Eco-Efficiency of Regions:

Toward Reducing Total Material Input

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Abstract:

The concept of eco-efficiency is here presented as a valuable contribution to a sustainable regional development in the European Union. Eco-efficiency and dematerialization strategies are more and more established at the business level where practical and easily understandable methods and management tools have been developed and applied in the past years and decades. On this (micro) level, cases have been identified where environmental protection complements job creation and competitiveness.

On the regional level the situation is somewhat different. Although sustainable development is increasingly integrated in EU-policies the knowledge about the application of eco-efficiency concepts for the regional level is lagging behind.

Therefore this paper aims at setting out:

-the principal relevance of eco-efficiency for regions as a contribution for reaching the broader concept of sustainable regional development,

-possible fields and sectors of regional policies with a particular suitability for the implementation of eco-efficiency methods,

-opportunities and limits of eco-efficiency strategies for regions.

-basic methodological steps for the development of a material index at the regional level based on the methodology developed at the level of nations.

Keywords: Region, Eco-efficiency, Material Index, Sustainability

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1 Introduction

Rising consumption demands are leading to more intensive economic activity that threatens the regenerative capacities of ecosystems. This trend does not seem to be affected by typical environmental guidelines based on an analysis of the state of the environment. A more preventive approach is required with “Source” metrics instead of “Impact” metrics: at the level of society activity. But ecological, social and economic indicators need to be developed.

This monitoring needs to be done at the level of industries, households and administrations (the micro level), at the level of countries, and eventually one day at the world level. The level of regions (at the *Meso* level, which includes also sectors, networks…) has been until now relatively put aside but represents also an important level to realise the development of sustainable local economies. It can bring relevant policy information, help at the monitoring of regional performance. In the long run, it can help linking production systems through industrial ecosystems and consumers to local producers. In many cases regions can change more rapidly towards sustainable society than nations or the world. Direct concerns, a more transparent decision making process and many other advantages make regions a possible staging area for the ecological transition. Regions are a level of great variety, and this diversity has to be studied in details.

Reduction of environmental pressure can take two complementary routes: the route of eco-efficiency, reducing the pressure per functional units, and the sufficiency route, reducing the number of functional units. We focus here, at the level of regions, on the eco-efficiency side.

2 The concept of eco-efficiency

The concept of eco-efficiency has been developed for the business level. A definition comes from the World Business Council for Sustainable Development (WBCSD), which says that eco-efficiency

> "is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level in line with the earth's estimated carrying capacity."[1]

Characteristic features can be summarised as follows[2], [3], [4]:

Eco-efficient processes

Making resource savings and reducing risk or impact in processes allows companies to diminish the costs of production and site operations within their own fence line.

Re-valorising by-products

Co-operating with neighbouring and partner companies can offer several opportunities to re-valorise wastes and by-products by making these materials valuable alternative resources and experiencing cost benefits at the same time.

Creating new and better products

Products and services, following ecological design rules with new and enhanced functionality, offer companies new and more profitable business opportunities and increased market shares, and cost savings.

On the macro level of a country's (or Europe's) economic development, eco-efficiency has been defined as "de-coupling growth of welfare from use of nature". This means more value with less impact for the entire economy. [5]

Since the mid-nineties, Sustainable development and the integration of environmental protection into other policies is an explicit goal of the European "constitution" (the Amsterdam treaty). In simple terms, this means that these goals should be guiding all policies:

- Economic sustainability: maintenance or improvement of the quality of life, which should not be confused with the increasing production of goods and services.
- Environmental sustainability: cyclic use of renewable resources, preference for renewable ones, and preservation of the assimilation capacity of nature. The preservation of ecosystems should guide the limits of the scale of production and consumption.
- Social sustainability: equality for resource use between individuals from different generations and between individuals of the same generation including those coming from different regions.

3 The role of regions in Europe

Even though sustainable development and the improvement of the environment is a declared goal of the European Union, environmental and sustainability concerns are not integrated with the same importance than socio-economic aspects.

In the field of social and economic development, the gross domestic product (GDP) and the employment or unemployment rate are two widespread, generally known and accepted indicators. This also applies to the objectives to be achieved (continuous growth and a high level of employment). These indicators should certainly be improved to translate the goals of sustainable development.

If we look for a general measure of environmental pressure that is capable of "competing" with these generally used indicators, particular significance should be given to the material input indicator, because

- it provides a comprehensive representation of the impact of human activities on the ecosphere
- a positive correlation can be assumed to exist between the material input and many damages which are often difficult to capture
- decreasing inputs are expected to result also in decreasing outputs of the economic cycles.
- It can deal with the complexity of the system analysed

Therefore, the total material flows/input have been established by the European Environment agency as a key indicator within a core set of relevant environmental indicators[6], which could become a rough indicator of environmental sustainable development.

Indicators for SD		
Economical dimension	>	GDP
Social dimension	>	Unemployment rate
Environmental dimension	>	*Total material flows*

Fig. 1.: Indicators for Sustainable Development

For a successful implementation, political action should be addressed to all system levels.

Existing data on the total material use per capita could enable an ecological evaluation of the Structure Funds Policy. The Total Material Requirement (TMR) in tons, developed by the Wuppertal Institute for Climate, Environment and Energy, is mentioned here as one of the most prominent approaches in this respect. Data for assessing the material flows in the EU 15 have recently been published in the regular indicator report of the European Environmental Agency[7].

Corresponding regional data, however, is not yet available.

4 Eco-efficiency of regions: what regions can do

Regionalisation increases the value of the region, as an answer to the globalisation of the economy and the declining ability to act by the national states. The role of regional networks of economic actors seems to increase relatively to that of the national state[8]. On the other hand, a "bottom-up" strategy for increasing the value of the region can also be identified. This includes communication *between* communities (e.g. traffic and waste problems; water and energy supply etc.).

4.1 Principal guidelines

The present objective of regional policies is to create equal conditions of life in the regions. It is aimed at the alignment of the considerably diverging financial and material conditions through economic growth, transfer of funds and the supply of material goods. A different approach, focussing on the improvement of the quality of life while taking regional differences into account, is suggested[9]. Here, the different regional potentials in societal, economical and ecological terms are taken into account, as well as the individual aspects of quality of life.

That means that the existing potentials of a region should be developed (within ecological guard rails) in order to support a high quality of life. Under this guiding principle the region is regarded as an area to fulfil the basic needs of its inhabitants on a high and sustainable level.

The following principles[10] are complementary to this guiding principle:

- Orientation of the demand for goods and services within the region,
- Creation of job security (in the long term),
- Protection of the ecosphere.

This can be reached, through a strategy of dematerialization:

- reduction of the total material and energy flows contributing to a long-term protection of resources.

If eco-efficiency strategies are pursued and a reduction of material flows can be reached, it will simultaneously lead to other positive effects: Lower costs of production, less emissions and waste, protection of the landscape, increasing tourist attraction, higher job security and social cohesion...

4.2 Strategic Objectives

For modelling a comprehensive eco-efficiency strategy at the regional level it is necessary to look at the regional economic processes from a point of view that goes beyond the area in question. The imports and exports in and out of a region are crucial when trying to develop an eco-efficiency strategy. As it can be seen from Figure 2, the status quo is generally characterised by relatively small quantities of material and energy flows within the region, whereas the imports and exports are dominating. The grey arrows indicate the "ecological rucksacks": all materials that are required for producing and transporting the product without being part of the final product. The black arrows, on the other hand, are direct material inputs being part of the product.

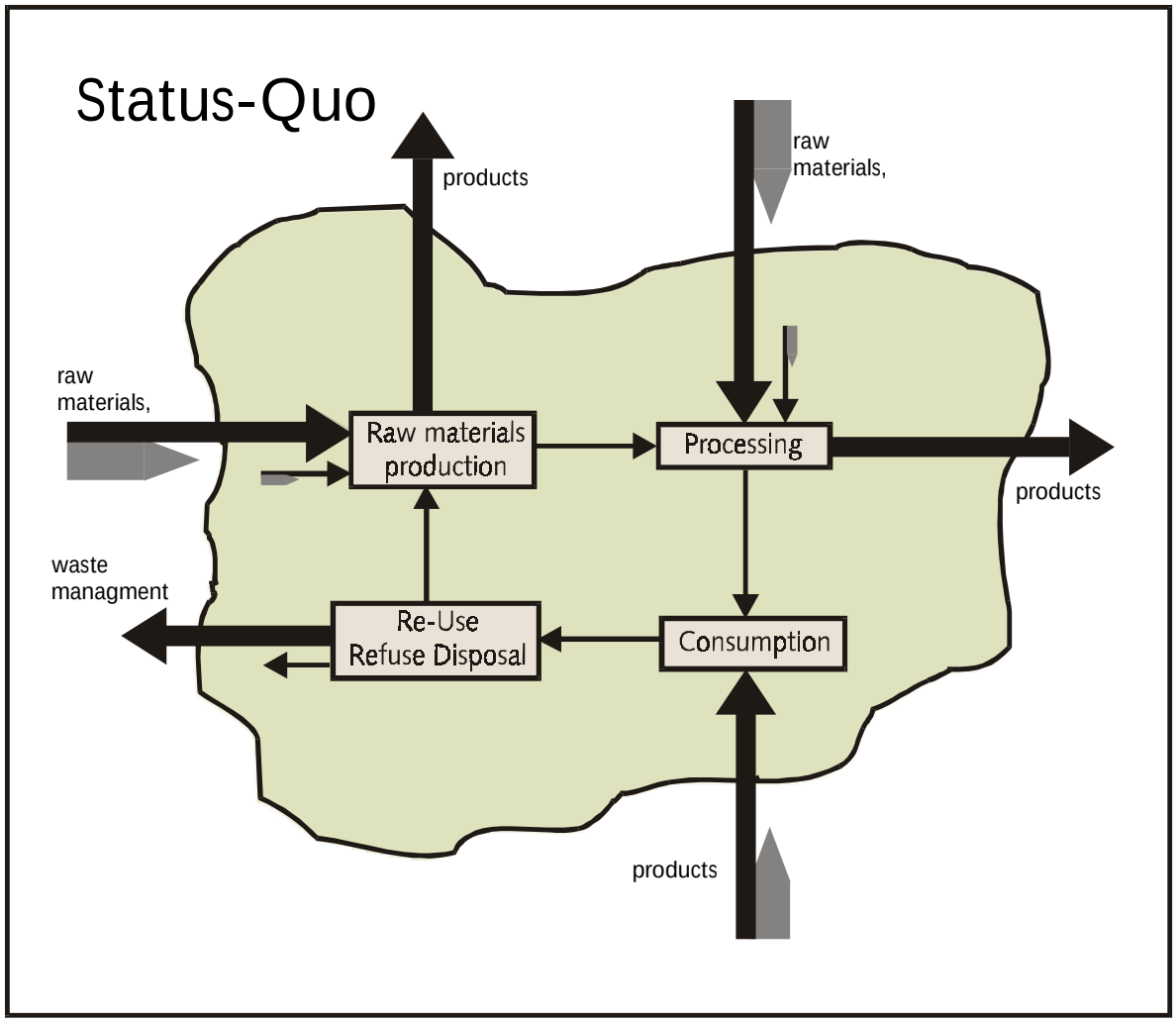

Fig. 2.: Regional material flows - Status Quo

In the course of a dematerialization strategy, a regionalisation of the economy is both facilitated and required[11]. This would result in a wide regionalisation of the material, energetic and informational processes ("In-ward Orientation"). Together with the construction and fostering of co-operative relations between all parties involved it is possible to gain increased regional independence, competitiveness and stability. The

activities of agriculture, firms, households and communities should aim at an increasing circulation of the regional economy. Proximity should therefore emerges in all areas of life. Furthermore, regional resources should be used taking into account their regional peculiarities. This would result in a reduction of the material- and energy flows between the regions (through the improvement of the regional economy and based on use of regional resources) and within a region (because of the increased resource efficiency of regional products and services).

Figure 3 shows such a situation, where the regional economy becomes more competitive while the environmental burdens are reduced.

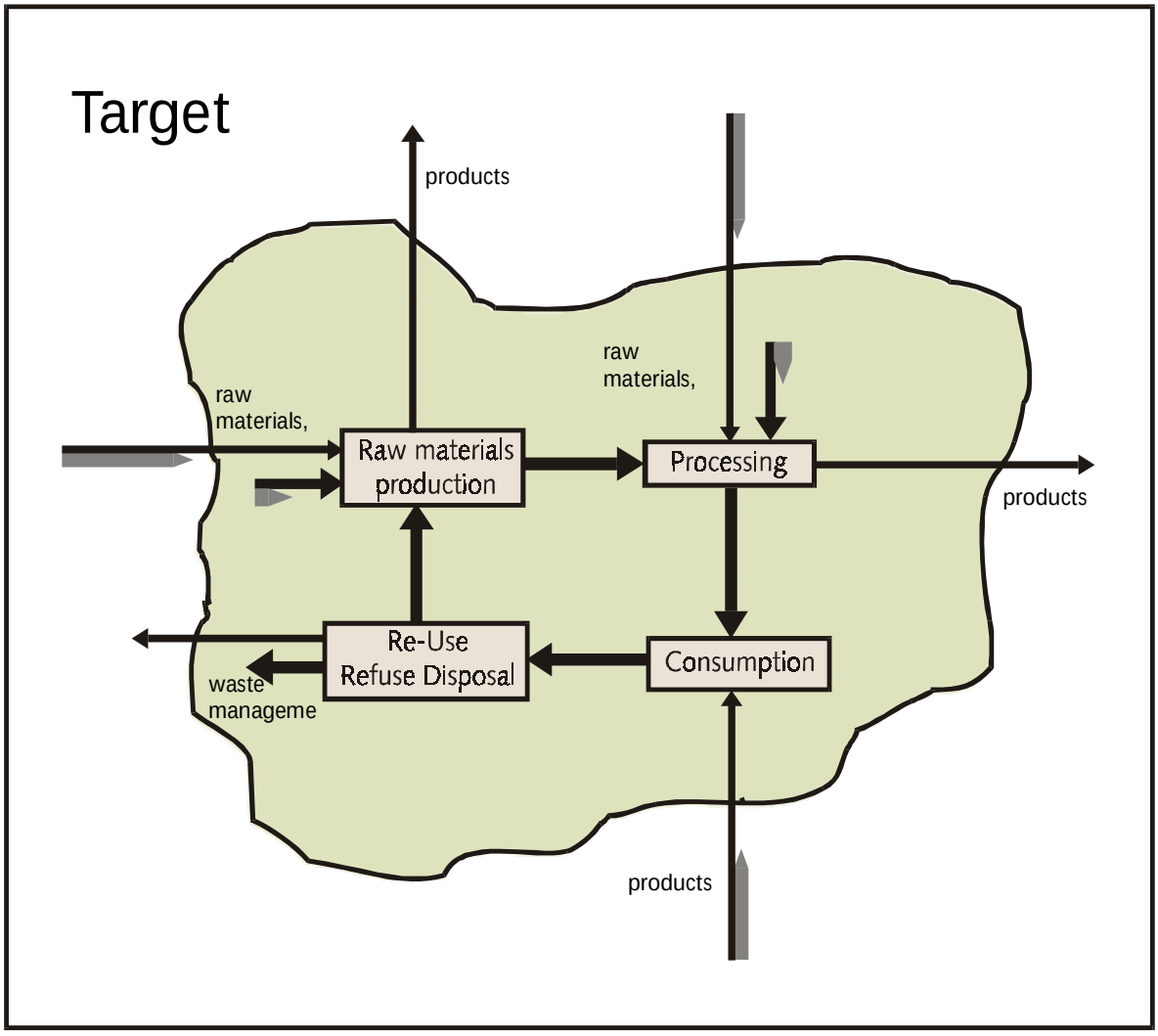

Fig. 3: Regional material flows - Target

It should be made clear that autarky is not a desired outcome. Regional economic forces and potentials should rather be mobilised without relying on external forces. This aims at mobilising the regional potentials. There are, however, constraints to such a development, as a regional strategy for certain goods or services is economically or ecologically inefficient or simply not feasible.

A re-orientation of regional policy towards a more sustainable development path involves that large intraregional material circles and value-added chains are shortened through enhanced regional co-operation. The promotion, establishment and fostering of networks in the region between producers, consumers, public authorities, interest groups and other relevant actors are a decisive factor when pursuing an eco-efficiency strategy.

This may involve the promotion of closer producer-consumer-relations as well as variety of networks and co-operation that are conceivable:

Co-operation on the enterprise level, be it vertical (along the value-added chain) or horizontal (common use of infrastructure for synergy effects); and at a larger level politics, administration, business and environmental associations and the involved citizens should co-operate.

The idea of fair share of wealth and resources is an important idea in the concept of sustainable development. In this context the eco-efficiency of region has cooperative dimensions: it involves setting examples of functioning eco-regional systems, but contains also an aspect of knowledge transfer and cooperation. As some regions are less favoured than others, the idea of regional eco-efficiency can help a fairer wealth share by developing local economies that are less dependent of the economies of richer regions.

There are, however, certain barriers that prevent the potential partners from co-operation[12]:

- External (economic) general conditions: These can influenced first and foremost by politics and usually lie beyond the scope of regional policy.
- Actually or presumably conflicting of interests: e.g. on tax revenue, competence, influence (price policy) etc. The analysis and mediation of potential conflicts of interests or potential synergy effects is, however, time-consuming and costly; a fact that can be a barrier for itself.
- Internal organisation: The partners fail to fix clear goals, the distribution of competence is far from being optimal or cultural barriers (e.g. communication problems) exist. Here, the exchange of information is essential.

5 Fields of activity

After presenting the general view on how to achieve eco-efficiency on the regional level, we now want to present several fields of activity in which contributions to a substantial reduction of (global) material flows can be taken at the regional level. Most of the measures presented in the following are not sufficient per se to enforce an extensive eco-efficiency strategy in a region. Nevertheless, it is important to have a solid basis on which a more comprehensive approach can be built on. Therefore it is suggested to analyse the specific regional potentials in order to find out the fields, where measures can immediately be taken in an environmentally most effective *and* economically most beneficial way.

Good chances for co-operative processes exist, if all participants can expect advantages. These can either be financial (a more efficient use of funds, increased sales etc.) or strategic (e.g. higher strategic stability through a reduction of competition). Generally, reasons for co-operation are as manifold as the potential partners. As long as the compromise found within a partnership offers benefits to all participants, co-operation will be an important means for promoting eco-efficiency in a region.

5.1 Regional material flow management

Material flow management is a core element of a successful regional eco-efficiency strategy. The principle idea is that, first, the entire life cycles of products (including their development, production methods and their disposal) should be the subject of examination. Second, all involved decision-makers are supposed to co-operate in order to meet three fundamental objectives[13]:

- Reduction of the material input: through a qualitatively and quantitatively improved selection of the material used.
- Eco-efficient use: The resource efficiency should be optimised in technical cycles. This can be reached through e.g. extension of the period of use, dematerialisation or an increase of the use efficiency.
- Reduction / adaptation of the material output: The materials leaving the anthropocentric technosphere should either be quantitatively reduced or qualitatively less harmful. The concept of an ecological waste management offers the necessary tools for this task. Moreover, it implies that this objective should already be addressed to in the phase of material extraction.

The starting-point of such a strategy would be at the enterprises level: the inputs should be examined with regard to their original source and the outputs to their final destination. This would automatically imply that a wider area is analysed – the regional level or beyond.

Such a thorough analyses offers distinct advantages for the companies:

- Ecological and economic weaknesses of products can be detected, which leads to:
- Identification of cost reduction potentials throughout the value-added chain. This can, for instance, be achieved through:

- Vertical co-operation with suppliers, customers and other relevant parties.
- Exchange of input materials (substitution materials with a lower material intensity).
- Taking advantage of internal or external possibilities for re-use, recycling etc.
- The facilitation of the use of cost-benefit analyse instruments (because more information is available).

An important aspect for a successful realisation of regional eco-efficiency is sufficient information for all participants. In particular, a lack of information might occur about[14]:

- The possibilities to obtain renewable energy, raw-materials or products made out of these within or beyond the region and
- the total material flows of different technologies, semi-finished products or other production inputs.

Regional advice centres for sustainable resource management could make a considerable contribution for the initiation and/or maintenance of an ecological-economical and social development. Here, regional authorities and public private partnerships can play a special role.

Small cities play an important role for the implementation of regional eco-efficiency. [15]

The Local Sustainable Development Network (LSDN) is an interesting illustration of what can be attempted in terms of development of specific know-how associated to sharing of knowledge and the creation of jobs.

Representing an innovative way of implementing Agenda 21, this EU supported project with a total budget of 4 million Euros is a cooperation of five small European towns (Dormagen, Fürstenwalde (Germany), Toro (Spain), Redange (Luxemburg), and Tulln (Austria)).

Each European partner records and analyses its experiences in the use of biomass with a study of material flows. With local partners, innovative concepts for the use of biomass for energy and heat production are developed and applied. The project further includes seminars, advanced Internet communication, youth exchanges which are used to create a dynamic of cooperation and awareness raising.

The advantages of such a strategy are manifold:

- Cost minimisation through the use of already existing facilities.
- Energy agencies are close-to-customers and could, moreover, use the link (as regards content and methodology) between energy and material use.
- Regional development agencies, on the other hand, could use their business relations to optimise economic and ecological goals of concrete business projects through increased resource productivity.

Additionally, research & development should play an important role as well. Existing information on eco-efficient regional development should be exploited by the promotion of (pilot) projects.

5.2 Small business strategies

A broad range of existing management tools can be applied at the business level. Since 1990, the Paris Office of the environmental program of the United Nations has forced the technique of "Cleaner Production (CP)"[16] throughout the world. Cleaner Production means "the continuous usage of an integrated preventive environmental strategy on processes, products and services to increase their efficiency and to reduce the implied risks for humans and environment". For production processes, CP includes the saving of material and energy, the avoidance of toxic substances in processes as well as the reduction of many toxic emissions and waste. For products CP is concentrated on the reduction of environmental changes along the whole life chain (from the acquisition of raw materials to the final disposal).

More comprehensively, the MIPS approach integrates material flows from cradle to grave. The sum of the material input (MI) is related to the service or use (S) of any product, for example the lifetime of the product (MI per S = MIPS). There are two basic strategies to reduce the MIPS-value of a product:

a) Decreasing the material input by technical changes/improvements

b) or increasing the number of services (for example: extending the lifetime of the product).

5.3 Regional and environmental planning

Material intensity targets should be integrated in environmental planning. The product- or plant-related MAterial Intensity Analysis (MAIA) would be the appropriate methodology for evaluation at the project level. This helps in detecting not only potentials for reducing material flows but could also bring out cost reduction potentials.

"PROREGIS - Resource Productivity Registries"[17]

Resource productivity factors for new materials must be established on a continuing basis. Existing resource productivity factors can change over time. Therefore, they must be periodically re-evaluated. From a scientific as well as from a practical point of view it appears necessary to establish registries for resource productivity factors.

The Factor 10 Innovation Network is currently studying conditions for collecting, generating, and validating natural resource productivity data - on behalf of the German research ministry and the Austrian innovation ministry. The results are quite likely the starting point for a European initiative to build up Resource Productivity Registries - PROREGIS centres.

It seems useful to establish regional PROREGIS centers, well interconnected with all others and exchanging data on a routine basis. It would also seem furthermore appropriate to establish central PROREGIS institutions, for instance for the EU and East Asia, and perhaps later on a global basis. This should ensure an overview of local and regional developments. For the regional PROREGIS centers regional-specific data should be collected, administrated and reported.

5.4 Agriculture and food industry

In the agricultural sector unsustainable developments are the loss of jobs, increasing energy consumption, an increasing burden on water and ground soil, declining food quality and the loss of decentralised supply structures. This is mainly due to concentration, intensification, specialisation and mechanisation in all fields of this sector, often caused by the EU-Common Agricultural Policy.[14] Long ways of transport and high material flows are the result of this policy.

Similar to the timber industry, it regionalisation of processing, marketing, consumption and waste management should be promoted. The creation of value within the region should be a paramount objective.

Suggested Measures:

- Improve regional marketing, co-ordination and an image of the regional agricultural sector.
- Consumers should be well informed about the quality of regional goods and regional advantages.
- Development of financial aid programmes.
- Regional and ecological training of farmers.
- Stimulation of regional networks between farmers and processing enterprises in order to make use of synergy effects and to establish a quality management.
- Regular regional fairs for the creation new business and customer relations within the region.

5.5 Construction

The construction of buildings is not only material and energy consuming, but also an important emission factor (esp. sulphur dioxide emissions, nitrous oxide emissions and carbon dioxide emissions). Principles for “greener” construction could be as follows[18]:

- Use of renewable energy sources: e.g. solar power for water heating
- Reduction of environmental impact: preserving the site’s integrity and natural characteristics; selecting with have lower material and energy intensity and those that are produced locally.
- Resource conservation: selecting materials that have at least some recyclable content
- Minimising construction waste.
- Installing water- and energy-efficient devices can conserve resources while reducing operating costs.
- Improving indoor air quality: Energy-efficient buildings are more airtight and therefore hold greater potential for the improvement of indoor air quality.

- Connecting to the community: Placing green building projects within easy access of public transportation, medical facilities, shopping areas, and recreational facilities decreases the need for automobiles and encourages bicycling and walking. In addition, successful green buildings blend into the community, preserving natural and historical characteristics, and will utilize existing infrastructure in order to reduce urban sprawl.

The reconstruction of buildings as a chance for climate and employment

In 1998 the German trade union for Building, Agriculture and Environment (IG BAU) and Greenpeace started a project called "Improving Employment and Environment". The objective was to point out *that* and *how* the conversation of the environment can create and secure jobs. By the means of a "Certificate for Employment and Environment" the house owners shall be motivated to energetically renew their buildings (e.g. by the improvement of windows or the isolation of building-walls). The requirements to obtain a certificate include energy consumption less than 100kWh/m^2a (which equals about 10l fuel oil), the restricted use of non-renewable materials and the obligation to obey to working, health and wage regulations.

An accompanying study[19] determined a scenario that an investment of 15 Billion DM a year – these are 3% of the total investments in this branch – between 1999 and 2020 would have the following impacts:

- Permanently secure respectively create 430.000 jobs, of which 174.000 would be in the renovation business,
- Reduce the energy-costs of buildings up to 50% and the CO_2 Emissions up to 58% in reference to the year 1999,
- Provide an extensive save of resources that will reach about 68 Mio. Tons in the year 2020.

The necessary investment program, which needs to be supported by government funding, would be counterbalanced by an increase in revenues for social security and direct as well as indirect taxes. Furthermore, because of the improved employment situation, the expenses for social contributions decrease.

5.6 Procurement

Effective environmental protection requires contributions beyond regulations. Public authorities themselves should set positive examples. "Green Purchasing", as it is often referred to, offers two major advantages: First, there is a good chance that people imitate the public authorities in their purchasing behaviour. And second, the market-access of the

suppliers of eco-efficient products and services is improved or, in the case of a new product, a market can be created.
The relevance of public procurement in the EU is obvious as it accounts for 11 % of the GDP.[20]

The recommended steps towards an eco-efficient procurement system are listed below[21]:
- A *procurement policy* should set up criteria according to which products or services are screened. Already existing concepts (TMR, Factor 4...) should be preferred.

- An examination should produce a *strengths/weaknesses-profile* of the actual procurement practice, from which a new

- *Procurement programme* can be derived and applied.

- Simultaneously *an ecological procurement management system* should be developed, which serves as a control institution.

Possible fields for a „green purchasing“ approach are office equipment, motor vehicles (+ equipment), building & construction, energy & water supply, horticulture & landscape planning, waste management. All these fields are equally important for private consumers.

Eco-efficiency and public purchasing[22]

An eco-efficient public purchasing helps relieving the environment and supporting the development of sustainable consumption patterns and the bringing onto the market and market penetration of eco-efficient products and services.

In *Carinthia* (Austria) exists an initiative to found a so-called *eco-efficiency exchange*. The basic idea is that eco-efficient products and services are collected in an Internet databank to transfer the information to the purchasers of the public administration. In this way the eco-efficiency exchange shall operate as an intermediary between supply and demand of eco-efficient products. By this means consumers receive a concrete overview about ecological and economic optimised products and producers and suppliers of such products ought to break into new and concrete markets.

Very important ways to reduce pressure is through the reduction of km travelled by car and plane especially, the reduction of paper use, and the reduction of energy consumption for heating and appliances. These goals require a profound reorganising of the offices. An analysis of the Estonian chancellery is being developed in order to reduce these large consumptions[23].

5.7 Regional waste policy

Generally, avoidance and utilisation should have priority, but when treatment and disposal of waste are inevitable, regional and local co-operation is especially important and (eco-)-efficient. Comprehensive concepts of regional sewage systems should cover all tasks to be fulfilled by communities and a region as a whole. If feasible, natural treatment methods should be preferred.

Regional management of household organic waste[24]

Eco-efficiency may be applied to the management of organic household waste. In this domain, Lower Austria has been very successful in implementing composting at the regional level. By weight 46% of the total household waste is composted in Lower Austria (including home composting). From 1988 to 1998, the amounts of home composting have multiplied by 3 or 4. By preventing the treatment chain 14,5 million Euros are saved every year with home composting. From the beginning a decentralised policy was defined: **"As much home composting as possible; Separate collection when home composting is difficult; As much agriculture composting as possible; As many decentralised small composting plants as possible; As many regional composting plants as necessary"** 250 people have been trained in composting between 1990 and 1995 becoming real intermediates toward the population. Every year the lower Austrian „müllometer" informs the local citizens about the performances. This management of organic waste enables an important reduction of the pollution from landfills and the amounts of waste to be dealt with and contributes to soil protection.

The management of organic waste has been defined at the level of a region. It aims at a closed cycle with very little import and exports. Hence, Lower Austria represents a complete model for eco-efficiency for organic waste management as it allies all the possible options of collection, with home collection, door to door, collection centres, garden use, local and regional plants.

Solid waste should, likewise, be avoided or further used. Suggested are more information schemes about avoidance, optimisation of collecting systems for waste or the organisation of exchange opportunities for second-hand goods. The region of Aachen (Germany) would serve as an example, where communities, companies and several information centres and initiatives work together to run a combine for the utilisation of old electronic and electric appliances. 95% of the materials can be reused, while simultaneously creating employment opportunities in the region, especially for long-time unemployed, which are given the chance to qualify with training-on-the-job.[25]

5.8 Tourism

A sustainable, eco-efficient tourism strategy combines higher tourist attractions with lower material and energy flows. The negative effects of mass tourism should be overcome by a more decentralised structure, a careful infrastructure-planning scheme, a corresponding marketing strategy etc.

The Rhoenschaf [26]

In Germany's Rhoen region, farmers united, to market the Rhoenschaf, the local sheep products. Chefs of the region created appealing recipes and helped in promoting a cultural heritage. Buying the wool, meat or salami directly from the source is another form of preserving a breed and a unique landscape.

Since 1987 the BUND (Association for Environment and Nature protection in Germany) has been taking measures to help preserve the best advertisement carrier for a region -- the Rhoenschaf.

6 Indicators for regional sustainable development

Many examples show that important steps toward sustainable development can be made especially on the regional level. To see if these efforts suffice, it is crucial to have a monitoring system at hand to measure the overall development of a region toward sustainable development. From the statements made earlier it follows that indicators of total material flows activated by a region within and outside its borders are an important "headline indicator" for that, which can be compared with figures of economic performance (GDP) and the social situation (employment, distribution of income). Such a procedure has been applied to some European countries as well as EU15 (see EEA 2000). A pilot study exists for a German region: Northrhine Westfalia and the Ruhr area. The methodology allows for a comprehensive monitoring of a regions' development toward sustainable development.

The material intensity of the Ruhr area [27]

In a pilot study for the highly industrialized Ruhr area, the material flows activated by production and consumption processes in that region were investigated. The results show that in 1990 337 tons of material (without water and air) were used within and outside the region per employed person on the average, only about 25 % of which within the Ruhr area.

The physical stock of that region, i.e. the amount of products, infrastructures and machinery (which can be measured by the physical input including imports minus outputs of waste and emissions) grows per year by almost 1/3 of the inputs, which is about 100 Mio t/year.

The Total Material Requirement of a region (TMR) represents all materials that are moved within and across its borders to provide consumers products and services in this region. The Total Material Consumption of a region (TMC) considers only the products and services provided in this region, it is obtained from the TMR by excluding the exports. DMI and DMC represent the direct inputs (without the ecological rucksacks).

The methodology developed in Wuppertal can be applied to measure, report and control if a region meets the goals set by regional sustainable development plans or similar statements.

It can be discussed with stakeholders to see and decide which further actions should be taken if the results of the monitoring are not sufficient.

Besides the domestic inputs of natural resources, the so-called “rucksacks” of these direct material flows should be accounted. This comprises the material inputs required in other parts of the world to produce imported goods as well as overburdens and waste produced at the extraction sites of domestic resources.

It would not only allow for comprehensively measuring the eco-efficiency of a whole region but also relate the result to the monitoring of national economies, Europe as a whole, on the one hand, and single projects, products or companies/households on the other.

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Appendix: The different steps of regional Material Flow accounts

A methodological guide has been presented at the level of a whole economy by Eurostat[28]. We present here the possible steps of such a methodology to the level of regions. Work is still required to solve all the methodological problems.

I- Goal and system definition, identification of data sources

Characterisation of the region

Goal definition

Methodological decisions

Identification of sources of information on the national level

- General data, e.g. population, share of each sector
- Import-export statistics per sector
- Extraction, production and consumption statistics

Identification of sources of information on the regional level

- General data, e.g. population, share of each sector
- Extraction, production and consumption data
- Import/Export information on the interregional and international level, what are the main trade partners?

Identification of sources of information on the international level

- Imported rucksacks, Total Material Inputs (including the process chain and the extractions or unused flows) of different imported products and materials may be available in international databases
- Unused regional extractions: International information may be relevant for the quantification of unused flows for the region too. These flows include mining or quarrying waste, biomass harvesting losses and soil/rocks excavations and dredge materials

Identification of data gaps and ways to deal with them

II- Quantification of Inputs

1- Direct Material Input (Regional)

The Direct Material Input (DMI) corresponds to materials that enter the economy for being used in products or processes. The estimation of regional production/consumption may be obtained directly by local data or on the basis of national basis with the share of each sector.

Estimation of Regional Extraction,

They include:

- fossil fuels

- biomass
- minerals

*Estimation of **InterNational Imports** (into the region) (INI)*

These can be estimated with the share of each sector. Imports are classified according to their degree of manufacture and basic components

*Estimation of **InterRegional Imports** (into the region) (IRI)*

Calculation of the Direct Material Input

Direct Material Input = Regional Extraction + Imports (INI+IRI)

2- Total Material Requirement

The total Material Requirement represents a material indicator, representative of the region's material consumption, measuring the total material base of an economy. It measures the direct and indirect input of materials for the regional production. It includes the flows of materials of products and materials that are exported from the region.

Estimation of Unused Regional Extraction

From local data, or derived from national or international data

These flows include mining or quarrying waste, biomass harvesting losses and soil/rocks excavations and dredge materials

Calculation of the Total Material Input

TMI = DMI + Unused regional extraction

Estimation of used extraction linked to imports

Derived from national and international data, this quantity is related to DMI in the rest of the world

Estimation of unused extraction linked to imports

Derived from national and international data, this quantity is related to unused extractions in the rest of the world

*Calculation of the **indirect flows associated to imports** ("imported ecological rucksack")*

Imported indirect flows = used + unused extraction linked to imports

Calculation of the Total Material Requirement

TMR = TMI + Indirect flows associated to imports

III- Quantification of Outputs and mass balance

1- Regional Material Consumption

*Estimation of **International Exports** (from the region)*

*Estimation of **Interregional Exports** (from the region)*

Calculation of the Regional Material Consumption

This corresponds to the total amount of materials directly used in the regional economy

Regional Material Consumption = Direct Material Input – Exports from the region

Calculation of the Physical Trade Balance

Physical Trade Balance = Imports to the region – Exports from the region

2- Regional Processed Output

Estimation of the Regional Processed Output

This is the total weight of materials used in the regional economy (and emitted). This includes emissions to air and water, and solid waste landfilled, as well as dissipative use of products and losses.

Calculation of Net Addition to Stocks

This is how much is stored in the region every year

NAS = DMC-DPO

Calculation of the Direct Material Output

Direct Material Output = Regional Processed Output + exports.

It measures the total amount of direct material outputs leaving the economy either toward the environment or toward the rest of the world.

Calculation of the Total Regional Output

Total regional Output = Regional Processed Output + Unused Regional Extraction

This measures the totality of materials that leaves the economy.

3- Total Material Consumption

Estimation of the indirect flows associated to exports

Calculation of the Total Material Consumption

TMC=TMR-Exports-indirect flows associated to exports

III- Interpretation of the results

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