Chapter 13

Policy Implications: Towards a Materials Policy?

Jeroen C.J.M. van den Bergh, Harmen Verbruggen and Marco A. Janssen

13.1 Introduction

Economic activities transform natural resources into materials with the purpose of producing goods and services that contribute to economic welfare. Structural ‘by-products’ are the generation of waste and pollution as well as the disturbance of the natural environment. Although many countries have formulated environmental policies over the last decades to cope with these by-products, coherent and all-embracing policies specifically oriented at the sustainability of materials use have not yet been developed. Materials can, nevertheless, be regarded as the core element of a policy approach that aims to stimulate sustainable development. Such a policy and traditional environmental policy are obviously intertwined, but nevertheless can be distinguished on the basis of specific goals, having to do with the time horizon and the type of environmental problems addressed. For example, noise externalities are usually regarded as an environmental problem but not necessarily as creating a unsustainable development. In this final chapter of the book, we will discuss the specific role that material and waste policies can play in the context of sustainable development.

The main purpose of this study was to integrate economics and industrial ecology. In Chapter 1, it has been argued that the main literature on industrial ecology, represented by Socolow et al. (1994), Graedel and Allenby (2003), Ayres and Ayres (2002), and the *Journal of Industrial Ecology* is very weak on the economic dimension, suggesting that industrial ecology is all about planning and design. In particular, the literature largely neglects economic angles and considerations, economic methods of analysis and their applications, and related policy dimensions. This book aimed to arrive at an improvement of policy advice by adding economic elements to theory, methods and applications in industrial ecology. An extra added value of the current book lies in the inclusion of multiple studies with similar objectives but employing different methods or models. The synthesis in the current chapter tries to create an added value, namely by bringing the elements (waste treatment, recycling and dematerialization), the levels (eco-industrial park, region, country, world), the instruments and the methods together. Evidently, integration of all these in a single, formal model is beyond our (and anyone's) ambition and capability.

13.2 Integrative methods for policy analysis: a summary

This section summarizes the methods for integrating economics and industrial ecology that were proposed, discussed and applied in the previous chapters. It has been shown that by adding an economic context to industrial ecology in the form of costs, benefits, investments, market distortions, international trade, and so forth, policy realism is enhanced. The reason is that direct and indirect effects of policies focusing on material throughput include depend very much on economic mechanisms like substitution in production, markets, international trade and economic growth. Different methods focus on specific combinations of these elements.

Statistical-historical modelling (Chapter 3) at the country level allows to confront a number of aggregate exergy and material use indicators with the traditional aggregate income (GDP) indicator. This method is powerful, as it shows that the type of aggregate indicator matters for the policy conclusions drawn. A main problem of applying this method is that in order to arrive at a sufficiently long time series that allows for rigorous statistical regression analysis, comparable, i.e. mutually consistent, data need to be collected or re-constructed for a long period of time. An important finding of the application in Chapter 3 is that the US economy turns out not to be "dematerializing" to a degree that is relevant for environmental policy goals. The study implies that, in order to be effective, policy should focus not so much on directly reducing the total mass of materials consumed, but on reducing the need for consumables, notably intermediate products. When time series are shorter, modeling or descriptive analysis can still render insightful conclusions, as illustrated by Chapter 5, employing econometric estimates, and Chapter 10, offering descriptive indicators of foreign trade and recycling. Again, the aggregation and classification schemes adopted are crucial, notably the distinction between secondary and primary materials, and between developed and developing countries.

Two types of complex systems modeling were illustrated in Chapters 5 and 6. Chapter 5 combined engineering, capital vintage and econometric analysis resulting in a dynamic computer model, which was applied to industrial energy use in the USA, focusing on iron and steel, pulp and paper, and ethylene industries. The approach is a type of integrated industrial systems analysis, which steps away from standard economic equilibrium analysis, where markets clear through prices (see below). Instead, this approach takes for granted that industrial systems are constantly changing, and therefore are in a disequilibrium state. Optimal investment is frustrated by market imperfections, uncertainty, and bounded rationality - myopia in combination with time lags of investment consequences. An important finding is that each policy instrument triggers particular kinds of responses, depending on the industry studied. Examples are shifts in production among segments in the industry, changes in the fuel mix, alterations in the use of intermediate products, transitions towards renewable energy sources, reductions in total energy use, and reductions in carbon emissions. A mix of policy instruments is therefore most effective in realizing policy goals. Yet to allow for an appropriate analysis, the models applied must include enough industry specific features that allow linkage of policy instruments.

Chapter 6 offered two dynamic models, namely the Australian Stocks and Flows Framework and the OzEcco embodied energy flows model. The first is a large stock-flow model of the Australian economy that accounts for important physical transactions in mass units in the Australian economy. The second operationalizes the notion of embodied energy, and integrates the driving forces of population, lifestyle, organisation and technology and translates these into environmental impacts. Together they can be seen as a systems dynamics representation of Australia's metabolism, which tries to operationalise the idea that the physical economy should conform to the physical laws of thermodynamics and mass balance. The nature of these models allows to study integrated policies - through scenario analysis - that affect materials flows through the economy, including energy policy, climate policy, and even land regulations. They show that more detail for physical realities and dynamics, like capital vintages, leads to slow reactions of the economic system to policy incentives. This resembles an insight of Chapter 3, namely that dematerialization occurs only in a few sectors, due to slow technological adaptations that lag behind volume increases.

Two types of modeling made use of input-output (I/O) data and techniques, an old and proven approach to realize integration of economic and environmental information, as well as find a compromise between bottom-up information and top-down economic modeling. A technique that has been around for some time but has not been widely applied, namely dynamic input-output modelling (DIO), was illustrated in Chapter 8. It enables an analysis of changes between sectors, as well as between regions, resulting from technological changes reflected in changed I/O coefficients. A more recent technique, namely structural decomposition analysis (SDA), was applied in Chapter 4. Both techniques allow to step away from the rigid framework of constant coefficients that characterizes static I/O analysis. SDA allows to decomposes changes in certain material use indicators over a given period of time into a range of effects, including I/O related structural or sector shifting effects, as long as two or more I/O tables are available for different points in time. The two approaches, SDA and DIO, are complementary in that SDA results can be translated into dynamic specifications of the DIO framework. This is something that certainly needs to be given attention to in future research. Whereas SDA offers relevant information for ex-post policy evaluation, forecasting using SDA information and DIO are useful in assessing potential overall or macro effects (aggregate income, demand, and sector output) of certain material, waste or recycling policies. The SDA approach presented here was innovative in two respects. First, it analyzed hybrid-unit I/O tables, which contain a mix of physical and monetary data. Second, it used the SDA results in forecasting scenario analysis. Finally, perhaps the most important improvement is that DIO and SDA solve the traditional problem of including technological change in a sophisticated way into I/O models.

Two types of equilibrium analysis, the most popular technique among mainstream economists, have been illustrated. Partial equilibrium analysis was discussed and applied Chapter 7, and general equilibrium analysis was illustrated in Chapter 9. Chapter 7 discussed STREAM, a partial equilibrium model for material flows in Europe, with emphasis on the Netherlands. The model provides a consistent framework for analyzing material use scenarios and related environmental policy analysis of dematerialization, recycling, input substitution, market and cost prices, and international allocation of production capacity. The model structure allows to deal with very specific instruments, such as taxation of primary materials, performance standards for energy and emissions, and deposit money for scrap. Chapter 9 presented a general equilibrium model of the waste market. Such a technique is suitable to study market distortions, in this case focused on flat-fee pricing. A stylistic application to the Netherlands demonstrated that introducing a unit-based price will stimulate both the prevention and recycling of waste and can improve welfare, even if implementation costs and enforcement costs are taken into account. A technique related to equilibrium modelling, referred to here as international-material-product-chain (IMPC) models, focusing on static optimization, was proposed and applied in Chapter 10. The latter chapter offered policy analysis at the level of international trade in materials. General equilibrium tools are strong in addressing the question of economic efficiency. However, they are top-down oriented, and often simplistic in the dynamics and physical detail that might be required for concrete policy advise.

Institutional analysis at the level of the eco-park was the focus of Chapters 11 and 12. These contributions were non-technical as opposed to those in the other chapters. This is due to the type of analysis, which emphasizes institutional, organizational, stakeholder and evolutionary aspects. The chapters stress the opportunities for eco-industrial parks, the mechanisms, the lessons that can be drawn from Kalundborg, in terms of both economic limitations of the Kalundborg symbiosis and the critical economic factors that contributed to its success. Chapter 12 in addition elaborated the idea that the eco-park approach is a special case of a collective action problem, and that the government should refrain from planning and tight regulation, and instead foster the self-organisation process through assistance in network building and possibly subsidies.

Concluding, all chapters together show the value of following a pluralistic methodological approach to the integration of economics and industrial ecology. Although, the first economic models that included physical dimensions appeared in the 1960s and 1970s, there is still no unified methodology. This is not problem, as different approaches allow the tackling of different questions. Only by using a variety of approaches can one understand the various economic aspects and the different levels and scales of policy, physical and economic processes. This in turn allows to assess the potential of, and barriers to, important transitions that will reduce environmental problems caused by use of materials. We do certainly not claim to have covered all aspects of the young economic branch of industrial ecology, but we do think we have covered all useful methodological approaches. In terms of policy relevance, the studies show disadvantages or ineffectiveness of many policies with regard to lack of incentives that avoid reduction of material use, or perverse incentives that stimulate displacement and illegal dumping, or physical realities that makes it impossible to replace the historically inherited physical infrastructure of the economy in the short term.

13.3 Sustainability and material flows

Given the state of the art of economics industrial ecology we will now explore possible policy implications with regard to material flows. Obviously, the current use of many materials is not sustainable. The depletion of non-renewable resources comes perhaps first to mind. But the degradation and depletion of renewable resources are possibly more serious threats to sustainable development. The reason is that overexploitation of renewable resources reduces the ability of future generations to derive welfare from these. In addition, the recovery and processing of non-renewable resources, as well as the exploitation of renewable resources, cause degradation of the environment. This involves the loss of ecosystems and biodiversity, and the pollution of air, soils and waters. A possible consequence is the reduction of ecosystem services for future generations. In other words, the use of primary material resources indirectly leads to sustainability problems.

This underpins the relevance of policy aimed at the sustainable use of natural resources and materials. A concrete concept in this context is ‘dematerialization’ (see Chapter 2 by van den Bergh and Janssen, in this volume). A suggestion to operationalize this include the notion ‘Factor Four’, interpreted as doubling wealth, halving resource use (von Weizsäcker *et al.*, 1997). This indicates, for example, that in an economy subject to annual growth at a rate equal to 3.5 %, which means a doubling of income over a period of 20 years, the use of materials needs to be reduced at a rate equal to 6.7 % per year, implying a quarter of the original resource use per unit of income after 20 years. Assuming that wealth is proportional to income, wealth will have doubled, while total resource use will be 50 % (income*materials use per unit of income = 2*0.25) of the total resource use at the beginning of the period. In Chapter 3, Ayres et al. present a very original historical quantitative-empirical study of dematerialization. They conclude that in most sectors of the USA there has been no dematerialization during the last 100 years.

The goal of dematerialization is based on the philosophy that less throughput in the economy leads to less depletion and overexploitation of natural resources, as well as less pressure on the environment. From a traditional economic perspective, this general goal cannot be regarded as sufficiently well-defined, as it would most likely be an inefficient way to realize higher goals, such as maximum social welfare. Traditional environmental economics considers that the allocation of natural resources over time and future generations will lead to maximum welfare when all external effects related to the use of materials are adequately reflected in prices and constraints faced by economic agents. Such an optimal policy would consist of a combination of the Hoteling rule for resource scarcity and the Pigovian tax (e.g. Lusky, 1975) to internalize external environmental costs. A set of constraints needs to be set to prevent the depletion of essential resources, because the Hotelling rule guarantees an optimal use of the resource in time, but not a sustainable availability of the resource. However, whereas the policy outlined above may sound ideal from an economic-theoretical perspective, it is very unlikely to be implemented. A major problem is that making the necessary trade-offs – private and social benefits and cost calculations – requires constructing and solving an extremely complex empirical model (Kandelaars, 1998). Future external effects are particularly uncertain. In fact, it is not even straightforward to evaluate environmental effects solely in physical terms by using life-cycle analysis. This indeed implies a number of considerations:

- Which resources and materials need to be used economically? And how should these be selected? For example, it is difficult, or even impossible, to judge whether substitution of a scarce material – like tropical timber – by a material that generates considerable pollution – like a heavy metal, aluminum (energy use) or a synthetic material (pvc) – is beneficial in terms of the net environmental consequences.
- The number of economically useful reuse and recycling options to deal with material waste has increased over time. Some applications of recycled materials already face a shortage at the national scale in some countries, which has given rise to a sharp rise in international trade in secondary materials over the last decade (see Chapter 10 by van Beukering, in this volume).
- Dematerialization means prevention of waste, which is preferable to material reuse and recycling. Closing material cycles seems less complex than realizing significant dematerialization. Reuse and recycling reduce the need for new (virgin) materials, but do not necessarily lead to a reduction of the volume of material flows through economic systems. One consequence is that, as opposed to dematerialization, reuse and recycling continue to put pressure on the environment through freight transport. Another is that recycling activities, such as secondary metal production, are often associated with high levels of energy use and various types of pollution.
- Lengthening the life of products can give rise to using a larger amount of, as well as more advanced, materials. In addition, it may conflict with easy decomposability of products for the purpose of recycling.

Even when there is a clear policy perspective on the sustainability objectives and environmental externalities of particular material and product flows, then the question remains where policy should attack, and through which instruments it should be implemented.

13.4 Sustainability policy for materials

Sustainable recovery or exploitation of a natural resource is a form of resource stock management, and, hence, will have to be regulated from the supply side. Depending on the type of resource and the prevailing property and use rights, resource suppliers need to agree on recovery and exploitation. For example, in the case of tin, with an estimated resource availability of about 40 years, suppliers on the global market – notably Bolivia, Brazil, China, Indonesia, Malaysia, Thailand and Peru – need to formulate a joint market strategy. This should take into account the essential demand for tin for economic transformation processes, the type of substitution possibilities that are available, and the range of possible technological developments. An international resource agreement seems to be the most appropriate way to arrange this. Regulation of the supply will lead to price increases and consequently to the availability of tin for more people in the future.[1]

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[1] The notion of International Commodity-Related Environment Agreements is related (Kox, 1991; Linneman and Kox, 1995). These are aimed at stimulating countries involved in the export of resources or simple commodities to implement production methods that cause less environmental pressure. Price support or reduced competition are the means for this. So

This type of regulation – aimed at sustainability – of the supply side is currently already operational for some resources, notably forests and endangered species (CITES), and is being developed for others, like water resources. However, important progress is still needed, as for many resources no regulation exists at all. Important barriers are formed by the absence or obscurity of property and use rights, governmental failures, and a lack of international coordination. Even existing regulation of resource supply is not always satisfactory, as in the case of fish stocks. Although urgency is evident to all participants, the allocation of total allowable catch (TAC) and related compensation generally leads to severe political conflicts and consequently to ineffective resource management strategies. This is strengthened by the scientific uncertainty about the level of sustainable harvesting, which has often caused politicians to define too high total catch levels. In addition, the inadequacy of sanctioning instruments has allowed the continuation of free riding.

The effectiveness and efficiency of sustainable resource management is at risk when regulation adopts a demand-side perspective, for example, by taxes on tin, timber and fish. The resulting reductions in demand will ultimately lead to price increases, which in turn stimulate higher levels of exploitation. This is an example of the rebound effect. A similar effect can occur in the case of recovery and reuse of materials. Here, also, demand regulation can be undone by the supply of secondary materials competing with the supply of primary materials.

13.5 Waste policy

Although materials policies have not seen much progress, waste policies have been widely implemented in OECD countries. In many countries, a waste hierarchy has dominated the formulation of waste policy. For example, the “UK Waste Hierarchy” is characterized by a preference for waste prevention above waste reduction, re-use, recycling, recovery and landfill, in that order (Phillips et al., 2002). The Dutch waste policy follows a similar but slightly different ranking: prevention has the highest priority, followed by recycling and then combustion and dumping. The U.S. Environmental Protection Agency (EPA) uses a similar reduce-reuse-recycle hierarchy.

These hierarchies are especially aimed at preventing negative external effects related to combustion and dumping. In countries with scarcity of land, combustion is often preferred above dumping. Irrespective of national differences, the objective is that use of materials be reduced as much as possible so as to reduce end waste. Cascading is employed to close remaining waste cycles. Waste policy has been characterized by a national, or even regional (provincial/state) context, aimed at efficiency in physical-technical terms. The concept of industrial symbiosis has become popularized due to the well-known example of the Danish Kalundborg. However, few studies have examined why Kalundborg happened, and how to apply this to other industrial parks. Instead, it has often been assumed that bottom-up calculations were enough to identify potential benefits, ignoring transaction costs (Chapter 12, Boons and Janssen, this volume). Supsequently, applications to other industrial parks have not been very successful (Chapter 11 by Jacobsen and Andersen, and Chapter 12 by Boons and Janssen, this volume). In general economic efficiency has received less attention than efficiency in physical-technical terms. Indeed, to date, insights from cost-benefit analysis of different waste treatment options have not had much impact up till now (Chapter 9, by Bartelings et al., this Volume). Instead, idealistic or altruistic considerations seem to have dominated (Ackerman, 1997).

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far, however, the regulations of the WTO conflict with these, as they do not allow differential treatment of identical commodities that are produced in different ways, notably causing more versus less environmental pressure.

In recent years, four developments have led to a reconsideration of waste policy formulation. First, governments and utility companies in the waste sector are abandoning their traditional position as a regulator and capacity planner. Second, the market for waste is subject to ‘internationalization’. For example, the national borders within the European Union no longer hold for waste treatment and useful applications of waste. However, regulation by the Basel Convention and the European Union for international transport of waste is inadequate to avoid undesirable international shifting of environmental problems. Third, waste policy is being considered in a broader context, linked to other than material-related environmental issues. In particular, energy policy goals may cause a reconsideration of the hierarchy in waste policy. Waste combustion for electricity generation – ‘thermo-recycling’ – changes the priority usually given to prevention. Fourth, enlarging cascades through repeated use of products can increase particular types of environmental pressure. The sustainability of a reused product, including its production, packaging, and processing of waste**,** is at stake here.

The economic perspective on waste policy is not simple. Many studies so far have adopted a partial approach, which does not render definite insights. Both theoretical and empirical studies have been able to show that the generation of waste can be very sensitive to user fees, if combined with programs that enlarge public awareness for the waste problem. Most studies disapprove of a flat-fee pricing system in which the tariff is independent of the amount of waste supplied. But economic studies provide different results in terms of what an optimal policy looks like. The main choice is between ‘upstream and downstream’ taxes. The first can take the form of a deposit refund system or a ‘waste tax’ on the consumption good to internalize the waste treatment costs in the price of the product. The ‘downstream’ tax can be implemented as a unit-based pricing system, in which the fee can depend on the actual amount of waste generated, or on proximate indicators, such as the number of persons in a household. The disadvantage of a ‘downstream’ tax is that either enforcement costs are high or that one ends up with illicit dumping, burning or other unintended forms of disposal - dumping waste in the neighbor's bin or disposal at work. Such behavior is from an economic welfare perspective unattractive as it involves high social costs. Some studies have therefore gone as far as to argue in favor of subsidizing legal waste disposal. Empirical studies have shown that significant levels of illegal disposal are not a hypothetical consequence of price-based waste policies: up to 30% of a reduction in waste generation may be caused by an increase in illegal disposal.

Chapter 9 by Bartelings et al. (this volume) was based on a general equilibrium approach, which is particularly useful for analyzing price-based instruments and welfare impacts that include environmental externalities. The broad perspective thus adopted allowed to show that even with costs of illegal disposal being taken into account, the downstream tax can be more efficient to tackle the waste problem than the upstream tax. A downstream tax means that private households feel a very strong and direct incentive to prevent and recycle waste, while an upstream tax does not provide any real incentive to increase recycling, and only a very weak incentive to reduce the generation of waste. The latter is the result of the fact that the price incentive is so small in comparison with consumer product prices, that it has no significant impact on consumption expenditure patterns. The conclusion of Chapter 9 is then very clear: the introduction of unit-based pricing is an inevitable component of any economically defensible policy aimed at the reduction of waste generation. As always, this is not the end of the story. Further research needs to be undertaken to examine what is precisely optimal from an empirical perspective, based on weighting environmental gains of waste reduction and consumption related welfare losses of regulation. This may differ among regions and countries, depending on consumer preferences and external costs of waste.

13.6 The international dimension of waste and recycling policy

International flows of waste, due to treatment of waste in another country than where it was generated, are controversial. Within the European Union a country is not allowed to question the environmental standards of countries to which it exports its waste. As a result, some countries create a barrier against the trade in waste, thus reducing economic opportunities for efficiently treating waste.

From the perspective of international trade theory, it is almost evident that trade in waste can lead to cost reductions and welfare maximization. Currently, a significant amount of waste is being traded and recycled internationally, notably between the North and the South, but also among countries in the South. In recent decades, international trade in most secondary materials has increased faster than its production. The total trade volume of secondary aluminum, lead, copper, zinc and paper increased from 2.5 10^9 kg to 21.5 10^9 kg during the period 1970-1997 (Chapter 10 by van Beukering, in this volume). International reuse is dominated by iron scrap and steel scrap, the trade of which increased during the same period from 20 10^9 kg to 37 10^9 kg. These developments have mainly been caused by significant differences in recycling costs and benefits between poor and rich countries. Moreover, there is an oversupply of secondary materials in the rich countries, and a shortage of high-quality secondary materials in the poor countries. As a consequence, domestic prices for waste are relatively low or even negative in rich countries, and relatively high in poor countries. Large differences in the price of labor are responsible for these cost and price differences. This holds, of course, especially for recycling activities that are relatively labor-intensive. An example is the manual disassembly of computers. The reduction of transaction and transport costs has further contributed to the 'globalization' of trade in secondary materials. Cost factors are important here, because these trade flows primarily concern materials with a relatively low value. In order to channel these trends, the regulation of international trade in secondary materials needs to be improved. In particular, there is a serious need to regulate working conditions in recycling activities involving dangerous wastes. This may be done through an adequate revision of the Basel Convention.

13.7 Indicators for dematerialization

Before discussing the desirability and possibility of an integrated 'sustainability and environmental policy' for material resources and waste, it is useful to examine whether there are sufficient and reliable data to design and support such a policy.

An important problem to be solved is that it is not always immediately clear how dematerialization focused on specific physical indicators contributes to the availability of critical resources in the future or to a reduction of environmental pressure. In particular, it is not evident which dematerialization indicator(s) need to be formulated and used. It is clear that an aggregated indicator in kilograms, such as the Total Material Requirement (TMR) proposed by the Wuppertal Institute, makes little sense from economic, environmental or welfare perspectives. This indicator has been developed around the notion of Materials Inputs per Service Unit (MIPS) (Von Weizsäcker et al., 1997). It is based on the debatable assumption that one can simply add all kinds of different materials (measured in kilograms) used during the life-cycle of a product or service in order to formulate an aggregate environmental indicator (also in kilograms). Virtually all (environmental and resource) economists regard the TMR indicator as conveying information that is completely irrelevant for solid environmental policy making. The reason is that so many materials with entirely distinct environmental effects per kg material used are lumped together in one indicator without applying a careful weighting procedure. Economists would advice, for example, to weight in accordance with externalities generated by materials per kg (while other weighting approaches have been proposed by environmental scientists). This is a good example where adding an economic dimension to industrial ecology changes the judgement of a method, with possibly serious implications for derived policy suggestions. Ayres et al. in Chapter 3 present as alternative indicators: (1) mass per capita and exergy per capita; (2) mass and exergy per unit of GDP; (3) embodied exergy per unit of mass; and groupings of material flows (fossil fuels, metals, agricultural products, construction materials, and chemicals).

It seems much wiser to employ either a set of various, homogeneous indicators, or to aggregate different materials using a well-motivated weighting scheme. From the perspective of sustainability, this could be based on the relative scarcity of different materials. From an economic welfare perspective, weighting could be based on marginal external costs assessed for each type of material. Through the economic (monetary) valuation of external effects dematerialization can be directly linked to a reduction of particular environmental impacts (Ackerman, 1997). Nevertheless, it should be noted that economic valuation as well as the optimization of external effects is based on a number of microeconomic assumptions, such as rational agents and perfect information, which mostly do not hold in reality. Therefore, a set of purely physical indicators is preferred. Similarly, these considerations suggest that price instruments will be less efficient and effective than is often stated in the standard economic literature on environmental policy (Baumol and Oates, 1988). In other words, optimal policy is an illusion, and at best a theoretical benchmark. Physical targets for dematerialization policy are then a possible substitute. In economic terminology, this is an example of the inevitable ‘second best policy’.

A dematerialization indicator can be formulated as a fraction, the denominator of which reflects an economic category (GNP, sectoral production levels, product, consumer). Dematerialization at a high level of aggregation is partly an autonomous process, which is caused by an increase in the share of services in economic production at higher levels of income. However, measurement of the change in services is difficult for a variety of reasons (Verbruggen, 2000):

- New services often show a fluctuating price pattern.
- The Baumol effect – higher prices of services due to more demand for these – will already cause an increase in the share of services in the GNP without a real increase of service production (Baumol, 1967).
- Due to international competition, labor-intensive industries like textiles and clothing, shoes and shipbuilding are shifting from OECD countries to non-OECD countries. That is, even without a change in consumption patterns, OECD countries are dematerializing their supply side of the economy.
- Services like design, image and quality will make up an increasing part of the price of material products. Since material products fall outside the category ‘services’, their increasing service component is subject to measurement problems.
- Production processes incorporate an increasing service component, due to these processes becoming more information-intensive. Such services do not receive adequate attention in traditional sector measurement categories.
- The only empirical fact that has been well-supported so far is that, on average, consumers spend a higher share of their income on services when their income increases. In other words, the income elasticity of the demand for services is larger than one.

To distinguish services from materials we need, as well as better categories of production sectors and product groups, the systematic collection and analysis of physical data, preferably in close connection with national accounts (see Chapter 4 by Hoekstra and van den Bergh, in this volume). Physical data provide more information than monetary data about structural changes, because they reflect the physical technological structure of the economy. Of course, the availability of physical data will allow a very interesting comparison with associated monetary data or, more concretely, the tracing of indicators over time that provide information on monetary value per kilogram material used.

GNP has, by definition, no physical or material dimension, as it is an indicator of value added. This relates to the fact that economic value, reflected in the prices on the market, ultimately depends on the services delivered by products. It is, therefore, somewhat arbitrary which physical aspects one should assign to a specific service, i.e. only the material contained in the physical product that directly generates the service, or also the waste and emissions caused in its production chain (backwards). And, how should one account for materials in durable products versus materials in other products (food, detergents, etc.) and packing materials? Ayres et al. (Chapter 3 in this volume) show that, during the production of 1 kg of computer chips, almost a symbol of dematerialization, indirectly more than 200 kg materials are used.

Against this background, it is evident that what a dematerialization indicator precisely measures or reflects remains questionable, especially when one uses an aggregated indicator of material use. It would already be a significant step towards a material policy if we were to determine to which degree economic sectors contribute to the use of different materials and how their contributions change over time. A detailed analysis along these lines requires the use of physical (or hybrid) input-output tables for a number of years. Subsequently, structural decomposition analysis can detect direct and indirect material use of production processes and their changes over time (see Chapter 4 by Hoekstra and van den Bergh, in this volume).

13.8 Towards an integrated policy

Is it desirable and feasible to develop a sustainability policy for materials and waste? Might it not be better and more efficient, given the uncertainties about available resources, technological developments and substitution possibilities, and ultimate environmental impacts of materials, to regulate only the environmental effects of materials over the whole production cycle? This is already an ambitious goal, especially if linked to the coordination of national policies at an international scale. When environmental policy is clear and effective, market mechanisms will cause necessary adaptations, technological developments and new applications. In such a case, there is no need for a general dematerialization policy. In addition, international agreements are needed to support suppliers of critical natural resources, to be identified separately. This support should then be aimed at assisting the respective suppliers to develop sustainable management of exploited resources.

However, a number of objections can be raised against this line of thought. The environmental effects of the recovery, exploitation and processing of materials lead, per unit of material, to more environmental damage and pollution than during the consumption and waste phases of the production cycle. This is mainly caused by the increasing complexity of economic processes, characterized by a long trajectory of intermediate products and components. Furthermore, the production of primary materials often leads to significantly higher environmental pressure than that of secondary materials. Aiming at a general dematerialization will thus contribute to reducing the environmental consequences of material use. In the long run, one might aim for 100% recycling of non-renewable resources, referred to as “waste mining” (Ayres and Ayres, 1996). This will, however, require an increasing amount of energy input.

Economists traditionally are not in favor of physical goals, of which dematerialization is an example. One should note, however, that physical goals do not imply physical regulation, and are consistent with price-based and other policy instruments. Furthermore, the idea of optimizing externalities through maximization of social welfare including external costs is based on a number of microeconomic assumptions, some of which may be too restrictive and unrealistic. This holds especially for bounded rationality, and imperfect information and uncertainty about investments (in dematerialization). As a result, price instruments will be less efficient and less effective than often suggested, and are really what economist refer to as imperfect "second-best" instruments. In other words, "optimal policy" is an illusion, and at best a theoretical benchmark. Moreover, effectiveness is at stake when technology, trade, and consumption patterns are historically "locked-in". Price incentives are then insufficient to realize social objectives.

These considerations suggest that a general dematerialization policy by national governments, as well as at the level of international governance – European Union, United Nations, international agreements – is meaningful, and an almost inevitable element of a "second-best" policy that aims at effectiveness through unlocking and stimulating large-scale transitions. A public dematerialization goal can then translate into dematerialization objectives and strategies at the level of the private sector. Firms have many opportunities for realizing dematerialization, but are often kept away from these by profit concerns and other types of public regulation. In view of this, and given the social benefits and the non-obvious nature of a dematerialization approach, governments certainly should take a lead in setting in motion a dematerialization process.

Dematerialization and waste policy support each other in the long run, even if, in the short run, they are often conflicting. A dematerialization policy might be implemented that covers the whole product chain and is focused on reducing "lock-in" situations caused by established technological trajectories, organizational relations and institutions. The aim is to facilitate technological innovation and the transition towards a material-poor economy. Such a policy can make use of the physical requirements of production processes and products, even when, from an economic point of view, this is second-best. Other strategies are the stimulation of material cascading by cooperation in the product chain, the introduction of price corrections in waste policy, and the enlargement of the international allocation of waste management, recycling and trade in secondary materials, subject to appropriate international regulation through international agreements.

Such a dematerialization policy requires physical data in combination with relevant economic information, in order to create a basis for the development of dematerialization indicators. The contributions in this book have provided a starting point for the creation of tools and methodology to better understand the long-run relation between economic structure, international trade and material flows.

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References

Ackerman, F. (1997). *Why Do We Recycle? Markets, Values, and Public Policy.* Island Press. Washington D.C.

Ayres R.U. and L.W. Ayres (1996). *Industrial Ecology: Towards Closing the Materials Cycle.* Edward Elgar, Cheltenham.

Ayres, R.U., and L.W. Ayres (2002) (eds.). *A Handbook of Industrial Ecology.* Edward Elgar Publishing, Cheltenham.

Baumol, W. (1967). Macroeconomics of unbalanced growth. *American Economic Review* 57: 415-426.

Baumol, W.J. and W.E. Oates (1988). *The Theory of Environmental Policy*. 2nd ed. Cambridge University Press, Cambridge, UK.

Graedel, T.E., and B.R. Allenby (2003). *Industrial Ecology*. 2nd edition (1st ed. 1995). Pearson Education, Prentice Hall, Upper Saddle River, NJ.

Kandelaars, P.P.A.A.H. (1998). *Economic Analysis of Material-Product Chains: Models and Applications.* Ph.D. dissertation. Thesis Publishers/Tinbergen Instituut, Amsterdam (also published by Kluwer Academic Publishers, Dordrecht).

Kox, H.L. (1991). Integration of environmental externalities in international commodity agreements. *World-Development* 19(8): 933-943.

Linneman, H. and H.L.M. Kox (1995). *International commodity-related environmental agreements as an instrument for sustainable development* (Summary report). Economics Department, Vrije Universiteit, Amsterdam.

Lusky, R. (1975). Optimal taxation policies for conservation and recycling. *Journal of Economic Theory* 11: 315-328.

Phillips, P.S, K. Holley, M.P. Bates and N.P. Freestone (2002). Corby waste not: an appraisal of the UK’s largest holistic waste minimisation project. *Resources, Conservation and Recycling* 36: 1-31.

Socolow, R., C. Andrews, F. Berkhout and V. Thomas (eds.) (1994). *Industrial Ecology and Global Change.* Cambridge University Press, Cambridge.

Verbruggen, H. (2000). Voorwaarden voor een duurzame kenniseconomie. *Naar een Duurzame Kenniseconomie.* Verslag jaarcongres RMNO. Rapport 145, RMNO, Rijswijk (in Dutch).

Weizsäcker, E. von, A.B. Lovins and L.H. Lovins (1997). *Factor Four: Doubling Wealth – Halving Resource Use.* A Report to the Club of Rome. Earthscan, London.