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Sustainable Development in the European aggregates industry:

a case for sectoral strategies

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Contents

1. Introduction

The EU Sustainable Development Strategy, ensuing National Strategies, and the EU Thematic Strategy on the Sustainable Use of Natural Resources (COM(2005)670 final) alike call for a decoupling of natural resource use from GDP growth. Empirical analysis demonstrates that the largest share of natural resources stems from construction minerals, i.e. aggregates such as sand, gravel, crushed rock. According to Eurostat, they represent 40% of the Direct Material Inputs into the European economy in 2002 (mineral fuels 25%).

This paper analyses governance processes enhancing the sustainability performance of aggregates that have begun to take stock in Europe.

Since aggregates are mainly no endproduct but serve basic human needs like housing and physical infrastructures, **driving forces** for aggregates consumption are found in construction. What they and a yet predominantly regional scope of production and use imply for the **economic relevance** of the aggregates sector is discussed in the first chapter. How the combination of specific environmental impacts, consistent high volume of use and sectoral growth prospects shapes a growing **environmental relevance** of aggregates in Europe is reasoned in chapter two. Data are gathered from recent Life Cycle/Material Flow Analyses and economic sectoral assessments.

A third chapter analyses existing EU **policies** and national economic instruments affecting aggregates and sectoral processes like sustainability initiatives and networks, thus exploring structures and mechanisms of inter-ministerial collaboration/horizontal policy integration. However, there are no policies yet addressing the use of aggregates in conjunction with their final demand in respective markets. Rather, policies are fragmented into extraction, production, consumption and waste stages and still incoherent.

The final **conclusions** underline the importance of addressing sustainability of construction in a most comprehensive manner. In following emerging governance processes, they also lay down elements for a sectoral action plan on aggregates and sustainable construction.

Aggregates – definition and use
Aggregates are granular materials, sand, gravel and crushed rock in particular. An end-product in themselves as railroad ballast, armourstones, filter beds or flux materials, aggregates are a raw material used in the manufacture of vital construction products such as ready-mixed concrete (made of up to 80% aggregates), pre-cast products, asphalt (made of 95% aggregates), lime and cement. Their main application area is the building and construction sector, i.e. residential and non-residential building and civil engineering in the field of traffic/transportation/supply infrastructures and the repair and maintenance of buildings and infrastructures (UEPG, 2005: 5).

Aggregates are used for the following goods of final demand:

- Homes – The construction of a typical new home uses up to 400 tonnes of aggregates (both end-product and concrete) - from the foundations through to the roof tiles (incl. sub-contractors).
- Other buildings and public places – From commercial buildings, local hospitals and schools to bridges and flood protection – most buildings are made by aggregates. In many cases they provide not just strength but contribute to, through special finishes, architectural beauty. The construc-

tion of a school uses up to 3,000 tonnes of aggregates. For a conventional sports stadium, up to 300,000 tonnes are needed.

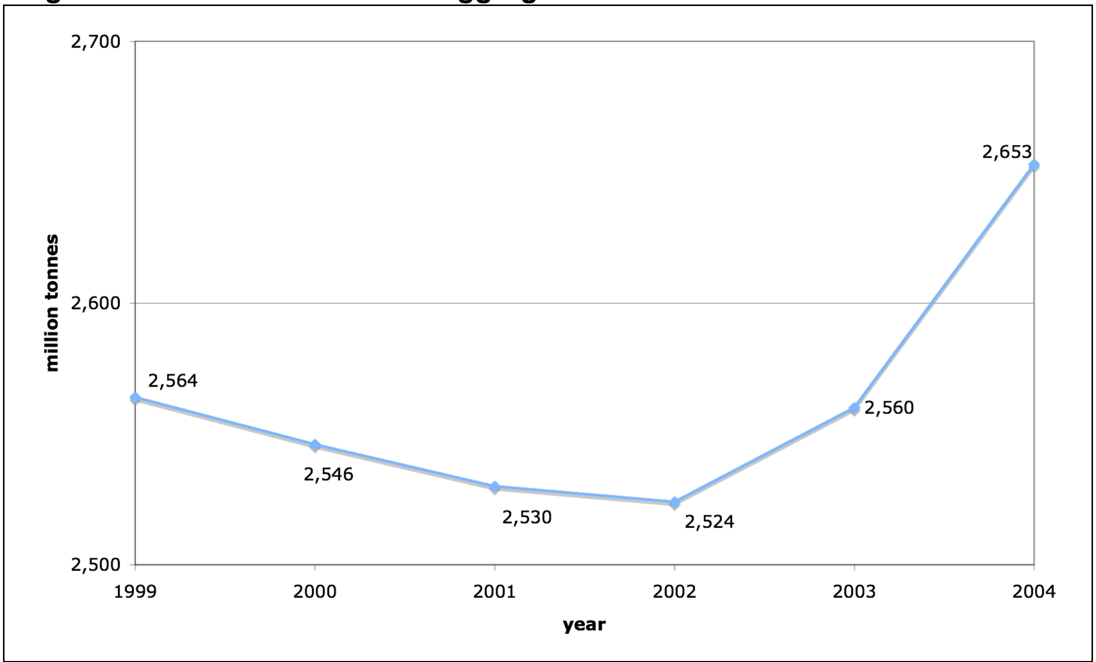
- Roads – Aggregates are used at all levels of the road construction up to the surface, including aggregates resistant to polishing, ensuring skid-resistance. The construction of 1 km of motorway uses up to 30,000 tonnes of aggregates.
- Railways – Aggregates are essential as track ballast for Europe's rail network. The construction of 1 metre railway for High Speed train (TGV) uses up to 9 tonnes of aggregates.

2. Economic relevance of aggregates throughout Europe and driving forces for production and use

The extractive industry of aggregates differs in at least two important aspects from most other industrial sectors: First, the location of the industry and the quality of the material produced is determined by geology in relation to areas of high demand, i.e. large cities; second, the success of the sector is dependent on the success and competitiveness of the downstream industries. Aggregates industry is a supplier to construction (NACE F 45) as well as to manufacturers of minerals, cement, concrete (NACE DI 26.1-6); its market position can be considered moderate. In turn, competitiveness is controlled by two factors: quality and quantity of aggregates deposits and the political, legal, administrative, social and economic environment in which aggregates extraction takes place (Wagner/Tiess 2004: 27). Both aspects underline that companies are used to take a long-term perspective: they need to ensure the supply of aggregates and to obtain permits (which takes approximately 10 years).

According to the British Geological Survey (2006), the production of aggregates in Europe appeared widely constant in the years from 1999 to 2004 and ranged between 2,500 to 2,700 million tonnes per year.

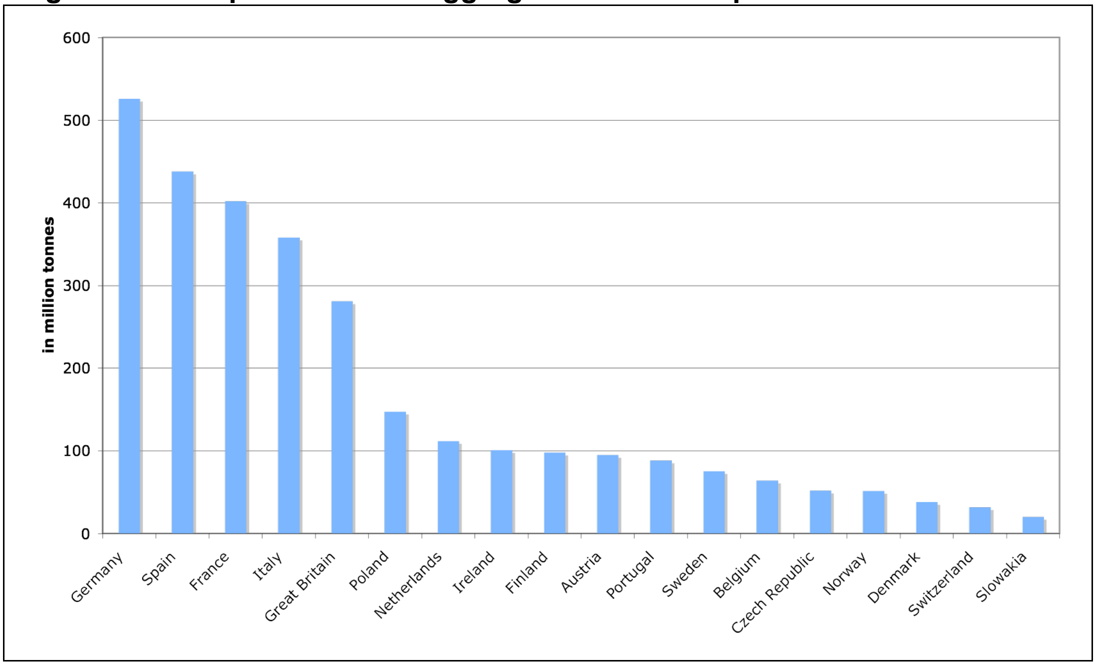
Figure 1: EU-31 Production of aggregates 1999-2004



Source: BGS 2006

In 2003, Germany (19 % of total production), Spain (15 %), France (13 %) and Italy (12 %) were the main producers of aggregates (see figure).

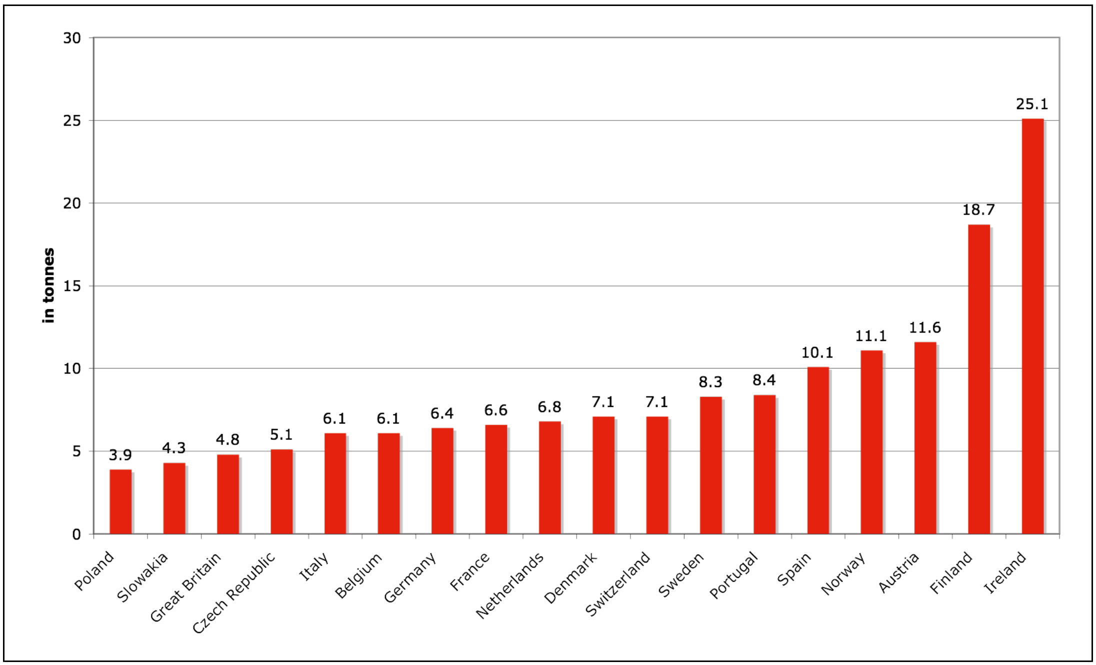
Figure 2: Total production of aggregates in 18 European countries in 2003



Source: Compiled on the basis of UEPG data 2006.

In contrast, the output of aggregates per capita/year shows a different picture. The average output is about 7 tonnes per capita. The leading countries in per capita output are Ireland (25.1 t/cap) and Finland (18.7 t/cap) whereas the main total producers are below average in per capita production (with the exception of Spain with 10.1 t/cap). High per capita production does not necessarily correlate with high exports from Ireland, Finland, Austria (see figure 5), it might also either indicate high demand or a more inefficient production.

Figure 3: Per capita production of aggregates in 18 European countries in 2003



Source: Compiled on the basis of UEPG data 2006.

Aggregates and construction can be considered a moderate growth market in Europe. Looking at the economic prospects, the "Euroconstruct" conference in Barcelona (2005) has been instructive (Rußig 2006). Forecasts for housing and construction markets are in the order of 2 % growth p.a., with higher growth rates expected for commercial buildings, infrastructure and maintenance of existing stocks while new private homes will slightly lag behind. In regional terms, the new member states Czech Republic, Hungary, Poland, and Slovakia, as well as Spain are likely to have highest increase in their demand for aggregates. UK, France and Italy remain in a stable position of being important markets while Germany and Portugal are likely to stagnate or even decline further.

Table 1: Economic relevance of aggregates production and expected expenditure for construction per capita in Europe

Country	Economic relevance (average = 1)	Expected expenditure for construction per capita 2006 – 2008 in €
Slovakia	2.8	< 1800
Poland	2.7	< 1800
Ireland	2.5	> 3300
Finland	2.4	> 3300
Portugal	2.3	> 3300
Czech Republic	2.2	< 1800
Spain	1.9	> 3300
Austria	1.5	2800-3300
Italy	1.0	2300-2800
Sweden	1.0	1800-2300
Norway	0.9	2800-3300
France	0.9	2300-2800
Germany	0.9	1800-2300
Belgium	0.8	1800-2300
Denmark	0.7	2800-3300
United Kingdom	0.6	2300-2800
Switzerland	0.4	2300-2800
Netherlands	0.1	2800-3300

Relevance calculated as production (t) per 1000 € GDP per capita, average = 1;
Source: own calculations, on basis of UEPG 2005, Rußig 2006.

The economic relevance of aggregates differs significantly among the member states. Comparing prospects for housing and construction markets with today's situation of industrial supply (see figures 2, 3) table 1 calculates and weighs the relevance of aggregates as a function of production (t) per 1,000 Euro GDP/capita. Table 1 reveals strong eocnomic relevance in countries such as Slovakia, Poland, Ireland, Finland, Czech Republic, Portugal and Spain. In some of those countries (Ireland, Portugal, Spain) demand is expected to increase and, hence, supply and demand are likely to match. Countries such as Finland, Slovakia, Poland, Czech Republic and Austria also inhibit strong capacities, which may not be fully utilised in the next years due to a more sluggish demand expected for those countries. Other countries such as Belgium, Denmark, Netherlands, Sweden and UK may not have the production capacities needed to meet market demand – they are likely to increase their imports from other member states. The interests of member states thus differ: while those with low production capacities are interested in a recycling of construction materials, others take an interest in an internal market for aggregates.

Prices as drivers of aggregates supply

Prices are an important driver of aggregates supply. According to economics, the market price is at the intersection of the supply and demand curves. It is at the equilibrium point where the quantity demanded equals the quantity supplied. Price changes may result from variations in supply or demand or both. However, there are three major imperfections relative to the operation of the aggregates sector that lead to a rather inelastic supply and demand:

1) First, since it normally takes at least four years to bring new supply or aggregates-based materials capacity on-stream, shortages can persist resulting in major price rises. Prices for crushed rocks show a trend towards a long-term decline due to technological advances in production (Wagner et al. 2002: 138).
2) Second, once capacity exists and fixed costs have been incurred, producers are reluctant to curb output as long as some contribution is being made to overheads.
3) Third, price variations are magnified by the nature of demand for some minerals. The major end-uses for a number of aggregates are the housing and construction industry, which is more profoundly affected by recession than other sectors of the economy. The effects of recession will be magnified for the producers of intermediate goods; in their case the recession will not only be deeper, but also more prolonged, since consumer demand has to pick up before new orders for plant and machinery are made. In Europe, cement production is also affected by electricity prices; thus market liberalisation for electricity and environmental policies (EU, ETS, energy taxes) has a decided impact (see chapter 5).

3. Environmental relevance of aggregates

The aggregates industry can be considered the most resource-intensive sector throughout Europe. According to Eurostat, in 2002 they represent 40% of the Direct Material Inputs (DMI) into the European economy while mineral fuels represent another 25%.[1] When the term sustainability is strictly interpreted, the production of aggregates is non-sustainable because aggregates are non-renewable and – at least in the end – scarce resources. Morevover, the environmental impacts of aggregates can be considered far from being negligible. Starting from extraction process, they cumulate over the different stages of their life cycle. Such life-cycle perspective will be pivotal for analysing aggregates and for the evaluation and identifying appropriate response options.[2]

At first, the following scoping problem should be noted. When environmental impacts of aggregates shall be considered, mounting statistical difficulties occur due to yet overlapping definitions and data. Present data are fragmentary, often inconsistent, partly not EU-wide and refer to different definitions and terminology of material groups like construction minerals, building materials or simply minerals which all include aggregates to a large extent (see BGS 2006). Although some studies indicate that the separation of a category like aggregates may be negligible in some cases because the output figures are

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[1] Presentation of Steering Committee of the European Technology Platform on sustainable minerals, Brussels, January 2006 (www.pef.uni-lj.si/strani/razpis2/etp-presentation.pdf)

[2] See EU Thematic Strategy on Sustainable Use of Resources (COM(2005) 670 final), p. 5: "It is necessary to develop means to identify the negative environmental impacts of the use of materials and energy throughout life cycles (often referred to as the cradle to grave approach) and to determine their respective significance. This understanding of global and cumulative impacts along a causal chain is needed in order to target policy measures so that they can be most effective for the environment and more cost-efficient for public authorities and economic operators."

very close to the total minerals extraction (see e.g. v. de Voet 2004: 70), the *problem of inconsistent definitions and data remains at present*.

At the *extraction processes*, direct and non-reversible landscape alterations (concerning the cultural assets of a region or more particular e.g. the groundwater) are generated[3] and also the competition of land uses (with agriculture and nature conservancy) is significant. *After extraction*, further environmental impacts occur during the (albeit rather long) life cycle of aggregates. Energy- and emission intensive manufacturing processes of the concrete, cement, glass and ceramic production, which use aggregates as basic material, account for the indirect environmental impacts of aggregates. Last but not least, aggregates mainly contribute to the *transformation of land into built-up area* (streets, highways, buildings) implicating impacts like soil sealing and landfilling when buildings are demolished. The following section will illustrate different environmental impacts of aggregates.

In general, aggregates are associated with three types of environmental pressure:

1. The depletion of non-renewable resources,
2. The threats they pose to the environment of the particular extraction site (e.g. land use issues),
3. The environmental pressure they generate through extraction, transport, use and further processing (i.e. energy, water and emission issues).

In the following section, the cross-cutting issue of material flows is subordinated under those types of pressure. This has been done in order to make reference to the concept of decoupling as put forward in the EU thematic strategy (COM(2005) 670 final).

Resource depletion

Sand, stone and clay belong to the materials contributing to resource depletion. The volume of material consumption (collected through Material Flow Analysis) shows that sand and stone materials contribute significantly to the overall apparent consumption of the EU-25 and three accessing countries (i.e. Bulgaria, Turkey, Romania) in the period of 1990 to 2000[4]. Construction materials, mainly comprised of aggregates and their downstream products, dominate the picture. Together, they account for roughly two thirds of domestic material consumption (v. de Voet 2004: 43).

The resource depletion potential per kg of a material (identified through Life-Cycle Assessment) is measured in antimony equivalents; the reference material is lead. Compared to metals and fossil fuels, the resource depletion potential per kg of sand and stone and clay is low, i.e. lead is equal to 1 antimony equivalent, sand/stone is below 0.00001 (factor 100,000) (v. de Voet 2004: 41ff.). However, the volume used is extremely high compared to other materials and thus accumulates the rather low resource depletion potential**.** Table 1 and figures 2 and 3 above also illustrate that some regions in Europe are faced with shortages of aggregate supply. The causes are unexplained yet.

Extraction and use of aggregates are not decreasing yet, i.e. there is no 'environmental Kuznets curve'[5] visible, and signals of decoupling are unspecific (v. de Voet, 2004: 6). In fact, the DMC of construction materials had slightly increased in the period 1992 to 2000 in Europe resulting in the overall effect of a slight increase of the total DMC by 4%. The

[3] Finnish Geological Survey currently develops environmental indicators for the extraction of aggregates; we will fuel in those information during the course of our project.

[4] The apparent consumption quantifies what is used for domestic production plus imports minus exports.

[5] The so-called 'environmental Kuznets curve' describes the relationship between some environmental pressure indicators and income (or GDP) as an inverted U-curve with declining levels of environmental pressure for higher per capita incomes.

GDP had increased by 20% in the same period. This underlines the conclusion that the increased domestic use of construction materials has prevented a development towards an absolute reduction of the direct material consumption in Europe (v. de Voet 2004: 6).

From a material flows perspective (Eurostat 2001, Bringezu 2002a) it is also important to pay attention to the *hidden flows* and *ecological rucksacks* respectively. Both concepts (often used in an identical understanding) refer to the amount of material that has been extracted but does not get into further processing. It is unused material (mining waste, excavation) that has no economic value. Compared to metals the burden in aggregates is relatively low but a portion of about 20% of the mineral resource requirement has been detected as hidden flow (excavation and dredging) in the EU-15 in different studies (Bringezu 2002a: 17; Moll et al. 2003: 49). Those hidden flows should also be taken into account when environmental effects of any economic instruments are assessed. Due to lack of data, however, a more comprehensive ranking for aggregates is not available yet.

Land use

The land for the domestic extraction of aggregates requires rather small parts of the total areas of EU countries compared to other materials like biomass. For Germany (the largest producer of aggregates at present), the land use equivalent for the extraction of 324.2 mt sand and gravel and 137 mt crushed rock was 14,115 square kilometre in 2001.[6] This is equivalent to less than 0.005 % of the total area of Germany (Gwosdz and Röhling 2003). According to Eurostat, the land requirement for mining and quarrying altogether amounts to 0.5 % of the total area in Germany. The dimensions are similar in other European countries (see table 2 below).

Table 2: Land use and for mining and quarrying in selected European countries 2000

2000 / Country	Land used for mining and quarrying in km²	In % of total area	Total area in km²
Germany	1,795.78	0.50	357,031
Portugal	217.00	0.24	89,371
United Kingdom	555.01	0.23	242,910
Belgium	37.13	0.12	30,528
Netherlands	51.00	0.12	41,526
France	682.82	0.12	549,192
Poland	380.00	0.12	312,685
Slovenia	14.75	0.07	20,273
Denmark	20.00	0.05	43,093
Austria	...	...	83,859

Source: Eurostat 2006

However, land that is used for the mining and quarrying of aggregates cannot be used for other purposes for a long time, even if the quarry is a temporary one. Particularly in densely populated regions quarries contribute to land use competition with agriculture, recreation areas, residential areas, archaeology (see Danish Technology Institute et al. 2004). The conflicting land use does not apply to marine aggregates extraction in the first place. However, marine extraction is an option for few North Sea bordering countries like Great Britain, Ireland and Norway (see Moolen and Wilson 2003). Depending on the geographic and climatic conditions, threats relating to the extraction of aggregates (either marine or non-marine) are non-reversible landscape alterations, noise, air, soil and water

6 This figure does not contain land use for excavation.

pollution, destruction and disturbance of natural habitats and biodiversity, effects on ground water levels and bio-geo-chemical cycles (EC 2000).

From a material flows perspective a further aspect has to be mentioned. The use of aggregates exceedingly contributes to the material accumulation of a country, referred to as *'physical net addition to stock'.* The average growth rate of the physical economy is estimated to be at 10 tonnes per capita and year, i.e. this amount of material is additionally being stocked each year in new buildings and infrastructures which are mainly composed of construction minerals such as aggregates and their downstream products like concrete and cement (Bringezu 2002a: 15). A growing stock of buildings and infrastructures entails additional soil sealing, maintenance and energy costs, emissions and generates traffic, etc. Therefore, all built up area must be regarded as an equivalent for the indirect land use of aggregates (see v. de Voet 2004: 134 and 123, see table 3 below).

Table 3: Land use for built-up area* in selected European countries 2000

Country \ 2000	Total area in km²	Total built-up area in km²	In % of total area
Belgium	30,528	5,640	18.5
Portugal	89,371	16,367	18.3
Denmark	43,093	7,291	16.9
Netherlands	41,526	5,754	13.9
Germany	357,031	45,735	12.8
France	549,192	42,104	7.7
Poland	312,685	20,531	6.6
Austria	83,859	3,817	4.6
Slovenia	20,273	795	3.9

* = built-area covers sub-categories like residential land, industrial land, land used for quarries, pits, mines, etc., commercial land, land used for public services, excluding transport, communication and technical infrastructure, land of mixed use, land used for transport and communication, land used for technical infrastructure, recreational and other open land.

Environmental pressure through energy and water use and emissions

The energy use for the extraction processes of aggregates is comparatively low (Ecoserve 2004). The energy use for the excavation of gravel has been calculated 0.02 MJ/kg and 0.01 MJ/kg for transport. The energy used in gravel production comprises 0.05 MJ/kg for quarrying and crushing and 0.01 MJ/kg for transport (Vares and Häkkinen 1998). Most of the energy use and emissions result from transport within quarries, from quarries to local customers and to the location sites for further processing. This will be increasingly important in case of more remote quarries and growing trade and imports (see Danish Technology Institute et al 2004). The average water consumption during 2003 was 0.4 m^3 per ton of saleable product. In particular, the production of gravel water intensive (UEPG 2006, p. 16).

Energy and emission intensity rises with any further production step. As aggregates are raw materials for diverse production processes and application areas, their different production stages and application areas generate severe environmental impacts (see v. de Voet 2004: 33ff.) Two products are of particular importance in the context of energy and emission issues of the basis material aggregates: *Concrete* and *cement*. Concrete is the most important building material in the world, the average production is between 1.5 and 3 tonnes per capita/year. About 70-80% of concrete consists of aggregates (Ecoserve 2004). Further 10-15% of the concrete contain cement (Vares and Häkkinen 1998) – a material that mainly consists of limestone and is not counted to the aggregates. The application of concrete, however, requires the input of cement, which is regarded as important parameter in respect to energy use and CO_2 emissions for aggregates. The production of one kg cement produces about one kg CO_2 emissions. The average amount of cement in one m^3 concrete is about 283 kg (Ecoserve 2004: 33ff., ERMCO 2005)[7]. Table 4 shows the per capita cement consumption in selected European countries, the CO_2 emission per capita and the contribution of cement production to the total CO_2 emissions in a country in per cent.

Table 4: Contribution of cement consumption to CO_2 emissions in 2001

	Cement consumption in tonnes per capita	CO_2 emissions per capita	Contribution of cement to total CO_2 emissions in %
Portugal	1.12	5.6	20.0
Spain	1.05	7.0	15.0
Ireland	0.77	11.2	6.9
Italy	0.69	7.8	8.8
Belgium	0.55	11.1	5.0
Switzerland	0.54	5.7	9.5
Austria	0.53	7.6	7.0
Germany	0.38	10.3	3.7
Netherlands	0.37	10.4	3.6
France	0.34	6.5	5.2
Finland	0.33	11.7	2.8
Poland	0.31	8.0	3.9
Denmark	0.28	9.7	2.9
Norway	0.27	7.2	3.8
United Kingdom	0.21	9.1	2.3
Sweden	0.18	5.4	3.3

Source: Compiled on basis of data from Ecoserve 2004 and EUROSTAT 2006.

Therefore the production processes of downstream products are decisive (EEA 2005: 39). *The analysis of the per kg impacts shows that the products glass, ceramics, concrete, sand and stone which are all used for construction processes, belong to the top-twenty materials contributing to global warming – a potential that is aggravated through the amount of those materials used.* The global warming potential is measured in CO_2 equivalents; reference material is nickel. The table below shows the rough dimensions.

Table 5: Per kg contribution of aggregates and succession materials to global warming

Materials \ Environmental impacts per kg	Global warming potential in CO_2 equivalents (nickel ≈ 15)
sand and stone	< 0.25
concrete	< 0.25
ceramics	< 0.5
glass	< 1

Source: own compilation, v. de Voet 2004: 41ff.

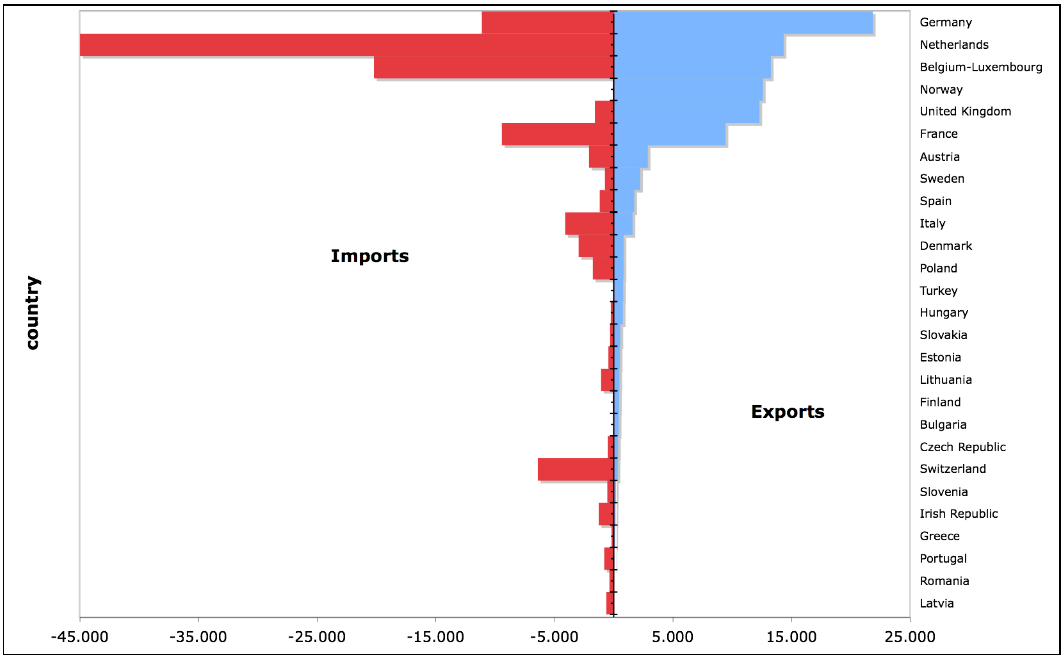
Again, these impact-specific results have to be put into perspective with the volumes produced.

[7] One m^3 concrete corresponds to about two metric tonnes (Ecoserve 2004: 53).

Trade and transport

The EU is largely self-sufficient in the material group aggregates. Depending on topographic and geological conditions the output figures of the European countries vary strongly. Recently, incremental site relocations eastwards can be observed in the cement and concrete production as well as growing trade and transport of aggregates. Aggregates are low-cost materials for the time being, therefore they are transport-sensitive (BGS 2006: v). The portion of transport costs in the aggregates sector is about 13% (Bundesamt für Güterverkehr 2004). Markets for aggregates are still predominantly supplied within a limited radius, the distance between operation sites and place of using is a key cost factor due to weight. Transportation costs often limit the radius of quarrying sites to the area of larger towns. However, within Europe, there is a growing trade of aggregates. In 2004, main net importers are the Netherlands, Belgium/Luxembourg and Switzerland, main net exporters are Norway, Germany and United Kingdom (see figure below).

Figure 5: Imports and exports of primary aggregates European Countries in 2004 in thousand tonnes



Source: British Geological Survey 2006

Comparisons with figures of 2001 show a tendency of increasing trade, particularly within Central and Northern Europe. This does not only affect transport but also energy costs and transport-related emissions. Due to its relatively high value, natural stone has become an important export product, with North America in particular providing a significant market outlet for European producers; competition is increasingly being experienced from low-cost producers in countries such as India, Brazil and China (EC 2000: 7). The worldwide demand for construction aggregates is estimated to be rising by 4.7 percent annually through 2007, driven by infrastructure construction in countries like China, India, Poland, Russia, Taiwan, Thailand and Turkey[8].

Only fragmentary data are available concerning the proportion of aggregates in long-distance goods transport. The tonnage of aggregates transported in Germany via freight vehicle amounts to 45% of the total goods transported (Bundesamt für Güterverkehr 2006).

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8 (http://www.freedoniagroup.com/World-Construction-Aggregates.html)

Recycling / secondary use

Extractive operations often generate large volumes of waste due to the normally high waste-to-product ratios and these wastes may be major sources of pollution, including topsoil, overburden, waste rock and tailings. Demolition does also generate high volumes of waste that might use valuable space when they are landfilled. Recycling of construction and demolition waste is therefore constantly increasing. Main products are for example secondary asphalt, secondary aggregates for new concrete and new road base, and cement bound (asphalts) granulate road base.

The following table 5 indicates the per capita production and construction/demolition waste generation, the recycled and secondary use in absolute figures and the percentage rate of secondary input. Recycling rates have to be interpreted with caution as they presently tend to over- or underestimation due to different ways of accounting of recycling, secondary use, etc. The order of magnitude however correlates to the different national availability throughout Europe and transportation costs.

Table 6: European aggregates construction/demolition waste and secondary input

Country	Waste generation of construction and demolition**	Recycled and secondary use in million tons	Percentage of secondary input
Great Britain	--	67.0	23.8
Netherlands	--	24.1	21.6
Belgium	10.5	7.0	11.0
Sweden	--	8.2	10.9
Germany	240.8	50.0	9.5
Switzerland	--	3.0	9.4
Czech Republic	7.2	2.5	4.8
Austria	--	3.0	3.2
France	--	9.0	2.2
Norway	0.8	0.9	1.8
Poland	0.3	2.5	1.7
Ireland	3.6	1.0	1.0
Italy	30.9	3.0	0.8
Spain	0.5	1.0	0.2
Total	**--**	**182.2**	**6.1**

Source: QPA 2006, -- = no data available

*Data for 2003 except Netherlands, data for 2000 **construction and demolition waste data for 2002, except Ireland, Italy, Spain, data for 2001 ETC 2006 http://waste.eionet.europa.eu/wastebase/quantities/index_html

The recycling rates of construction and demolition waste are assessed to be increasing in future. Estimations of recycling potentials show that the 180 million tonnes of C&D waste that are annually being produced in the EU may be recycled up to 50%. This would correspond to about 45 million m^3 concrete (Ecoserve 2004: 53). The total production of ready-mixed concrete in 2005 (data collected for 20 ERMCO member countries, ERMCO 2006) amounted to about 430 million m^3. Compared to the volume needed to meet the current demand, this is roughly 10%.

Conclusion

The overall contribution of aggregates to resource depletion, land use competition, global warming and energy use can be assessed as rather low when only extraction processes are considered. Other groups of materials usually dominate the picture of specific environmental impacts, e.g. land use is dominated by agricultural biomass and global warming by fossil fuels. Given that specific impacts can be multiplied by the amount of those materials used however and given that the EU thematic strategy suggests a life-cycle perspective, aggregates are becoming a serious issue for EU environmental policy.

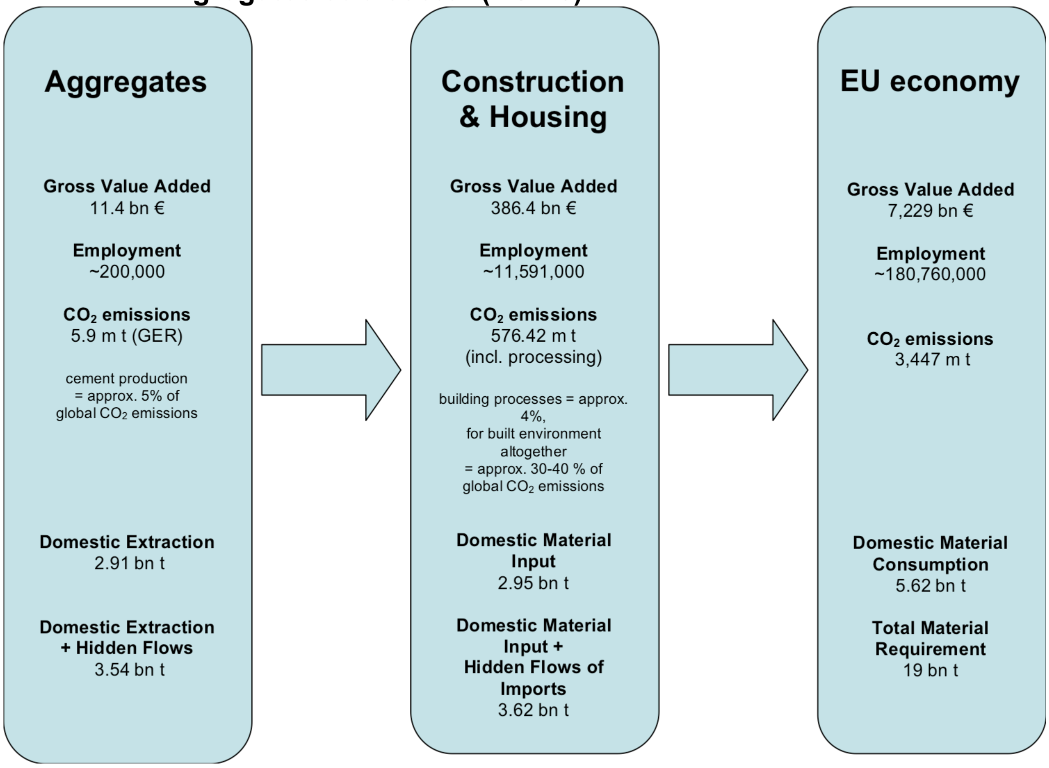
The environmental relevance of aggregates is furthermore highlighted by recent regression analyses according to which the Domestic Material Consumption (DMC) is influenced by the Gross Domestic Product (GDP) per capita, i.e. the higher the GDP per capita, the higher the DMC per capita. The same holds true for the Environmentally weighted Material Consumption (EMC) (v. de Voet 2004: 74)[9]. Applied environmental research reveals further aspects that illustrate the close interrelation of aggregates with downstream stages of their life-cycle:

- The widest influence on per capita DMC comes from the *construction sector*. The effect is that a 1% increase in the construction sectors' share in GDP results in a 3.6% increase per capita DMC in the long run.
- The importance of construction activities for DMC is underlined by the *per capita dwelling stock* in a country. A 1% increase in the dwelling stock results in 0.5% rise in per capita DMC directly, and 0.8% in the long run (v. de Voet 2004: 84).
- The EMC is strongly determined by the size of the agricultural *and* construction sectors in an economy. The effect of an increase in the construction industry is slightly lower than the DMC effect. But: an increase of 1% in the amount of dwellings in a country will result in a 1% higher *EMC* in the long-run. (Voet et al. 2004: 86.)

In order to give a summarising impression of the proportions the following figure compares the aggregates (sub)sector with the construction and housing sector and the EU economy concerning the variables gross value added, employment, CO_2 emissions, and material extraction/input/requirement. It also underlines the pertinent argument that aggregates are particularly relevant due to their embedding into construction and housing activities throughout Europe.

[9] The Environmentally weighted Material Consumption (EMC) indicator combines information on material flows with information on environmental impacts (v. de Voet 2004: 5).

Figure 6: Comparison of various variables indicating the proportions of the EU economy, the construction & housing sector and the aggregates sub-sector (EU-15)



Sources: Eurostat internet data base 2006, UNEP 2006, OECD 2005, German Federal Statistical Office 2006, own calculations

*all data for 2003, Gross value added at constant prices (1995), material data for 2000

It is the combination of environmental impacts, high volume of use and expected growing future demand that constitute the environmental relevance of aggregates. Despite comparatively long utilisation phases all construction minerals will end up as waste in the long run. Resource extraction, production chains, life cycle impacts, waste generation and recycling measures require deeper analysis in connection with socio-economic and sectoral prospects. It is clear that aggregates industry and their supply to construction activities are pivotal for a sustainable management of natural resources in Europe, in particular in relation to the EU thematic strategy and the Lisbon agenda of decoupling GDP growth from resource use.

4. Existing policies affecting the sustainable management of aggregates

The aggregates markets are subject to various national policies. A stringent European policy on aggregates does not exist; the EU has no direct competencies in legal terms. Only a few of the Member States have clearly defined and published mineral policies for the national level (Wagner / Thiess 2004: 15). Three main types of legislation can be identified: Mining Laws, General Land Use Planning Laws, other regulation (especially environmental/waste laws). Regarding aggregates, a trend for a principal legislative control exercised under environmental laws is emerging. So far, environmental laws aim on limiting possible harmful effects resulting from extraction by formulating conditions linked to mineral extraction licences (ibid. p. 18). This scope may change due to the EU thematic strategy on sustainable management of natural resources and ensuing national or sectoral strategies.

Existing policies on aggregates predominantly regulate the extraction and early production process. There is no common aggregates policy in the EU yet. The following table (7) summarises national mining policies affecting the aggregates industries in EU Member States, which range from quarry application processes to site after-care and restoration. The regulation is presently inconsistent.

Table 7: National Mining Policies affecting aggregates industries

Policy	**Countries**
National Mining Plans	Austria (in preparation), Portugal (Sector plans for Mineral Resources in preparation)
Policy guidance	e.g. Czech Republic, Denmark, Norway, England, Portugal, Slovenia
Specific requirements in legislation	e.g. France, Germany, Netherlands, Poland, Sweden
Indirectly through other legislation	National parks, cultural heritage, etc. which preclude mining in certain areas (e.g. Finland, Poland)
Process of Obtaining Permits (mining rights, mining licenses (exploration, mining), permits according land use planning, environmental permits (a) Permission for exploration activities (b) Permission for mineral extraction	All Member States
Authorisation Process Standard application More public bodies take part (mining authority, environmental agency, nature conservation agency, water authority, health and safety agency) Environmental Impact Assessment EIA	All member States Belgium, Denmark, England and Wales Some Member States For all applications: Greece, Norway, Portugal, France
Regulatory conditions controlling mineral extraction	All Member States
Restoration and After-care	only in Denmark covered in mining legislation
Fees and compensation	Similar across EC
Monitoring and Law Enforcement	All Member States

Source: after Wagner/Tiess 2004, p.

However, the emergence of environmental protection (EU) legislation/policy has added a number of additional factors that have an impact on the process of aggregates extraction and production. The influence of EU legislation and policy on national legislation and practice has grown distinctly in recent years, especially regarding environmental matters and climate change. Many national laws have been amended for the implementation of EU legislation. The following table (8) shows pivotal EU directives that are of particular importance for the aggregates industries.

Table 8: Key EU directives affecting aggregates industries

Title	**Status/Source**	**Overall purpose**	**Notes**
Conservation of Natural Habitats and Wild Flora and Fauna	(FFH Directive) 92/43/EEC	To contribute towards ensuring bio-diversity through the conservation of natural habitats or wild flora and fauna	Affects exploitation of new mining sites and their transportation infrastructure.
Strategic Environmental Assessment (SEA) Directive	2001/42/EC	On the assessment of the effects of certain plans and programmes on the environment	Had to be complied by Member States in July 2004.
Protection of Groundwater against Pollution	COM (2003)550	Limiting inputs of pollutants and preventing further deterioration of groundwater	Proposed EU limits on sulphate concentration, the definitions of “indirect discharges into groundwater” and “water status deterio-

			ration”.
Communication promoting **Sustainable Development in EU Non-energy Extractive Industry**	COM (2000) 265	Risks are: air pollution, noise, soil and water pollution, effects on ground water levels, destruction or disturbance of natural habitats, visual impacts on surrounding landscape	Mining and quarrying is increasingly influenced by other competing land uses, such as urban development, agriculture, nature conservation Issues of resource productivity are only implicitely covered.
The Construction Products	Council Directive 89/106/EEC amended by The Construction Products Directive 93/68/EEC (CPD) Amended by Council Directive 93/68/EEC	Purpose is to eliminate obstacles to trade coming from existing legal, regulatory or administrative provisions, the technical specifications deriving from the Directive should take fully into account the justifiable technical traditions in Member States. This means that technical specifications should not hinder or prevent the use of construction products which enable works to conform to the essential requirements and which are in use in the Member States.	‘construction product’ means any product which is produced for incorporation in a permanent manner in construction works, including both buildings and civil engineering works => affects the architecture of homes and buildings as well as re-use.
Directive restructuring the Community Framework for the **Taxation of Energy Products and Electricity**	2003/96/EC	Harmonisation of energy/electricity taxation, proper functioning of internal market	Energy taxation heavily influences markets for aggregates, in particular cement industry.
Directive establishing a **Scheme for Greenhouse Gas Emissions Allowance Trading with the Community** (EU ETS)	2003/87/EC	Covers around 11,500 installations in 25 Member States (45% of total EU CO_2 emissions)	Cement industry (and ceramics) is regulated under the EU ETS; production, see also statements by “Heidelcement” or by “Porenbeton” – Autoclaved Aerated Concrete (High resource efficiency, low environmental impact) http://www.eaaca.org/
Mining Waste Directive	COM (2005) 67	Sets minimum requirements specifically addressing waste from extraction, processing and storage of mineral resources and the working of quarries	
Landfill Directive	99/31/EC	To prevent or reduce as far as possible negative effects on the environment from the landfilling of waste, by introducing stringent technical requirements for waste and landfills.	Legislation and related directives affect waste from construction.

Source: UEPG 2005, IMA 2005, EU 2006, Steadman et al. 2004 and http://europa.eu.int/comm/enterprise/construction/internal/direct.htm

The concept of sustainable development is generally being affirmed by the aggregates industries. The formulation of the Thematic Strategy on the Sustainble Use of Natural Resources, however, had some critical issues jointly raised by the associations UEPG, Euromines and IMA. These included an insufficient elaboration process of the strategy and emphasised that an effective enforcement of existing regulatory is required before proposing changes and drafting new measures.

In 2002, the European Commission launched a Thematic Network under the Specific Programme 'Promoting Competitive and Sustainable Growth'. The title of the network is "European Construction in Service of Society" - ECO-SERVE NETWORK. Inter alia, this research network explores the aggregates extraction and production. In 2006, UNEP has launched an initiative called "Sustainable Building & Construction Initiative" and claims a strategic necessity for this sector (UNEP 2006). The Cement Sustainability Initiative (CSI) of the Word Business Council for Sustainable Development has recently started an online dialogue to explore sustainability issues around the use of concrete as a construction material (www.wbcsdcement.org).

To conclude, there are no policies existing yet addressing the use of aggregates in conjunction with their final demand in respective markets. Rather, policies are still fragmented into extraction, production, consumption and waste stages. The waste policies of the EU in particular are considered most affecting the aggregates industry. Regarding indirect impacts from existing economic incentives, climate and energy policies are most relevant. The areas of housing and construction have witnessed not only the increasing world market prices for gas and oil in the previous years, but also some European policies of increasing prices for electricity, transportation and energy in general. Because of rising prices for oil and gas, the demand for coal has been increasing too – an effect, which has triggered the market price for carbon within Europe to an unexpected peak in 2005 (www.pointcarbon.com). Cement and concrete – and aggregates as an essential input – are extremely sensitive to those changes. These policies could trigger the demand for less energy-intensive material substitutes in housing and construction, whose impacts needs to be assessed. Any impact assessment of a tax on aggregates needs to be seen in conjunction with possible impacts from those policies.

5. Economic instruments and aggregates

The general advantage of economic instruments is the promotion of the polluter pays principle in a cost-effective way. In getting the prices right, they encourage economies towards a more efficient allocation of natural resources while internalising negative externalities.[10] Main approaches are

1. Emissions trading / tradable permits
2. Taxes / charges
3. Subsidies for market introduction of sustainable technologies.

While permits and taxes primarily aim at internalising negative externalities, subsidies can be more specifically utilised as a means to create a new market and to address positive externalities typically associated with innovation. Thus, subsidies are not only used in fostering renewable energies, but also a possible instrument to the implementation of the EU Environmental Technology Action Plan (ETAP, COM (2004) 38).

Despite wide acceptance of economic instruments in general, however, it has to be stressed that regulatory measures (i.e. command and control policies) are still the most widely used method for environmental policy. One obstacle to any application is the principle of unanimity voting on the European level with regard to taxation, which leads to slow progress in introducing new EU-wide environmental taxes. A further policy-related aspect stems from the experience that all EU Member States with economic instruments in place have established rules either partly or fully exempting potentially vulnerable

[10] See e.g. Andersen/Sprenger (2000) or www.economicinstruments.com, a website provided by Dublin University.

industrial sectors – which clearly departs from the ‘polluter pays principle’, but may be justified for reasons of competitiveness or protection.

Looking at aggregates, one should keep in mind that aggregates are natural resources. Taxes on natural resources do not belong to the categories of the statistical framework for environmental taxes established by Eurostat. However, such taxes are implemented in many resource-rich countries and are a major source of government revenues (EEA 2005: 58). Aggregates taxes (including sand, gravel and/or crushed rock) are implemented in Belgium (Flanders), Bulgaria, Denmark, Russia, Sweden (“natural gravel tax”), Ukraine and United Kingdom (“aggregates tax”). Two forms of mining taxes that include materials like soil, sandy and clay loam, sand, gravel, dolomite, and gypsum have to be distinguished: ad valorem taxes (monetary tax base) and ad quantum taxes (physical tax base). Denmark and Sweden are examples for ad quantum taxes. Further countries, which rate the extraction of mineral raw materials ad valorem are Czech Republic, Moldova, Poland and Russia (EEA 8/2005: 58).

Aggregates are predominantly extracted and used on a regional scale (Wagner/Tiess 2004: 11); i.e. many legal and economic problems that arise from competitiveness concerns of an internationally operating industry or from tackling imported materials are less likely to occur (EEA 2006). It nevertheless has to be assessed whether taxes on aggregates lead to side-effects such as increasing imports, which may shift environmental problems abroad (Wei Kua et al. 2005).

Regarding the introduction of economic instruments on aggregates in countries that have no such instruments in place yet, the national context matters in two respects: firstly the regulatory context of legal and other economic incentives and, secondly, the sustainability strategy pursued in any member state.

Another question is whether and to what extent the instruments in place serve well-defined purposes of revenue raising, stabilising rents from mineral extraction, and/or financing re-naturation of extraction sites (Otto 1995).

A more comprehensive step will have to consider the larger scope, i.e. whether and to what extent economic incentives also address broader issues of sustainability such as switching to a renewable resource base of economies, improving resource productivity and reducing environmental impacts during the whole life cycle of aggregates. It has also to be checked whether environmental objectives are targeted by other regulation.

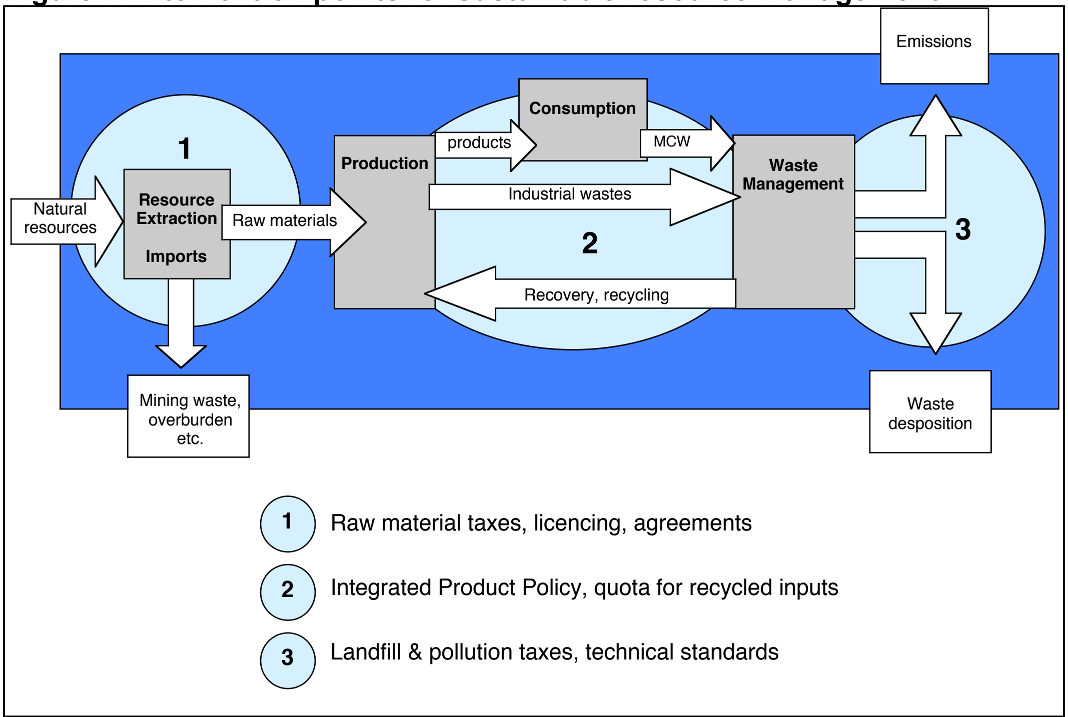
Research in that perspective will need to establish causal links between supply and demand of aggregates on the one hand, and their utility on the other hand. Evaluating utility means analysing areas such as housing and construction infrastructures. Such analysis would also contribute to analysing value chains and purposes of production; it would also contribute to horizontal policy integration.

Another reason speaks in favour of broadening the scope. Certainly, any instrument addressing aggregates will have an impact on other sectors and on final demand, especially on housing and construction. There is no reason to determine that aggregate industry itself should be sole subject to economic instruments in order to increase resource productivity while reducing environmental impacts. Because of the interdependencies among industrial sectors and final demand, any instrument will achieve greatest sustainability benefits if it tackles questions of supplying aggregates, sustainable housing and infrastructure simultaneously.

6. The way ahead: towards a sectoral strategy for sustainable management of aggregates

The EEA report on sustainable management of natural resources lists the following points of intervention: resource extraction or imports, production and consumption, and management of wastes and emissions (EEA 2005: 46). A key to identifying strategies is the relationship between aggregate materials, production and consumption, and their related environmental impacts.

Figure 7: Intervention points for sustainable resource management



Source: Bringezu 2002a

A sectoral strategy, as called for by the EU thematic strategy on sustainable resource management, would have to address aggregates, other relevant materials, homes, construction and physical infrastructures and related environmental impacts, and the services/functions demanded in private homes, office buildings and transport systems. This is the way ahead.

Economic instruments can play a role towards such a strategy. Their price signals would trickle down from upstream extraction and production of aggregates down to homes, construction and physical infrastructures. To evaluate economic incentives and to conclude on a revision of existing packages of instruments thus is a core objective of the ongoing activities towards sustainable management of aggregates. Current studies focus on ex-post analysis of economic instruments on aggregates in Czech Republic, Italy, Sweden and UK. They analyse the purpose, how efficiently it has been achieved – and seek to assess the impact those instruments might have had on construction markets and sustainability performance.

Further strategies that could be pursued to address aggregates in a comprehensive manner:

Reduction of demand for primary aggregates through

- reduction of amount of additional infrastructures/buildings (e.g. reduction of subsidies for new development)
- improved use of existing infrastructures/buildings (e.g. refurbishment of old buildings)
- extension of life-span of infastructures/buildings

Optimisation of extraction processes through

- new quarrying technologies
- improved utilisation of by-products

Substitution by other materials that are renewable like

- wood, fibres (see also Moll/Bringezu/Schütz 2003, p. 75)
- functionally-integrating building walls and roofs

Institutional innovation through

- networks for secondary use and recycling after demolition of infrastructures/buildings; “urban mining”
- environmental architecture with regard to life-span and recyling of building materials
- audit of sectoral resource productivity for houses and residential buildings

I. Annex

Table 9: Response indicators to be applied for evaluating economic instruments for a sustainable management of aggregates

Category	Type of indicator	No. of indicator	Specifics	Illustration / Comment
Relevance	A	1	Measures in place in the political system (or in relevant subsystems) addressing aggregates or having an impact on the demand for aggregates	See table 6 + 7
	A	2	Flow of aggregates from demolition to landfill (in physical units, time series as long as possible), %	
Effectiveness	A	3	Target / programmes for sustainable management of aggregates, yes/no	
	B	4	Change in aggregates extracted (in physical units, time series as long as possible), %	
	B	5	Change in associated ‚indirect flows' of aggregates, (in physical units, time series as long as possible), %	‚Indirect flows' refer to materials, which are extracted or otherwise moved by economic activities but that do not normally serve as input for domestic production or consumption (mining waste such as overburden). See: Eurostat 2001. Other terms: ‚hidden flows', ‚ecological rucksacks'. To be checked: ‚Stockpiles'.
	C	6	Change in the use of substitutes, as well as re-use and recycling of materials made of aggregates (in physical units, time series as long as possible), %	
	C	7	Change in land use related to the extraction of aggregates (in physical units, time series as long as possible), %	
	C	8	Changes in energy use related to aggregates extraction, transportation, processing (in physical units, time series as long as possible), %	
	C	9	Change in imports / exports of aggregates (in physical units, time series as long as possible), %	
Efficiency	B	10	€ / unit change in % since introduction	
	C	11	Value of tax (economic incentive) as percentage of aggregates' price	
	C	12	Revenues raised from the instrument, change in % since introduction	
	C	13	Innovation effects: change in the sectoral resource productivity for aggregates, gross value added (NACE 14) / DMC or TMR, (time series as long as possible), %	DMC refers to Domestic Material Consumption, TMR to Total Material Reqirements, see: Eurostat 2001. Share of aggregates within NACE 14 needs to be checked.
	C	14	Institutional innovation: establishment of networks for re-use of aggregates, activities for sustainable aggregates and construction, metric scale 1 - 4	See for example: www.efanrw.de http://www.indigodev.com/Ecoparks.html
Utility	C	15	Sectoral resource productivity for houses and residential buildings, gross value added (NACE 45) / DMC or TMR, (time series as long as possible), %	DMC refers to Domestic Material Consumption, TMR to Total Material Reqirements, see: Eurostat 2001.

Source: Own compilation - Type of indicators:

A) Number/types of policies/instruments applied
B) Indicators that measure the implementation of policies (‚leading indicators')
C) Indicators that measure the impact of the responses in terms of improved management, capacity building, innovation (‚lagging indicators')

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