The Methodological Development of Regional Sustainability Analysis[1]

JUDIT RONCZ
JUNIOR ASSISTANT PROFESSOR

e-mail: regroncz@uni-miskolc.hu

KLÁRA SZITA TÓTHNÉ, Ph.D.
UNIVERSITY PROFESSOR

e-mail: regszita@uni-miskolc.hu

SUMMARY

Keeping in mind the needs to preserve the environment and quality of life, the Life Cycle Assessment (LCA) methodology has been developed to meet these needs. At present the main two direction of LCA research are to fulfil the requirement of the broader sustainable development concept and to somehow do away with previously dominating product-specific, plant-level modelling techniques. The Regional LCA Competence Laboratory – based in the Institute of World and Regional Economics – has recently been working on the elaboration of a demonstrative project which can serve the ambitious goal of finding a way to successfully combine the advantages of the above-mentioned approaches. In this paper we summarise the various sustainability models and introduce our regional sustainable development model proposal.

Key words: LCA, sustainable development
Journal of Economic Literature (JEL) codes: Q01 - Sustainable Development

INTRODUCTION

Life Cycle Assessment (LCA) is a comparatively recent tool that has rapidly grown to become a standard procedure for environmental scientists and engineers alike to investigate and assess the environmental performance of a wide range of human dominated processes. As the concept of three-pillar sustainable development became widely accepted, the LCA approach has also widened with these new aspects. The goal is to obtain a more consequent picture and evaluation from ongoing human and natural activities. As LCA models typically use product-specific, plant-level data, one of the biggest challenges among LCA researchers is to develop a new model based upon general macro- or regional (mezzo-) level economic datasets. The aim is to indicate regional economic and environmental effects from the production of goods and services and to support the regional policy makers. Both of the research directions are challenging but pose difficulties.
The aim of the Regional LCA Competence Laboratory is to develop a new methodology that can combine the advantage of a life cycle and input-output analysis to evaluate environmental, social and economic performance at a regional level. The novelty of the research on the one hand is that only the USA had such research programs; in Europe a similar, complex economic, social and environmental LCA approach has not yet been formed. On the other hand this research can serve as an impetus for domestic LCA research, which is only in its infancy. Moreover, high value added can be realised on both the methodological (development of research potential) and practical application sides (contribution to regional policy decision making). The Laboratory aims within this project are: to develop a new methodology, which can give a reliable evaluation for the regional environmental performance; to assess the sustainability of the region; and to support strategic decision-making by developing optimalisation scenarios for the region.

ABOUT LCA ANALYSIS

The concept of life cycle in economics is related to the cyclic character of micro-economy and to innovation, and has come into common use due to the works of Schumpeter (1939). Originally it was interpreted in relation to the product, and was used to mean the period of time which lasts from the beginning of the production of a certain product or group of products and/or its appearance in the market to the completion of the production and/or its disappearance from the market. Later it was expanded to technologies and even to organisations, first of all enterprises in connection with the strategic activities of the companies, investments and the changes in the mission and long-term objectives of

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companies. The concept of life cycle used in environmental economics is of more recent origin than the former: it appeared about 20 years ago, at the beginning of the 1990s. Its emergence and the spread of its use were caused by the development of environmental sciences and the general change in the way of thinking related to the environment. The essence of that process of change is that thinking and the formulation of action plans and tasks were shifted from environmental protection to environmental management, to the prevention of damage and to the definition of the essence of sustainable development.

In this sense, life cycle analysis embraces the period 'from birth to death', the period 'from the cradle to the grave', and its complete effect on the environment covers this period. On the input side it examines the use of non-renewable resources or resources renewable to a limited extent, and on the output side it examines the damage caused to the environment in the chain of production and use as well as of destruction, i.e. in the complete life cycle, determining them quantitatively (in terms of physical indicators and/or money). The meaning and objective of Life Cycle Assessment (LCA) is given by the very fact that it looks for the products, technologies and organisations which ensure the most beneficial, optimum environmental total impact for satisfying a given need under the given conditions in a unit period of time (in general calculated for one year), i.e., those that exert the least possible load on the environment. When the environmental impacts are known, LCA assessment may promote the modernisation and improvement of the existing means, or just as well its replacement and superseding with new means. The life cycle according to the two ways of thinking and their analyses thus stem from different origins, their contents are different from each other and thus one cannot replace the other. At the same time, however, they can exist side by side, and complement each other in certain aspects, for both of them are related to innovation and are intended for evaluating innovation.

LCA Analysis for Sustainable Measurement

The concept of sustainability as terminology is well-known and accepted among those involved in the topic and it has become fashionable to some extent without there being spectacular achievements behind it. In the beginning, several approaches narrowed the concept only to the sustainability of economic growth in the interpretation of sustainability. Today, and mainly in the sense used by environmental economists, it is about a strategic look into the future based on three pillars: in its course the economy develops while respecting environmental aspects, the ecological balance is maintained in the ecosystem, and the development satisfies the expectations of the society as well (Tóthné, 2007). If we accept that development does not necessarily means material growth and increase of mankind in terms of numbers, but rather the intellectual development of mankind, then it is theoretically possible to preserve the state of the biodiversity of the Earth and sustainable development is feasible. According to a renowned representative of ecological economics: "sustainable development is achieving continuous social welfare without growing in a way exceeding ecological sustaining ability" (Daly, 1996).

Analysing sustainability in the life cycle approach was first put on the agenda in 2006. Since 2006 Life Cycle Assessment has become an important tool for the definition of the environmental impact of products and services. LCA is important for sustainability decision making at the European level, but it needs to develop continuously and catch up with the expansion of social, economic and environmental aspects, since the precise determination of LCA performance is now one of the major goals in sustainable development and is crucial for political decision making. In several research projects, life cycle assessment is already organically connected to sustainability analysis and life cycle costing and social life cycle assessment supplement environmental life cycle analysis (see the later CALCAS model, Klöpffer, 2008)

Developments aimed at the products generally set the objective of improving the environmental profile, which includes a reduction in materials and energy as well as a reduction in emissions or toxic materials (in the case of products, systems or products and the search for alternative solutions). A 'green product' possesses incontestable environmental advantages (the impact exerted by the product on the environment is smaller than that of its traditional rivals). On the basis of the threefold requirement of sustainability, the developments limit the use of non-renewable resources to the minimum, minimise the use of energy and water as well as of pollutants and avoid the use of hazardous materials in the production of the product. In addition, the product has a longer useful life, its recycling is ensured, and is at least of as good a quality as the not-environment-friendly rival product. It is an important criterion that it should be widely available at a competitive price (Karlsson and Luttropp, 2006). For environmentally friendly products a very carefully thought-out pricing mechanism (skimming, price discrimination, mixed pricing) is to be chosen, which depends basically on the consumers' environment-consciousness and willingness to pay and also on the competitive position. In the case of price discrimination, the company segments the market according to the consumers' willingness to pay and positions the product at different prices accordingly. But if the consumers' environmental consciousness is of a low level, the company uses mixed calculation instead and may include part of the additional costs in the prices of its other products. The LCA-based approach to environmental friendly developments focuses on the analysis of energy consumption (EUP directive), or in other cases on the replacement of toxic materials, or it promotes a better choice of packaging materials.

ENVIRONMENTAL IMPACT ASSESSMENT AND/OR LCA ANALYSIS

The importance of environmental protection is becoming increasingly prominent in all spheres of human society, while more and more environmental impact analysis methods have tried to give a reliable and coherent estimation (Fullana et. al., 2009). Among others, life-cycle assessment (LCA) has become a widely used tool in the last decade to estimate environmental effects of the entire life cycle of products and services. Unfortunately there is no methodology without uncertainty factors, or suspected inaccuracy. The characteristic uncertainty of the given estimations can be grouped into three categories:

- uncertainty or lack of data (due to the need of data aggregation, collection and lack of data sources)
- narrowed focus of analysed processes or effects (only one, mostly environmental aspect stands in the midpoint of the analysis, the analysed effect has multiple effects that are difficult to identify)
- unreliable data sources (national data sources often derived also from estimations).

In the next few paragraphs we briefly introduce the most commonly used and newly developed methodologies for giving estimations on sustainable development. These concepts served as a methodological basis of our suggested model and can be classified according to three characteristic features: whether it is an econometric model, built upon the LCA approach, or a more indicator-based statistical analysis.

1. Econometric modelling of SUS development

The econometric models, although often appearing as a model of sustainable development, mostly seek to forecast only the positional evolution of economic growth.

PANTA REI and SuE models: The scope of these models is to include the measuring of energy and material consumption and thus they are well suited to indicate the linkage of economic development and environmental impact. Both models are shown to meet the sustainability requirements.

PANTA RHEI is an ecologically extended version of the sector econometric simulation and forecasting model INFORGE (INterindustry FORecasting GErmany) and belongs to the class of econometric input-output models, which differs from neoclassical approaches assuming bounded rationality. PANTA RHEI has a high degree of interdependency. The bottom-up construction principle says that each sector of the economy has to be modelled in great detail and that the macroeconomic aggregates have to be calculated by explicit aggregation within the model. The about 40,000 equations of PANTA RHEI describe the interindustrial flows between the 58 sectors, their deliveries to personal consumption, government, equipment investment, construction, changes in stocks, exports, as well as prices, wages, output, imports, employment, labour compensation, profits, taxes, etc. for each sector as well as for the macro-economy. In addition the model describes income redistribution in full detail. The model is extended with biotic and abiotic material inputs and the erosion of ground.

“Sustainable Europe” or SuE is a system dynamics model for the analysis of long-term dynamics based on physical accounting of resources where embodied energy is calculated as energy cost (natural capital accounting). SuE accounts directly for energy consumption, instead of deriving it from the price elasticity of different sectors for energy. The model does not calculate the reduction in energy and materials consumption resulting from resource taxation, but it will be capable of demonstrating the long-term impact on economic development and the resource consumption such a reduction in physical supply will cause (Bockermann et al., 2000).

REEIO model: After examining some of the econometric models Brettell (2003) proposed a model for regional sustainable development that involves economic but also more environmental impact factors as:

- Gross value added
- Personal income
- Consumer spending and investment
- Output of industrial production
- Employment
- Waste and industrial waste
- Waste management methods
- Key emissions
- Energy demand
- Water consumption (household & industrial).

The advantage of the model is that it can help the better understanding of development processes and the evaluation and comparing of scenarios to be able to forecast future paths. Weaknesses include heavy data requirements and a multiplicity of competing economic explanations to underpin the model explanation (Brettell, 2003)

FUGI model: The FUGI (futures of global interdependence) global modelling is a scientific policy simulation tool to provide global information and to find out possible coordination of policies among countries in order to achieve sustainable development of the global economy under the constraints of rapidly changing global environment. The FUGI global model 9.0 M200PC divides the world into 200 countries and regions. The scientific integrated economics design concept of the FUGI global modelling system has been influenced by recent advancements in life science, biotechnology and information technology. Each country/regional model is globally interdependent through direct linkages of the world trade matrices, export/import prices, primary commodities prices, foreign exchange rates, official development assistance, private foreign direct investment, external debt, interest rates, population changes, economic development policies, energy policies and environmental policies. A full set of parameters of the model is carried out very efficiently by automatically selecting either OLS (ordinary least squares) or MLBM (maximum likelihood method) in accordance with the indicators of DW (Durbin–Watson ratio) (Onishi, 2005).

2. Indicator based statistical methodology

Those models belong in this group which address the sustainability dimensions and apply a chosen structural criteria for selection of a core set of indicators, in order to assess a sustainable path.

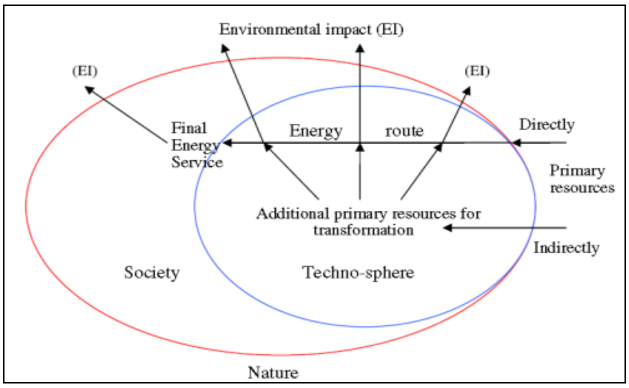
EPSILON: The EPSILON project (Environmental Policy via Sustainability Indicators On a European-wide level -- 2002-2005) delivered a computerised model through an aggregation of indicators. Assessing sustainability has been addressed over four spheres/pillars: the environmental, the economic, the social and the institutional dimension in order to benchmark European regions. A coherent objective based structure has been defined relying strongly on the analytical DPSIR framework (Driving-Forces, Pressures, State, Impact and Response model from the European Environmental Agency) leading to the selection of a core set of regional indicators, common to all regions, tracking all dimensions of interest to sustainability. The results are represented on sustainability maps in the form of air, soil, water and land quality indicators. These results should not be considered as absolute figures but rather as an attempt at a relative sustainability assessment (Blank et Al., 2005).

Another example of an indicator-based sustainability evaluation is the work of Marsalek et al. (2006), who compiled a set of core indicators suggesting a need for and comparison of social, environmental and economic indicators to measure sustainability.

3. LCA based approaches

This model often uses the approach of an input-output analysis, but evaluates the performances from cradle to grave, gathering inventory data and linking it with impact categories to get a better picture from present and future environmental, social and economic states.

Modelling sustainable development through exergy: This belongs to the kinds of models where sustainability function is found not as a classical economic function but in the form of material/energy flows of products and services. According to its concept, the exergy embodied in resources, products, and waste materials has the potential to cause changes in both the industrial environment and the natural ecosystem. It estimates the present sustainability paths with an Ecoinvent-based LCA assessment of energy transformation/system routes (Rodriguez et al., 2010).



Source: Rodríguez et al., 2010.

Figure 1. Energy route model

EVR model: The basic idea of the EVR (Eco-costs/Value Ratio) model is to link the value chain to the ecological product chain. In the value chain the added value and the added costs are determined for each step of the production. Similarity, the ecological impact of each step in the production chain is expressed in terms of money, the so-called eco-costs. These costs have been estimated on the basis of technical measures to prevent pollution and resource depletion to a level which is sufficient to make our society sustainable. The specific EVRs have been calculated on the basis of LCAs, for materials, energy and industrial services. This model complies with ISO 14040 and 14044 and uses Ecoindicator'95 for characterization (Vogtländer et al., 2009). The model focuses more on environmental and economic aspects of sustainability but is capable of comparing governmental strategies from the point of view of both the consumer and producer.

CALCAS model: The aim of this concept is to broaden the LCA on the basis of the three-pillar model of sustainability and is called Life Cycle Sustainability Analysis (Klöpffer, 2008).

$$\text{LCSA} = \text{LCA} + \text{LCC} + \text{SLCA}^{2}$$

The model struggles with operationalisation difficulties and problems about the integration of the pillars (environmental, economic and social aspects) and system boundaries. As a new direction the model also suggests involving technological,[3] physical[4] and economical[5] relations.

[2] *Life Cycle Sustainability Analysis = Life Cycle Analysis + Life Cycle Costing + Social Life Cycle Assessment*

[3] *Life cycle costing (LCC), Total cost accounting (TCA), Total cost of ownership (TCO), Hybrid analysis, Life cycle activity analysis (LCAA), Life cycle optimalisation (LCO), Social life cycle assessment (SLCA), Carbon footprint (CF), Environmental risk analysis (RA).*

[4] *Economy-wide material flow analysis (CGE), Substance flow analysis (SFA), Material input per unit of service (MIPS), Energy/Exergy analysis (EA).*

[5] *Computable general equilibrium model (CGE), Input output analysis (IO), Environmentally extended input output analysis (EE-IOA), Partial equilibrium models (PEM).*

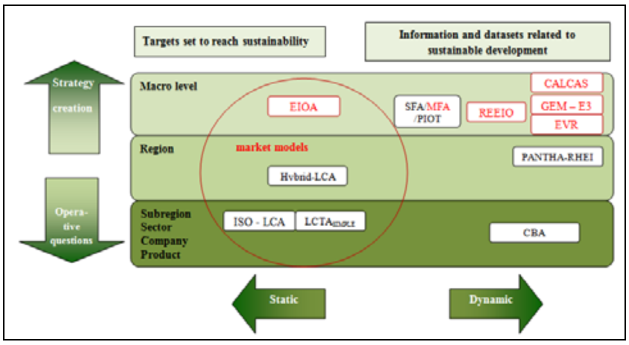
EIO-LCA and REIO-LCA: LCA studies have used mostly product-specific or plant-level data. The Economic Input-Output Life Cycle Assessment (EIO-LCA) uses information about industry transactions – purchases of materials by one industry from other industries – and the information about direct environmental emissions of industries to estimate the total emissions throughout the supply chain (www.eiolca.net). Although both process LCA and EIO-LCA have been important decision-making tools, neither of them has been able to perform regional and state level analyses efficiently. However, many decisions by regional policy makers would be better informed by local or regional aggregate data (Hendrickson et al., 1998).

To solve the mentioned deficiency Horvath et. al intended to construct and apply a regional economic input-output analysis model combining with a life cycle approach (REIO-LCA) based upon publicly available datasets. The model uses Gross State Product (GSP) estimates to calculate regional economic multipliers and then link them to regional electricity and fuel use, and air emission factors (Hendrickson et al., 2007)

SUGGESTED METHODOLOGY FOR REGIONAL SUSTAINABLE DEVELOPMENT

Suggested methodology for regional sustainable development

The methodological aspects of the sustainability LCA are inducing increasingly more interest among LCA researchers. Many assessments connect to sustainable product systems, to renewable resource systems or to regional and local sustainable models. In this paper we propose a regional sustainability assessment method based partly on LCA and partly on sectors' mutual relationship.



Source: Own compilation

Figure 2. Overview of sustainable development analysing models

The basic concept of our analysis is built on the LCA standards of ISO 14040 and ISO 14044 but supplemented by economic and social elements; according to our concept all (three) pillars of sustainability should be integrated into the assessment. In the development of the concept we used several models as a starting point (EIOA, MFA, REEIO, CALCAS, GEM-E3, EVR), selecting their advantages to build a measurable, relatively simplified, transparent, and coherent model specified to our region (at NUTS 2 level), representing an underdeveloped, area that was formerly a heavy-industrial centre.

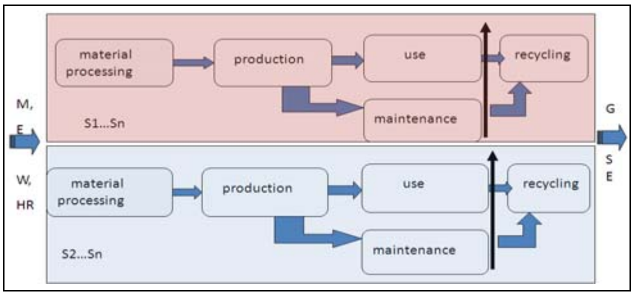
In this model LCA is built on a matrix structure, and the regional environmental impacts have been aggregated in an environmental performance index (REI):

$$\mathrm{REI} = \mathrm{I_n S I_k^T},$$

where, I_n is a n-dimension unit row vector and $\mathrm{I_k^T}$ is a k-dimension unit column vector. The regional environmental performance is the sum of the element of matrix S that represents the single sectors environmental burdens by pollutants. So matrix S can be defined as:

$$\mathrm{S} = \begin{bmatrix} \mathrm{S_{11}} & \cdots & \mathrm{S_{1k}} \\ \vdots & \ddots & \vdots \\ \mathrm{S_{n1}} & \cdots & \mathrm{S_{nk}} \end{bmatrix},$$

where the rows represent the single sectors (i=1, …, n) in the region's economy and its columns represent the measured pollutants (j=1, …, k). So the S_{ij} element of S matrix is the sector i's environmental burden caused by pollutant j. More specifically the given S_{ij} element is the aggregated environmental burdens of the dominant companies caused by the given j pollutant in the environmental burdens of sector i.



Where M = material; E = energy; W=water; HR=human resources; G=goods; S=services; E=emissions

Source: own compilation

Figure 3. Proposed regional LCA based sustainable development analysis

The economic and social impacts will be measured by scenario and trend analysis. For the system border we chose the region's geographical border, while the function unit is the unit of GDP produced in the region. The data analysed in the model is generated from regional material flow and sector-specific production data statistics. The model does not integrate the whole economic activity; it focuses on those sectors which have a more considerable role in the development of the region and can determinate its sustainable path.

[6] *Combining life cycle assessment and economic input-output is based on the work of Wassily Leontief in the 1930s.*

Data Need for the Sustainability Assessment

Industrial sectoral data and environmental impact categories are to be provided by the datasets of GaBi 4 and Simapro software. Regional data will be derived from macro level I-O tables and regional specific characteristics can be integrated by company data collection (input-output monetary flow survey)

Delineation of the Dimensions of the Research

To decrease the complexity, so to simplify the model, it is suggested decreasing the number of analysed activities in the region. Those sectors or supply chains should be involved into the sustainability analysis that produces relatively high economic and social value added but that also contribute to a relatively high percentage of environmental pollution and resource depletion. The selection of the dominant sectors is based on long-term statistical data analysis provided by the Hungarian Central Statistical Office (turnover, employed, emissions, input flows).

Analysis involves only:

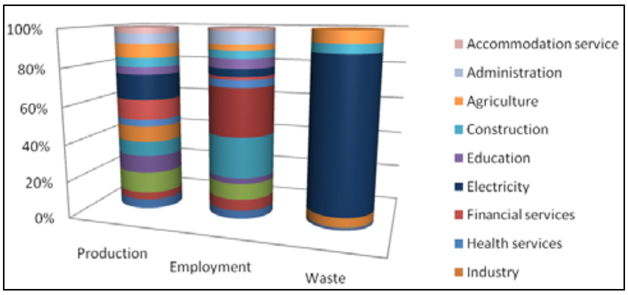
- sectors which covers together the 80 percent of the environmental load focusing on the largest polluter producers at company level - environmental aspect;
- sectors where the added value is the highest, for each sector minimum 10% of the regional added value alone - economic aspect,
- sectors which employs the most, for each sector minimum 10% of the regional added value alone - social aspect.

Uncertainty factors in our model:

- Setting reliable data series for material and energy flows.
- Making emission information more accurate on account of the different public administration borders (in case of regions) and scopes of environment protection agencies,
- Mapping the significant polluters in the region,
- Setting sectoral models, and testing the analysis (Tóthné Szita, Roncz, 2010).

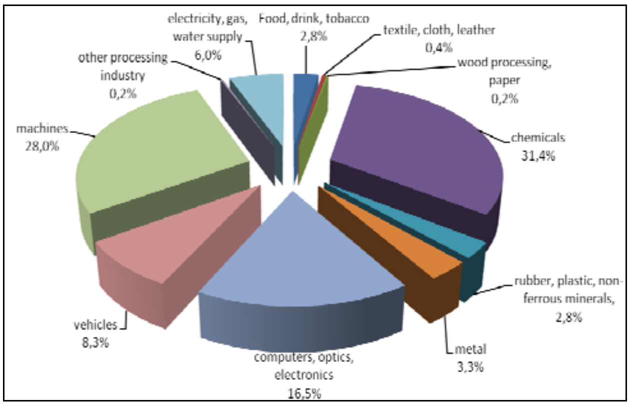
Delineation of the Dimensions of the Research in Case of the North Hungarian Region (First Results)

The target is to restrict the research area to only those sectoral relation analyses that produce the high value added but have outstanding resource usage and environmental impact. In this region the services produces the highest added value (real estate and financial services together add up to 23% of regional production). In case of electricity generation a higher gross value added and outstanding waste generation can be registered. In addition to the energy sector, industrial production (manufacturing) generates 30% of waste in the region while contributing to more than 10% of production (in value).



Source: own compilation by Hungarian Statistical Office

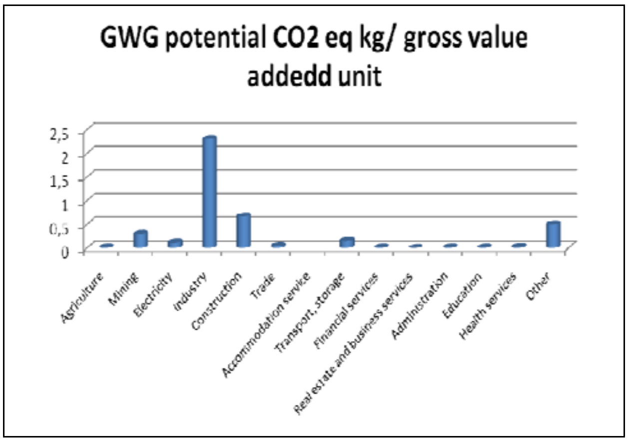
Figure 4. Gross Value added produced by sectors, North-Hungarian region (%), 2008.



Source: own compilation by Hungarian Statistical Office

Figure 5. Manufacturing broken down by subsectors (%), 2008.

Examining the detailed chart of manufacturing subsectors, the chemical industry and mechanical engineering give the biggest share (31% and 28%) of the region's manufacturing production. In this way the product-based supply chain and concerned companies should be selected from these subsectors of the regions. The employment shares cover a similar percentage. In order to get better estimations on environmental emission data, company-level waste-output data collection is needed.



Source: own compilation by Hungarian Statistical Office

Figure 6. First robust estimations by main sectors, GWG potential CO2 eq kg/GVA unit, 2008.

If we calculate the average performance of each sector integrated with Ecoinvet7 data we can get a robust estimation of sectoral GW (global warming) potential. As can be seen in Figure 6, as we already assumed the biggest environmental potential/GVA is in the categories of industry, construction and electricity production. According to the Ecoinvet dataset, mining also contributes to global warming at a relatively high extent. The group of others is an outstanding category due to the waste production intensity of the wastewater treatment activities of local waste management companies.

CONCLUSION

As the members of the Regional LCA Competence Laboratory we are working on the elaboration of a demonstrative project based on an LCA approach and I-O analysis. These are the two newest directions of the recent environmental performance analyses, so we can say that in completing the Laboratory's mission Hungarian LCA research can enter the mainstream of LCA research. The practical advantages are also promising: the consequent environmental, social and economic evaluation of regional performance can support regional decision-making policy in order to help the region to catch up by a more sustainable route.

However, the path to developing future scenarios for the region poses difficulties we have to face with the usual uncertainties: the lack of reliable statistical data, methodological implications, and the need for simplification. In this paper we have briefly summarized the current available literature on the topic. Building upon their findings we made a proposal for a regional sustainable LCA evaluation methodology assigning the data need, territorial and sectoral delineation of the research field. Analysing the production, employment and waste production rates of the sectors, the energy production, industry (chemical and machine engineering), waste treatment and mining were outstanding in terms of GWG potential/GVA. Due to the minor employment share of the mining and waste management sectors, the sectors of industry, construction and electricity production should be in the focus point of our analysis. This leads us specific subsector analysis demand, and can help us characterise the further steps and directions to improve the model and sustainability assessment.

[7] *We applied Siampro software to get Ecoinvent data.*

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