total electricity consumption	5,977,360	kWh
Total heating oil consumption	**4,079,675**	kWh

4.2 New inventory for study area 2

For the case of Study Area 2, the proposed symbiotic activities (see Chapter 2.2 for more details) can lead to an estimated reduction of 6,388 MWh of electricity (which corresponds to about 9% reduction of current consumption) basically attributed to methane recovery. The specific savings lead to a new inventory and a new LCA model that can be re-evaluated in order to compare the new findings with the current situation of the area (assessed in detail in Chapter 3), thus examining the potential benefits of the proposed symbiotic scenario. As in the case of Study Area 1, there are several more symbiotic activities proposed in Chapter 2.2, which cannot be directly quantified and modeled using LCA. These activities are expected to significantly contribute to regional development with a focus to transform the classic industrial center to a modern economic center of innovative and educational initiatives. Respectively, the results-benefits presented in this Chapter, are considered under-estimated. The same approach followed in Chapter 3 to assess the current situation of Study Area 2, is adopted also in this case to perform the LCA of the symbiotic scenario:

Definition of the objectives (Goal): The goal of the specific LCA is to compare the potential reduction of the environmental impact of current anthropogenic activities within the boundaries of Study Area 2 (BG), with a proposed symbiotic scenario under the circular economy framework.

Functional Unit: The functional unit set is the satisfaction of the energy needs (serving as a key indicator of anthropogenic activity in the area) of the residents and visitors of Study Area 2 for one year (cuurent vs symbiotic scenario).

Boundaries of the system under examination (Scope): The same boundaries with the analysis performed in Chapter 3 are adopted to support comparability of the results. The following data have been identified that need to be quantified to develop the symbiotic LCA model for Study Area 2 (in bold font the values that have changed in comparison with the current situation are indicated).

Households

	Value	Unit
Total electricity consumption	**6,769,132**	kWh
Total heating oil consumption	23,614,450	kWh

Tertiary Buildings

	Value	Unit
Total electricity consumption	**52,047,310**	kWh
Total heating oil consumption	80,927,154	kWh

Municipal Buildings

	Value	Unit
Total electricity consumption	**320,806**	kWh
Total heating oil consumption	819,252	kWh

Public Lighting

	Value	Unit
Total electricity consumption	**910,000**	kWh

Transportation *(in this case consumption of energy is estimated indirectly based on the available LCA modules)*

	Value	Unit
Private Transportation		
Operation of scooters	-	km
Operation of heavy duty vehicles	163,761,260	km
Operation of passenger cars (diesel)	193,783,800	km
Operation of passenger cars (petrol)	256,876,200	km
Public Transportation		
Operation of scooters	-	km
Operation of heavy duty vehicles	-	km
Operation of passenger cars (diesel)	1,542,427	km
Operation of passenger cars (petrol)	2,044,613	km
Operation of buses	286,200	km
Operation of regional train	-	personkm
Operation of small ships	-	tkm
Operation of large ships/tankers	-	tkm
Operation of passenger aircraft	-	personkm

Operation of freight aircraft	-	tkm

Tourism

	Value	Unit
Total electricity consumption	**3,062,686**	kWh
Total heating oil consumption	4,676,790	kWh

4.3 LCA Model

The following revised models are shaped for Study Areas 1 and 2, based on proposed symbiotic actions:

LCA Model Structure for Study Area 1 (GR)

1st Level: Materials/Assemblies: Households (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	41,187,497	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	**77,424,192**	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Tertiary Buildings (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	27,889,270	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	**21,699,665**	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Municipal Buildings (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	2,902,548	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	**3,200,287**	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Public Lighting (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	2,866,590	kWh	Ecoinvent

1st Level: Materials/Assemblies: Transporation (1p)

2nd Level: Sub-Assembly: Private Transportation (1p)

Processes Utilized	Value	Unit	Database
Operation, scooter/CH S	31,485,000	km	Ecoinvent

Operation, lorry >16t, fleet average/RER S	35,540,764	km	Ecoinvent
Operation, passenger car, diesel, fleet average/RER S	19,179,543	km	Ecoinvent
Operation, passenger car, petrol, fleet average 2010/RER S	93,641,299	km	Ecoinvent

2nd Level: Sub-Assembly: Public Transportation (1p)

Processes Utilized	Value	Unit	Database
Operation, scooter/CH S	52,500	km	Ecoinvent
Operation, lorry >16t, fleet average/RER S	937,500	km	Ecoinvent
Operation, passenger car, diesel, fleet average/RER S	91,800	km	Ecoinvent
Operation, passenger car, petrol, fleet average 2010/RER S	448,200	km	Ecoinvent
Operation, regular bus/CH S	924,662	km	Ecoinvent
Operation, regional train, SBB mix/CH S	1,533,000	personkm	Ecoinvent
Operation, barge/RER S	2,152,673	tkm	Ecoinvent
Operation, barge tanker/RER S	358,730	tkm	Ecoinvent
Operation, aircraft, passenger, Europe/RER S	4,851,199	personkm	Ecoinvent
Operation, aircraft, freight, Europe/RER S	7,260	tkm	Ecoinvent

1st Level: Materials/Assemblies: Tourism (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/GR S	5,977,360	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	**4,079,675**	kWh	ETH-ESU 96

LCA Model Structure for Study Area 2 (BG)

1st Level: Materials/Assemblies: Households (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	**6,769,132**	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	23,614,450	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Tertiary Buildings (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	**52,047,310**	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	80,927,154	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Municipal Buildings (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	**320,806**	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	819,252	kWh	ETH-ESU 96

1st Level: Materials/Assemblies: Public Lighting (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	**910,000**	kWh	Ecoinvent

1st Level: Materials/Assemblies: Transporation (1p)

2nd Level: Sub-Assembly: Private Transportation (1p)

Processes Utilized	Value	Unit	Database
Operation, scooter/CH S	-	km	Ecoinvent
Operation, lorry >16t, fleet average/RER S	163,761,260	km	Ecoinvent
Operation, passenger car, diesel, fleet average/RER S	193,783,800	km	Ecoinvent
Operation, passenger car, petrol, fleet average 2010/RER S	256,876,200	km	Ecoinvent

2nd Level: Sub-Assembly: Public Transportation (1p)

Processes Utilized	Value	Unit	Database

Operation, scooter/CH S	-	km	Ecoinvent
Operation, lorry >16t, fleet average/RER S	-	km	Ecoinvent
Operation, passenger car, diesel, fleet average/RER S	1,542,427	km	Ecoinvent
Operation, passenger car, petrol, fleet average 2010/RER S	2,044,613	km	Ecoinvent
Operation, regular bus/CH S	286,200	km	Ecoinvent
Operation, regional train, SBB mix/CH S	-	personkm	Ecoinvent
Operation, barge/RER S	-	tkm	Ecoinvent
Operation, barge tanker/RER S	-	tkm	Ecoinvent
Operation, aircraft, passenger, Europe/RER S	-	personkm	Ecoinvent
Operation, aircraft, freight, Europe/RER S	-	tkm	Ecoinvent

1st Level: Materials/Assemblies: Tourism (1p)

Processes Utilized	Value	Unit	Database
Electricity MV at grid/BG S	**3,062,686**	kWh	Ecoinvent
Residual oil Europe in boiler 1MW S	4,676,790	kWh	ETH-ESU 96

4.4 Interpretation of the results

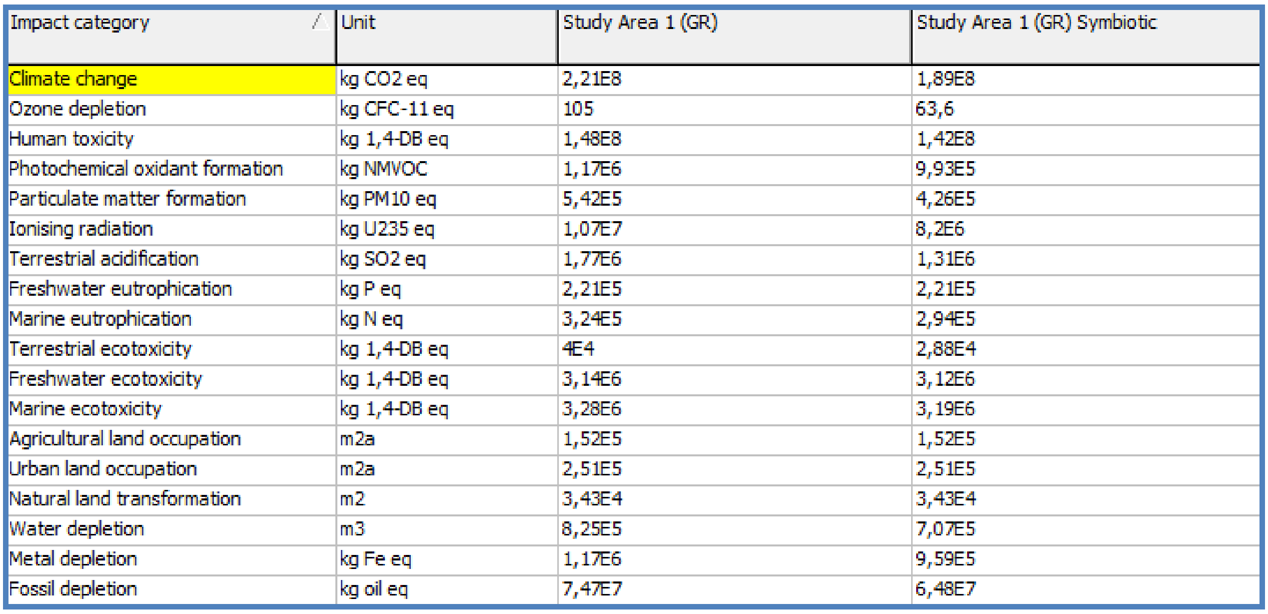
4.4.1 The ReCiPe method (Midpoint evaluation)

The final LCA results comparing the existing and symbiotic situation for Study Area 1 are presented in Table 4-1. The respective characterization and normalization results are depicted in Figures 4-1 and 4-2. The following key conlusions can be extracted based on the info presented in these Tables/Figures:

- The implementation of the proposed symbiotic activities leads to a noticeable reduction of the environmental impact in most categories and especially Ozone delpletion (a reduction of 41.4 kg of CFC-11 eq is observed) and Terrestrial ecotoxicity (a reduction of 11,200 kg 1,4-DB eq is observed).
- The carbon footprint of the Study Area 1 is reduced by 32,000 tonnes CO_2eq. If we also consider a further reduction of 4,320 tonnes as described in Chapter 2.1 due to CO_2 capture and reuse for the development of local Greenhouse, this leads to a total reduction of 36,320 tonnes of CO_2eq.

- The impact categories freshwater eutrophication, agricultural land occupation, urban land occupation and natural land transformation are not affected by the proposed symbiotic activities.

Table 4-1: Comparison of LCA results for Study Area 1 (GR) using the ReCiPe method (existing situation vs symbiotic situation).



Impact category	Unit	Study Area 1 (GR)	Study Area 1 (GR) Symbiotic
Climate change	kg CO2 eq	2,21E8	1,89E8
Ozone depletion	kg CFC-11 eq	105	63,6
Human toxicity	kg 1,4-DB eq	1,48E8	1,42E8
Photochemical oxidant formation	kg NMVOC	1,17E6	9,93E5
Particulate matter formation	kg PM10 eq	5,42E5	4,26E5
Ionising radiation	kg U235 eq	1,07E7	8,2E6
Terrestrial acidification	kg SO2 eq	1,77E6	1,31E6
Freshwater eutrophication	kg P eq	2,21E5	2,21E5
Marine eutrophication	kg N eq	3,24E5	2,94E5
Terrestrial ecotoxicity	kg 1,4-DB eq	4E4	2,88E4
Freshwater ecotoxicity	kg 1,4-DB eq	3,14E6	3,12E6
Marine ecotoxicity	kg 1,4-DB eq	3,28E6	3,19E6
Agricultural land occupation	m2a	1,52E5	1,52E5
Urban land occupation	m2a	2,51E5	2,51E5
Natural land transformation	m2	3,43E4	3,43E4
Water depletion	m3	8,25E5	7,07E5
Metal depletion	kg Fe eq	1,17E6	9,59E5
Fossil depletion	kg oil eq	7,47E7	6,48E7

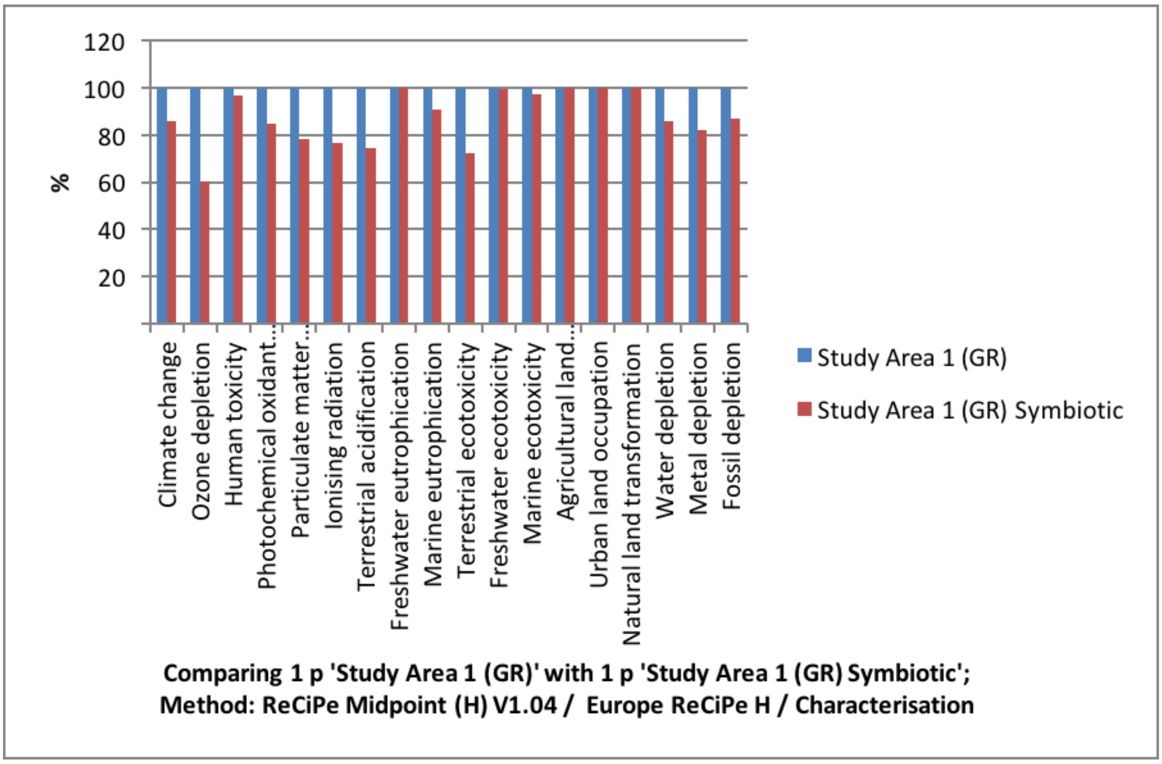


Figure 4-1: Characterization results for Study Area 1 (GR) using the ReCiPe method (existing situation vs symbiotic situation).

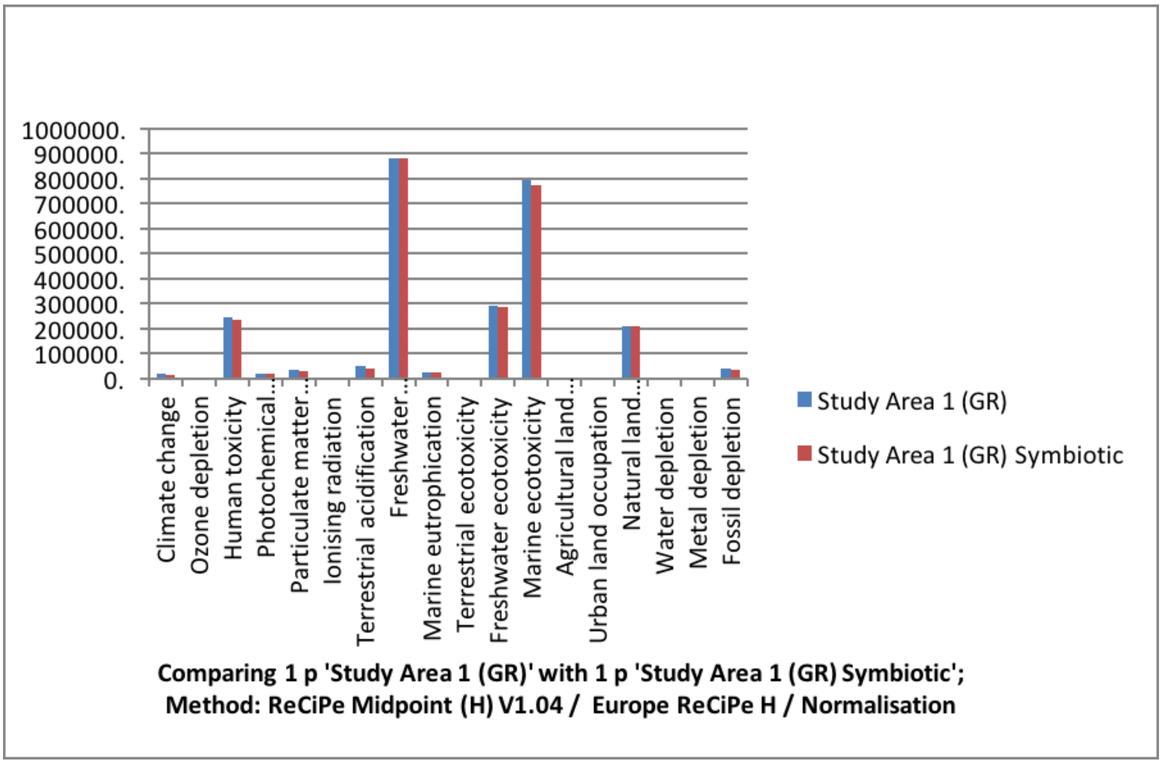
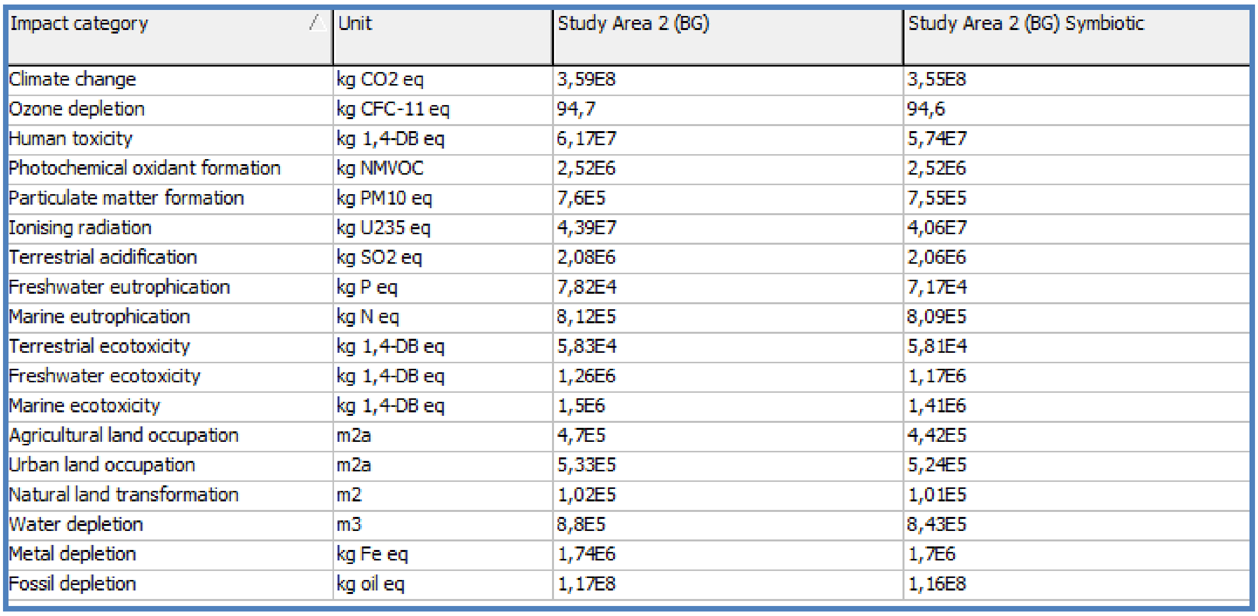


Figure 4-2: Normalization results for Study Area 1 (GR) using the ReCiPe method (existing situation vs symbiotic situation).

Respectively, the final LCA results comparing the existing and symbiotic situation for Study Area 2 are presented in Table 4-2. The respective characterization and normalization results are depicted in Figures 4-3 and 4-4. The following key conlusions can be extracted based on the info presented in these Tables/Figures:

- The implementation of the proposed symbiotic activities leads to a noticeable reduction of the environmental impact in most categories and especially Human toxicity (a reduction of 4,300 tonnes of 1,4-DB is observed), Ionizing radiation (a reduction of 3,300 tonnes of U235eq), Freshwater eutrophication (a reduction of 6.500 kg of Peq) and Freshwater ecotoxicity (a reduction of 90,000 kg 1,4-DB eq).
- The carbon footprint of the Study Area 2 is reduced by 4,000 tonnes CO_2eq. which is significantly lower than the achieved reduction of Study Area 1. Different symbiotic activities affect different aspects of the environmental performance and this is an indication that there is not a “one fits all” solution.
- In this case all impact categories are affected (even slightly) by the proposed symbiotic activities. That means that interventions leading to reduced electricity consumption present a more overall environmental impact to the examined categories.

Table 4-2: Comparison of LCA results for Study Area 2 (BG) using the ReCiPe method (existing situation vs symbiotic situation).



Impact category	Unit	Study Area 2 (BG)	Study Area 2 (BG) Symbiotic
Climate change	kg CO2 eq	3,59E8	3,55E8
Ozone depletion	kg CFC-11 eq	94,7	94,6
Human toxicity	kg 1,4-DB eq	6,17E7	5,74E7
Photochemical oxidant formation	kg NMVOC	2,52E6	2,52E6
Particulate matter formation	kg PM10 eq	7,6E5	7,55E5
Ionising radiation	kg U235 eq	4,39E7	4,06E7
Terrestrial acidification	kg SO2 eq	2,08E6	2,06E6
Freshwater eutrophication	kg P eq	7,82E4	7,17E4
Marine eutrophication	kg N eq	8,12E5	8,09E5
Terrestrial ecotoxicity	kg 1,4-DB eq	5,83E4	5,81E4
Freshwater ecotoxicity	kg 1,4-DB eq	1,26E6	1,17E6
Marine ecotoxicity	kg 1,4-DB eq	1,5E6	1,41E6
Agricultural land occupation	m2a	4,7E5	4,42E5
Urban land occupation	m2a	5,33E5	5,24E5
Natural land transformation	m2	1,02E5	1,01E5
Water depletion	m3	8,8E5	8,43E5
Metal depletion	kg Fe eq	1,74E6	1,7E6
Fossil depletion	kg oil eq	1,17E8	1,16E8

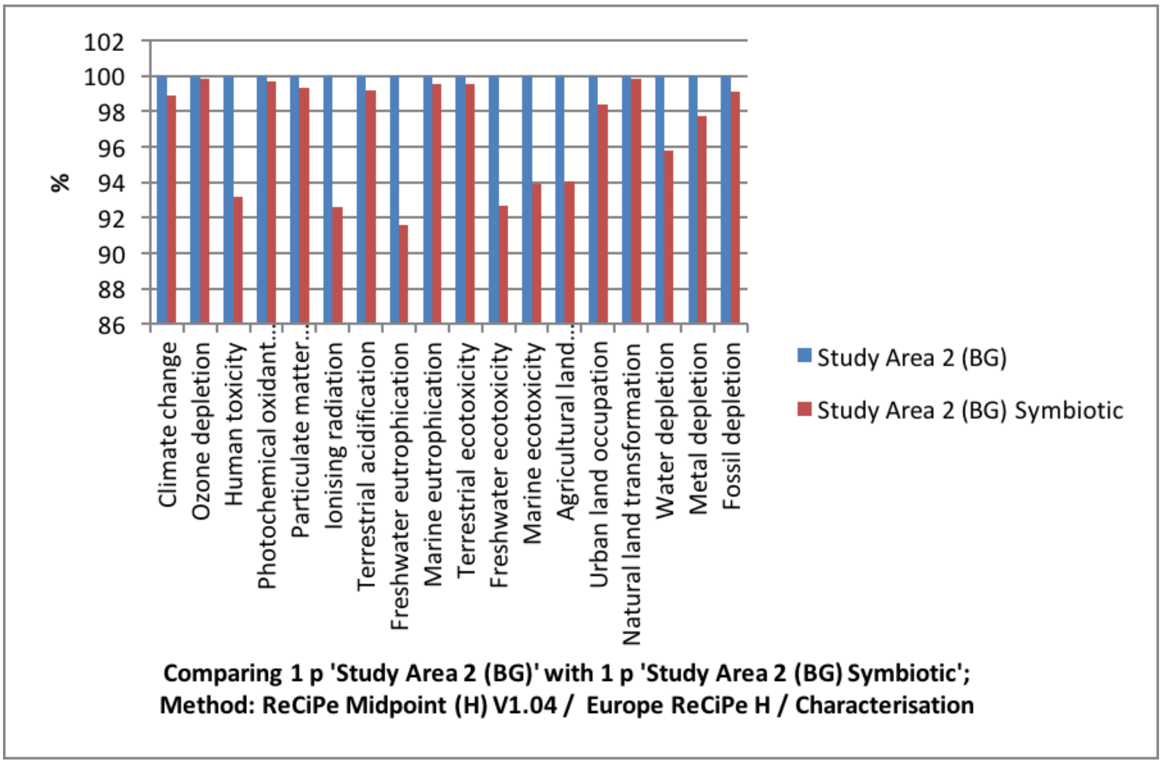


Figure 4-3: Characterization results for Study Area 2 (BG) using the ReCiPe method (existing situation vs symbiotic situation).

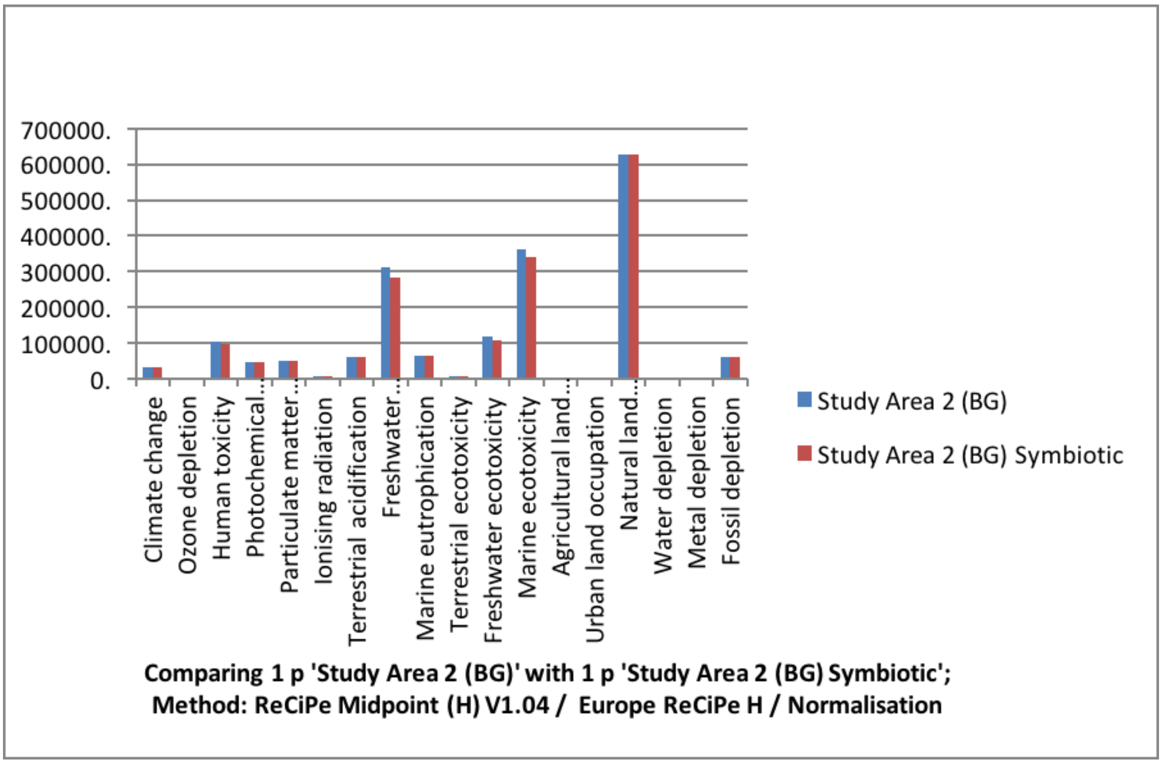


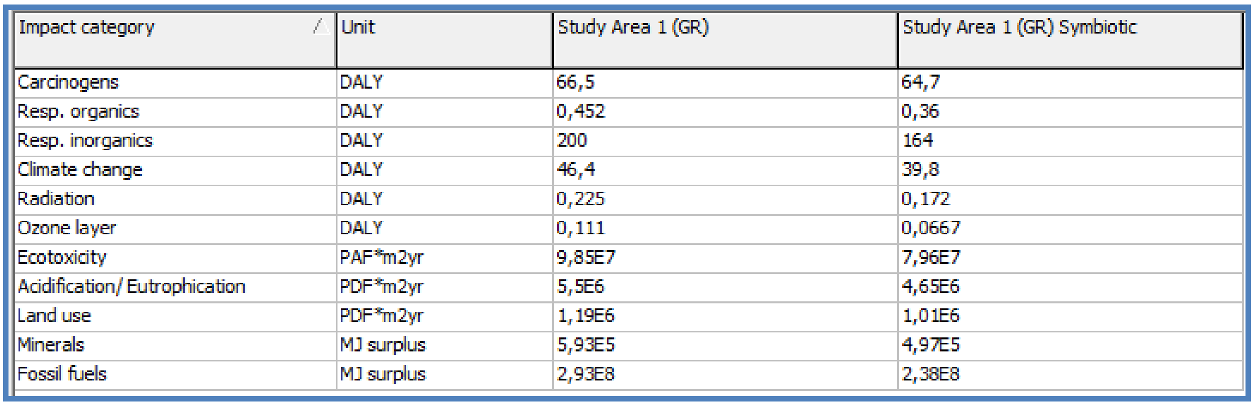
Figure 4-4: Normalization results for Study Area 2 (BG) using the ReCiPe method (existing situation vs symbiotic situation).

4.4.2 The Eco-Indicator 99 method (Endpoint evaluation)

The Eco-Indicator 99 method aims to capture the damage caused by environmental impacts. The final LCA results comparing the existing and symbiotic situation for Study Area 1 are presented in Tables 4-3 and 4-4. The respective characterization and Single-Score results are depicted in Figures 4-5 and 4-6. The following key conlusions can be extracted based on the info presented in these Tables/Figures:

- As in the case of ReCiPe method, the implementation of the proposed symbiotic activities leads to a noticeable reduction of the environmental impact in most categories (both at a characterization and single-score level) and especially Ozone layer (a reduction of 0,04 DALY is observed). The least reduction is observed for the impact category Carcinogens.
- In this case, all 11 impact categories are positively affected.
- The total environmental impact is reduced by 2.700.000 Pts which equals to the annual environmental impact of 2,700 European citizens. This is mostly attributed to the the reduction of fossil fuels and respirable inorganics.

Table 4-3: Comparison of LCA results for Study Area 1 (GR) using the Eco-Indicator 99 method (existing situation vs symbiotic situation).



Impact category	Unit	Study Area 1 (GR)	Study Area 1 (GR) Symbiotic
Carcinogens	DALY	66,5	64,7
Resp. organics	DALY	0,452	0,36
Resp. inorganics	DALY	200	164
Climate change	DALY	46,4	39,8
Radiation	DALY	0,225	0,172
Ozone layer	DALY	0,111	0,0667
Ecotoxicity	PAF*m2yr	9,85E7	7,96E7
Acidification/ Eutrophication	PDF*m2yr	5,5E6	4,65E6
Land use	PDF*m2yr	1,19E6	1,01E6
Minerals	MJ surplus	5,93E5	4,97E5
Fossil fuels	MJ surplus	2,93E8	2,38E8

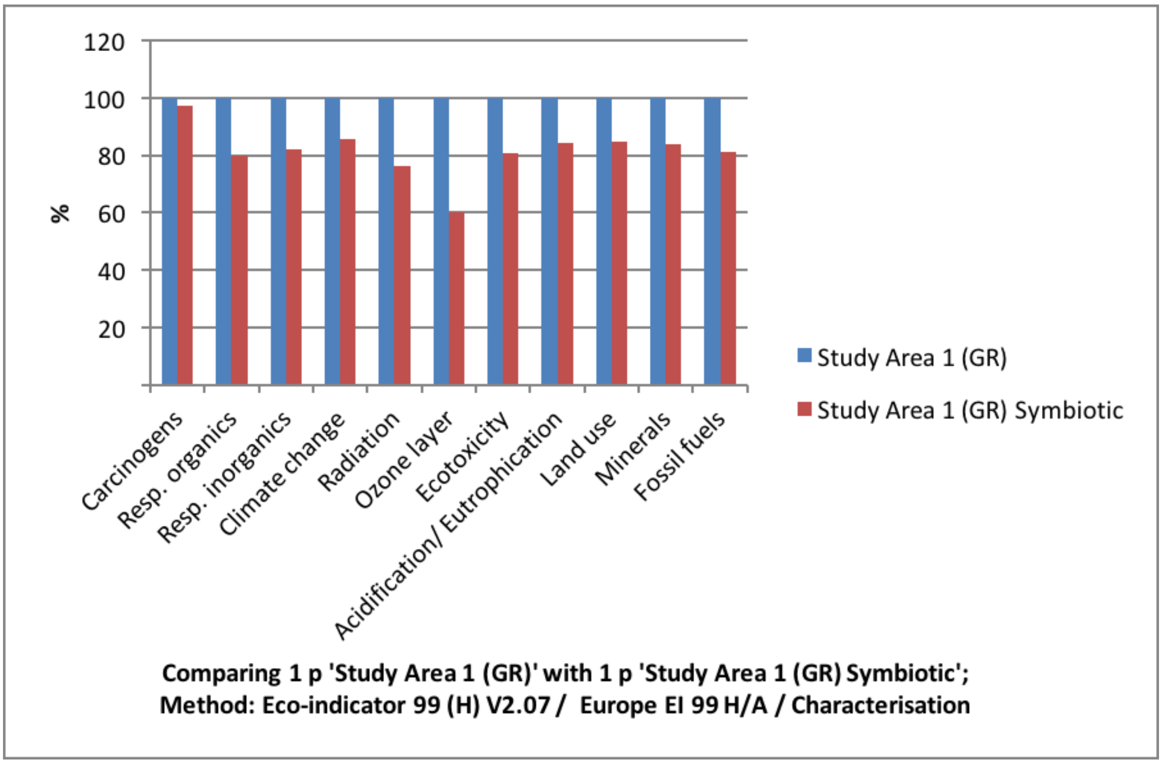
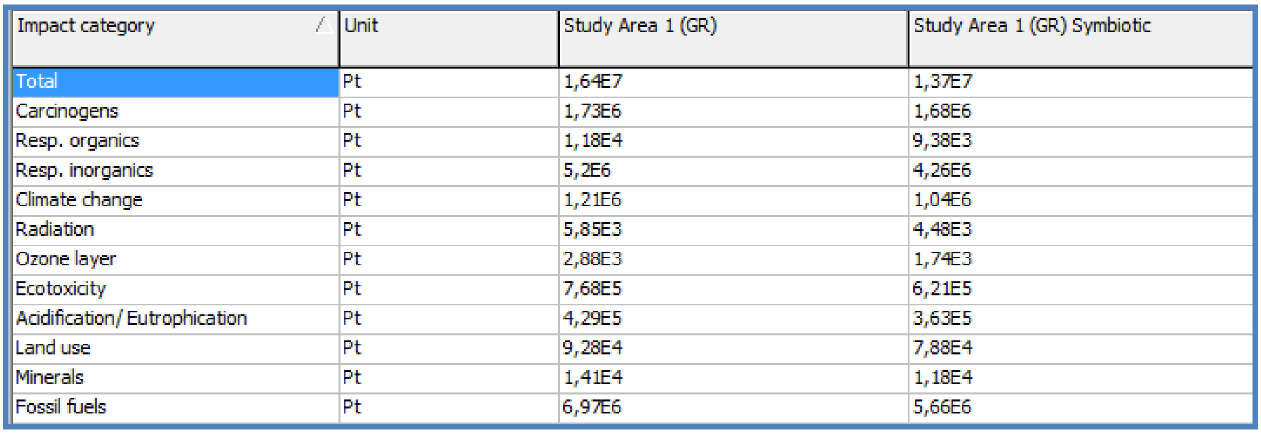


Figure 4-5: Characterization results for Study Area 1 (GR) using the Eco-Indicator 99 method (existing situation vs symbiotic situation).

Table 4-4: Comparison of LCA results (Single Score) for Study Area 1 (GR) using the Eco-Indicator method (existing situation vs symbiotic situation).



Impact category	Unit	Study Area 1 (GR)	Study Area 1 (GR) Symbiotic
Total	Pt	1,64E7	1,37E7
Carcinogens	Pt	1,73E6	1,68E6
Resp. organics	Pt	1,18E4	9,38E3
Resp. inorganics	Pt	5,2E6	4,26E6
Climate change	Pt	1,21E6	1,04E6
Radiation	Pt	5,85E3	4,48E3
Ozone layer	Pt	2,88E3	1,74E3
Ecotoxicity	Pt	7,68E5	6,21E5
Acidification/ Eutrophication	Pt	4,29E5	3,63E5
Land use	Pt	9,28E4	7,88E4
Minerals	Pt	1,41E4	1,18E4
Fossil fuels	Pt	6,97E6	5,66E6

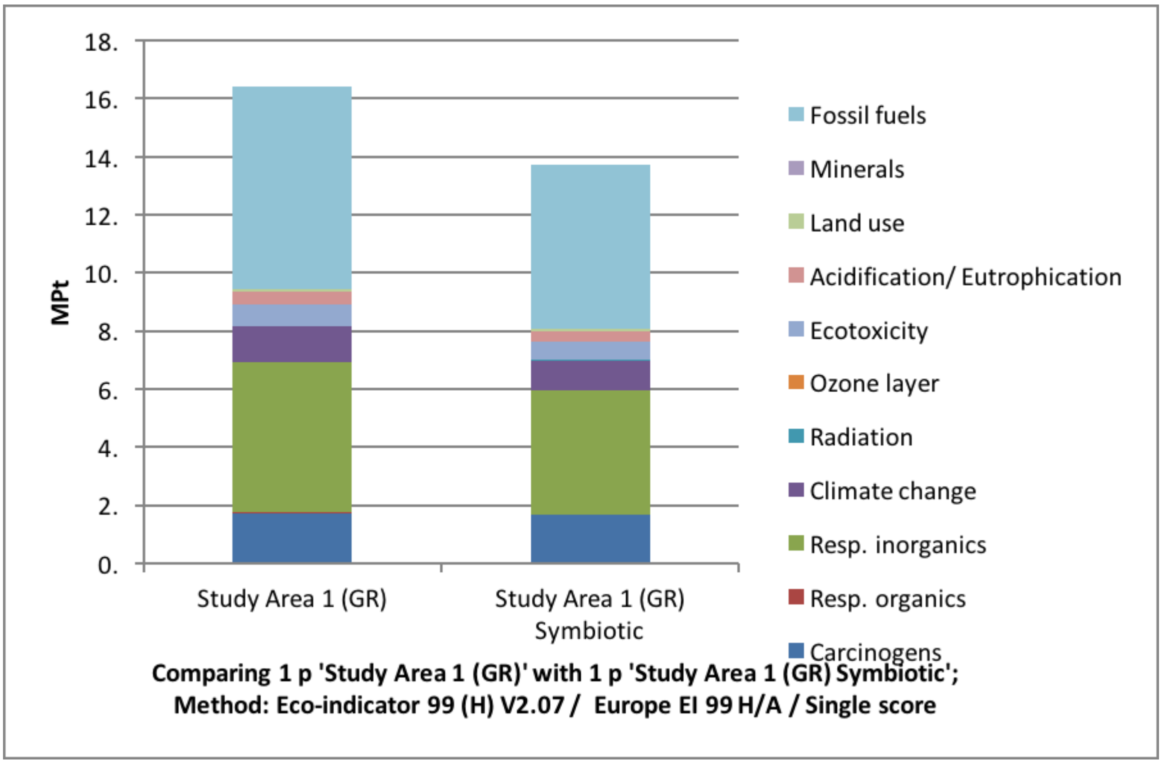
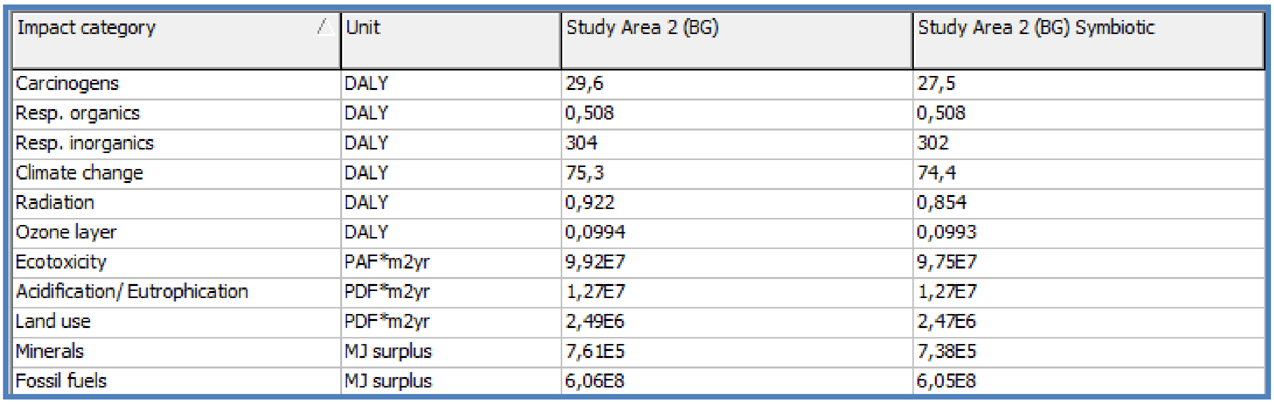


Figure 4-6: Single Score results for Study Area 1 (GR) using the Eco-Indicator 99 method (existing situation vs symbiotic situation).

Respectively, the final LCA results comparing the existing and symbiotic situation for Study Area 2 are presented in Tables 4-5 and 4-6. The respective characterization and Single-Score results are depicted in Figures 4-7 and 4-8. The following key conlusions can be extracted based on the info presented in these Tables/Figures:

- In contrast with the results extracted from the utilization of ReCiPe method, the implementation of the proposed symbiotic activities leads to much lower reductions of the environmental impact in most categories (especially if compared with Study Area 1). In this case the reduction of electricity consumption seems to have a much lower impact to endpoint categories. This confirms the notion the selection of an impact assessment method and approach (midpoint vs endpoint) can significantly alterate the final results.

Table 4-5: Comparison of LCA results for Study Area 2 (BG) using the Eco-Indicator 99 method (existing situation vs symbiotic situation).



Impact category	Unit	Study Area 2 (BG)	Study Area 2 (BG) Symbiotic
Carcinogens	DALY	29,6	27,5
Resp. organics	DALY	0,508	0,508
Resp. inorganics	DALY	304	302
Climate change	DALY	75,3	74,4
Radiation	DALY	0,922	0,854
Ozone layer	DALY	0,0994	0,0993
Ecotoxicity	PAF*m2yr	9,92E7	9,75E7
Acidification/ Eutrophication	PDF*m2yr	1,27E7	1,27E7
Land use	PDF*m2yr	2,49E6	2,47E6
Minerals	MJ surplus	7,61E5	7,38E5
Fossil fuels	MJ surplus	6,06E8	6,05E8

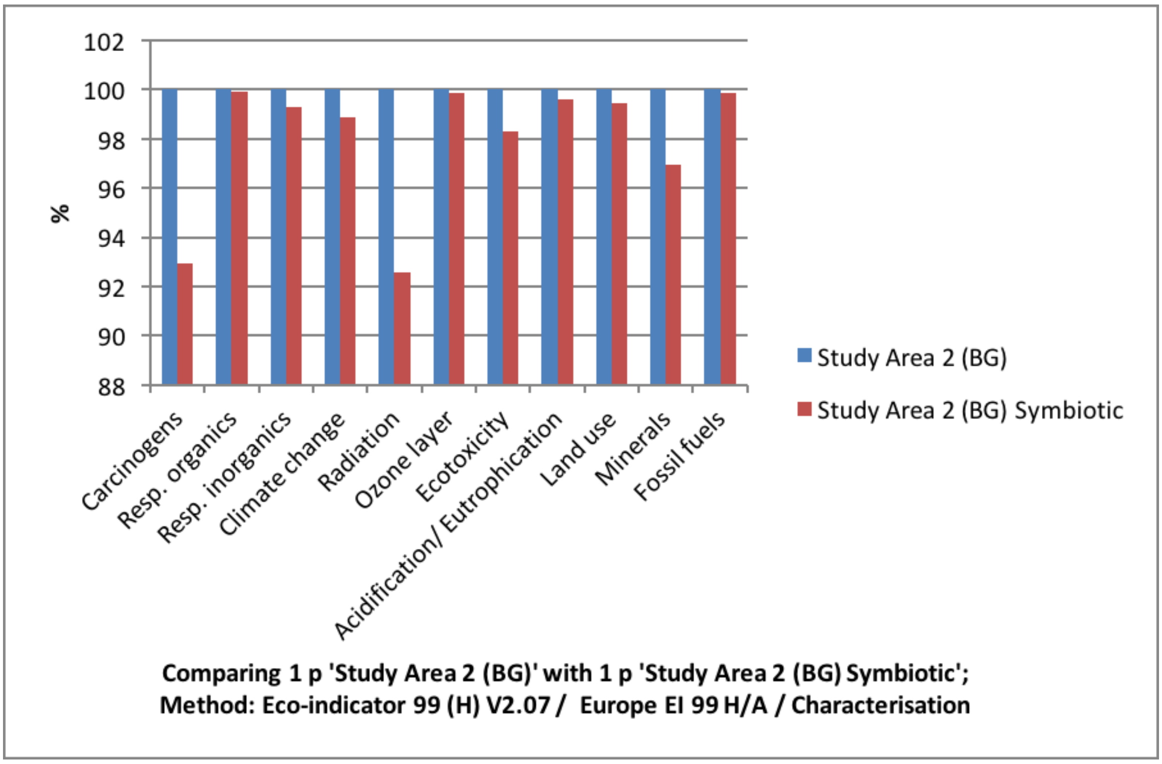
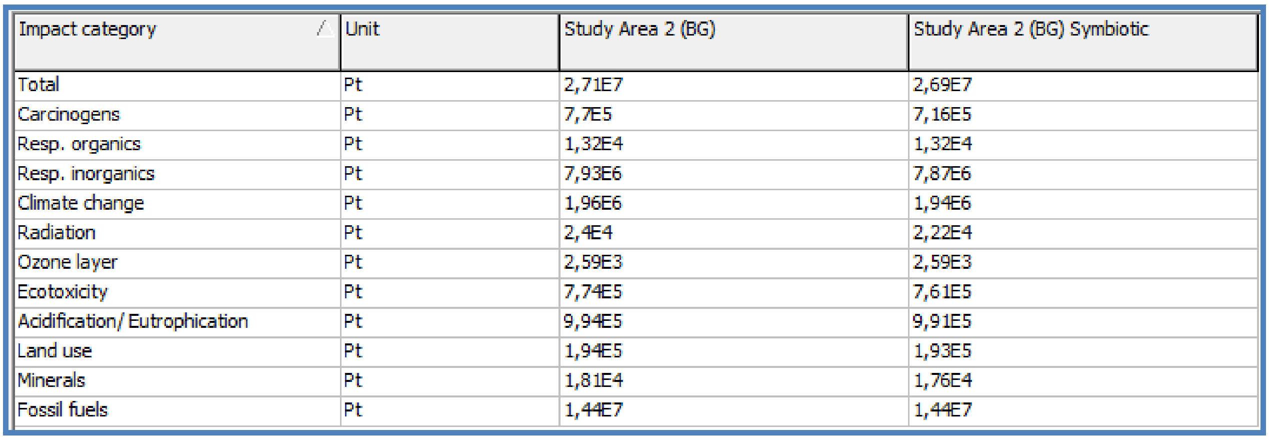


Figure 4-7: Characterization results for Study Area 2 (BG) using the Eco-Indicator 99 method (existing situation vs symbiotic situation).

- The total environmental impact is reduced by 200.000 Pts which equals to the annual environmental impact of 200 European citizens. This is mostly attributed to the reduction of respirable inorganics and carcinogens. It is clear that a much lower total reduction is observed in comparison with Study Area 1. This is attributed to the fact that the transportation sector which is dominating the current environmental performance of Study Area 1 is not affected by the proposed symbiotic activities. As result, there is a need to identify also solutions that can reduce transportation impact.

Table 4-6: Comparison of LCA results (Single Score) for Study Area 2 (BG) using the Eco-Indicator 99 method (existing situation vs symbiotic situation).



Impact category	Unit	Study Area 2 (BG)	Study Area 2 (BG) Symbiotic
Total	Pt	2,71E7	2,69E7
Carcinogens	Pt	7,7E5	7,16E5
Resp. organics	Pt	1,32E4	1,32E4
Resp. inorganics	Pt	7,93E6	7,87E6
Climate change	Pt	1,96E6	1,94E6
Radiation	Pt	2,4E4	2,22E4
Ozone layer	Pt	2,59E3	2,59E3
Ecotoxicity	Pt	7,74E5	7,61E5
Acidification/ Eutrophication	Pt	9,94E5	9,91E5
Land use	Pt	1,94E5	1,93E5
Minerals	Pt	1,81E4	1,76E4
Fossil fuels	Pt	1,44E7	1,44E7

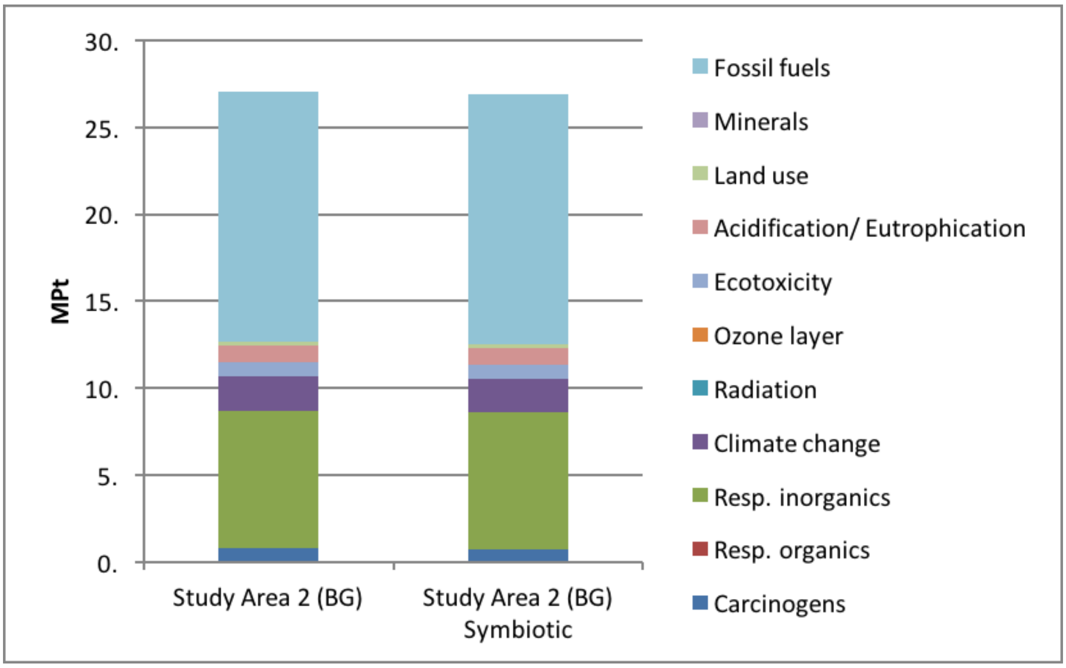


Figure 4-8: Single Score results for Study Area 2 (BG) using the Eco-Indicator 99 method (existing situation vs symbiotic situation).

4.5 Social LCA of the symbiotic potential

4.5.1 General Information

Social LCA is a set of methods that seeks to assess the potential or real social impacts of a product or service (Chhipi-Shrestha et al., 2014) where social impacts are mainly understood as the impacts on human capital, human well-being, cultural heritage and social behaviour. S-LCA purports to cover the entire life cycle or at least significant parts thereof and thus (if applicable) the material extraction and manufacturing or production phases, the use phase and, ultimately, the end-of-life phase of a product or a service (UNEP, 2009).

S-LCA assesses social and socio-economic impacts found along the life cycle (supply chain, including the use phase and disposal) with generic and site specific data. It differs from other social impacts assessment techniques by its objects: products and services, and its scope: the entire life cycle. Social and socio- economic aspects assessed in S-LCA are those that may directly affect stakeholders positively or negatively during the life cycle of a product. They may be linked to the behaviors of enterprises, to socio-economic processes, or to impacts on social capital. Depending on the scope of the study, indirect impacts on stakeholders may also be considered.

In broad terms, two methodological approaches can be distinguished in social LCA, namely "*performance reference point*" methods and "*impact pathways*" methods. Performance reference point methods focus on living and working conditions of – mainly – workers (e.g. whether there is forced labour, child labour, discrimination and freedom of association or collective bargaining) related to, or occurring at different life cycle phases (Chhipi-Shrestha et al., 2014). The choice of reference points is usually based on internationally accepted minimum performance levels such as International labour organisation (ILO) conventions, the ISO 26000 guidelines on social responsibility (ISO 26000, 2010), and OECD Guidelines for Multinational Enterprises (Parent et al., 2010). Importantly, performance reference point methods do not assume a causal relationship between production processes or technologies and the aforementioned conditions. What these methods do assume is that there is an empirical correlation between production processes mainly characterised in spatio-temporal terms and the occurrence of specific socio-economic conditions.

S-LCA does not have the goal nor pretends to provide information on the question of whether a product should be produced or not. S-LCA documents the product utility but does not have the ability nor the function to inform decision making at that level. It is correct that information on the social conditions of production, use and disposal may provide elements for thoughts on the topic, but will, in itself, seldom be a sufficient basis for decision.

In theory, S-LCA may be conducted on any products, even those that are knowingly harmful to society (e.g. weapons). It is recommended to use S-LCA ethically and it is assumed that peer review will prevent using the methodology inappropriately. Socially responsible investing firms often provide lists of product categories being excluded for ethical reasons. If the product category studied is listed, it is recommended to detail, in the goal and scope phase of the study, the reason why it is ethical and reasonable to conduct a S-LCA of this particular product. Documentation of the product utility and assessment of the use phase of the life cycle will also generally reflect the unethical or harmful nature of the product. (UNEP, 2009).

4.5.2 Social LCA – Environmental LCA (Similarities and Differences)

Social LCA and Environmental LCA (seen in previous chapters), share a number of similarities. Key among these is that both approaches – at least in principle – seek to capture the environmental/social impacts of a good or service from the cradle to the grave (Sala et al, 2015). More specifically, both methodologies:

- Share a common trunk which consists in the ISO framework (goal and scope definition, life cycle inventory analysis, life cycle impact assessment and interpretation); although there are some specificities for each of these phases in S-LCA;
- Have a huge need for data;
- Work as iterative procedures;
- Encourage and request peer review when communication to the public or comparative assertions are planned;
- Provide useful information for decision-making;
- Do not have the purpose to provide information on whether or not a product should be produced;
- Conduct Hotspots assessments that play the same role;
- Conduct data quality assessment;
- Do not generally express impacts by functional unit, if semi-quantitative or qualitative data are used.

However, there are also a number of important dissimilarities between both approaches. The most obvious difference between E-LCA and S-LCA is the focus. While the former is concerned with the evaluation of environmental impacts, the latter aims to assess social and socio-economic impacts. While, an E-LCA will mainly focus on collecting information on (mostly) physical quantities related to the product and its production/use and disposal, a S-LCA will collect additional information on organization- related aspects along the chain.

Moreover, social concerns are diverse and their importance is subjective to the context. Contrary to environmental indicators, social indicators are very hard to quantify and their impact changes with the behaviour of the company (Swarr, 2009). Another key issue in S-LCA is the definition of the functional unit. While this is usually not a problem in environmental LCA (and arguably also not for impact pathway methods as described above), it is less clear for performance reference point methods how to conceptualise the functional unit. The reason is that these methods attribute social impacts through proxies, e.g. working hours or monetary values or a combination of both (Sala et al. 2015).

4.5.3 S-LCA stakeholders and the impact of the identified symbiotic activities

The goal and scope of the particular S-LCA chapter is to assess the social impact of the proposed symbiotic activities. Industrial symbiosis is known through literature to have several social benefits:

- Benefits of the community as a source for new employment oppotunities
- Securing existing work positions
- Cleaner and healthier local environment
- Increased land value
- Reinforrcing better consumption habbits

and many more.

Looking beyond the benefits already mentioned in literature, utilizing the UNEP guidelines for Social LCA studies, the environmental impacts of proposed symbiotic activities will be examined, based on five main stakeholder categories:

1. Workers/employees.
2. Local community.
3. Society.
4. Consumers (end-consumers).
5. Value chain actors (local government).

Due to the diversity of the proposed symbiotic acitivities in Study Area 1, those data will be utilized in the existing chapter.

Workers/employees

One of the main aspects of the symbiotic scenario for Study Area 1 is the development of new production activities/businesses in the area, in order to boost the local economy and community in general. In this symbiotic scenario, the development of 50 acres' local greenhouse was proposed, the development of a biomass power plant, as well as the development of new agricultural opportunities and businesses (local farmers market).

All these activities, it is safe to assume, that could potentially create new working positions and employment opportunities for people of the local community. The exact number of new employment opportunities is not something the could be quantified as things stand, but it is a certainty and an overall goal of developing those symbiotic activities.

The study would be further legitimized by the use of the PSILCA list of indicators (Ciroth et al, 2015) where each stakeholder has specific subcategories. In the case of Worker/Employes the subcategories are: Child labour, forced labour, fair salary, discrimination, health and safety, social benefits, legal issues, freedom od association, collective baraining, right to strike. Once again, it is not easy to have quantified measurements for all these indicators, but it is fair to say that BIO2CARE doesn't advocate exploitation of employment or extreme/hazardous working conditions.

Local community

As in the previous stakeholder category, the development of new production activities under safer regulations, with minimized environmental impacts, is something that could boost the local community. In the symbiotic scenario of Study Area 1, the local community benefits from the reuse of industrial wastewater for district heating. That means cheaper, or even free heating for the local community. Furthermore, as already mentioned, there will be new employment opportunities for people of the local community.

A safer and more environmentally friendly industrial activity in the area, leading to minimized environmentall impacts, promotes a healthier lifestyle for the local community, as well as a better land value for the areas near this newly developed symbiotic network.

Society

In a broader social spectrum, the symbiotic scenario in Study Area 1 could still present some benefits, even more difficult to be quantified exactly. The new proposed activities, as well as the boost of the local economy and community could have a significant contribution to the economic development of the administrative region, and the country in general. According to Eurostat statistical data, the administrative region of Eastern Macedonia and Thrace is considered among the poorest administrative regions of Europe, with the GDP per citizen being at 46% of the European average. A symbiotic project like the proposed one coud boost the local community numbers, as well as the administrative region numbers, moving in a new and sustainable direction.

Consumers

Changing the behavior of production, while presenting a greener and sustainable way of utilizing raw materials, by-products, and waste, is an easy way to lead towards a more responsible consumption behavior. In the case of this symbiotic scenario, consumers have more knowledge regarding the products they consume from the proposed farmers market, while contributing to the local economy. There will be complete transparency of the good through the use of labels (BIO2CARE labelling scheme), which could define the consumer behavior.

Furthermore, consumers have the opportunity to learn more about sustainable industrial practices, and acquire an end-of-life product responsibe behavior, while observing the industrial activities doing the exact same thing, trying to miminize the waste, in a circular economy model. Last but not least, as already mentioned in the local community paragraph, consumers would eventually have a healtier and safer lifestyle, in a community with less pollution and environmental impacts.

Value chain actors (local government)

The role of the local government in this symbiotic scenario is two-sided. In order to enjoy the benefits of a symbiotic network, the local government needs to facilitate the development of this network and work alongside every potential partner of the symbiosis. The legislation needs to be revised in order to facilitate symbiotic activites, while ensuring that the well-being of the environment and local community is taking into account.

It is the role of the local government to ensure a fair competitive environment and benefit from it, with zero corruption, transparency, and promotion of social responsibility. In this case, the benefits mentioned before for the local community and every other stakeholder, are present for the local government as well. Especially in the case of an administrative region with small finanancial development, as mentioned, it is crucial to facilitate such project in order to benefit from them.

Chapter 5 - Conclusions

The focal point of this study was the implementation of Industrial Ecology principles and tools in order to assess the existing situation, propose an alternative scenario for economic, environmental and social development, and assess the potential scenario as well. The examination of the environmental performance of each Study Area was carried out through the spectrum of Life Cycle Assessment, utilizing specific impact categories and methods. The alternative scenario towards a sustainable development of the two study areas revolved around the identification and proposition of potential symbiotic activities, implementing industrial symbiosis principles, while assessing the potential benefits from this proposed symbiotic scenario again through a descriptive LCA study model.

Initially, in the first chapter, a selective literature review provides the theoretical background of the concecpts of Industrial Symbiosis and LCA, while presenting the benefits from the implementation of symbiotic actions through the examination of best practices around the globe.

The symbiotic scenario of each Study Area, was developed base on literature, knowledge from best practices, as well as the distinguishing characteristics and potential of the two Study Areas. Regarding Study Area 1, sixteen (16) potential symbiotic activities/exchanges were identified (see Figure 2-4, page 55), trying to utilize, boost, and minimize the environmental impacts of existing procuction activities, while also proposing the development of new activities in order provide benefits for the local economy, community and environment. The environmental benefits of the proposed symbiotic activities are summarized in Table 2-1 (page 56), and including the reduction of more than 4.000 tonnes of CO2, the reduction of at least 72.000 tons of oil, and more.

Regarding study area 2, 18 potential symbiotic activies were identified, based mostly on economic development, but presenting a significant reduction on environmental impacts as well. An important example of environmental benefits is the use of methane produced energy (through landfills and manure management) which could potentially lead to the reduction of almost 6500 MWh of electrical energy consumption.

During the first LCA study of the existing situation for both study areas, two methods were used to interpret the results. Midpoint evaluation showed that the carbon footprint of the two Study Areas according to the LCA principles and the ReCiPe impact assessment method amounts to 221,000 and 359,000 tons of CO_2 eq. respectively. The results are in close proximity with the estimations performed using the methodological framework developed in D.3.2, further validating its applicability. Further results with more impact categories and environmental indicators can be shown on Chapter 3.4.1 The ReCiPe method (page 87). Endpoint evaluation was carried using the Eco-indicator 99 method. According to this evaluation The annual environmental impact of the two Study Areas resulting from the consumption of electricity and fuel for the specific anthropogenic activities included in the analysis amounts to 16,400,000 Eco Pts or 560 Eco Pts / inhabitant for Study Area 1 and 27,100,000 Eco Pts or 390 Eco Pts / inhabitant for Study Area 2. Further explanation and results on Chapter 3.4.2 The Eco-Indicator 99 method (Endpoint evaluation).

For the second LCA study, based on the identified symbiotic activities, a new inventory analysis was carried, using as data the reduction of energy and material consumption resulting from the symbiotic acitivities. Once more a midpoint and an endpoint evaluation was utilized to interpret the results. Some key conclusions based on the two LCA studies are: The implementation of the proposed symbiotic activities leads to a noticeable reduction of the environmental impact in most categories and especially Ozone, and Terrestrial ecotoxicity, the impact categories freshwater eutrophication, agricultural land occupation, urban land occupation and natural land transformation are not affected by the proposed symbiotic activities. Analytical presentation of the results, as well as a comparison between the two lca studies could be found on Chapters 4.4.1 (page 128) and 4.4.2 (page 132).

Regarding the Social LCA studies of the existing and symbiotic potential, a more theoretical approach was adopted. Based on the official guidelines of UNEP, utilizing stakeholder categories identified from those guidelines, an examination of the socioeconomic environment of both study areas showcased that the implementation of symbiotic activities could have a beneficial role for the development of both areas. It is proposed, and deemed necassairy, that a further examination, a wider Social-LCA study, probably utilizing new tools such as the PSICA database, should be in mind, for deeper knowledge and more quantified and not theoretical data and results.

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