PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

The service economy: 'wealth without resource consumption'?

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The service economy: 'wealth without resource consumption'?

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The present economy is not sustainable with regard to its per capita material consumption in the industrialized countries. A dematerialization of the economy of industrialized countries can only be achieved by a change in course, from an industrial economy where success is measured in throughput and its exchange value, to a service economy where success is measured in wealth (stock) and its usage value. Wealth management, new corporate and industrial design strategies and different economic policies can lead to a higher sustainability as well as an increased international competitiveness due to a substantially higher resource productivity. The term 'service economy' refers not to the tertiary sector, but to an economy where the majority of value is created by services and the majority of jobs are in service activities.

1. The need for a change in course in order to move closer to the vision of sustainability

The present industrial economy, which has developed over the last 200 years in today's industrialized countries, is based on the optimization of the production process in order to reduce unit costs and thus overcome the scarcity of goods of all kinds, from food to shelter to durable goods, which was the norm 200 years ago. Emphasis is on more efficient process technologies and a better quality of the goods at the point of sale.

There are indications that the industrial economy is no longer efficiently catering for our needs: (i) the part of goods that go directly from production to disposal (zero-life products in figure 1) has reached 30% in some sectors; (ii) the number of goods that are disposed of is comparable to the number of goods sold, for many products, indicating a substitution of wealth rather than an increase in wealth; (iii) technological progress is still focused on production, not on use; (iv) for many goods, increases in efficiency through system breakdown are comparable to increases in efficiency through product innovation (e.g. safety through traffic jams versus air bags).

Furthermore, there are indications that the industrial economy itself is incompatible with the aims of a sustainable society. These are discussed below.

The factor 'time': sustainability is a *long-term* societal vision, concerned with the stewardship of natural resources (stock equals wealth) in order to safeguard the opportunities and choices of future generations. The industrial economy is a *short-term* optimization of throughput in monetary terms. Changing course towards a more sustainable society means introducing the indeterministic factor 'time' into economic thinking, which again implies an indeterministic vision of economics.

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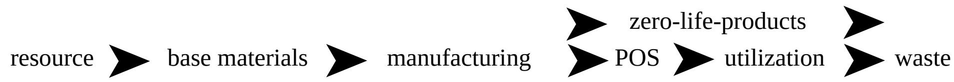

Figure 1. The linear structure of the industrial economy (or 'river' economy).

Resource productivity: the linear structure of the industrial economy has as a consequence that its success, both micro and macro, is directly coupled with resource flows, of both matter and energy—it might be called a *'river economy'* (figure 1). However, a generalization of the present per capita resource consumption of industrialized countries is not possible without a system collapse. In order to be sustainable, the economy must therefore operate at a much higher level of resource productivity, i.e. be able to produce the same usage value out of a greatly reduced resource throughput—it might be called a *'lake economy'* (figure 2)†. Changing course towards a more sustainable society means to decouple economic success from resource throughput—one way to do this is to change to a service economy, in which the measure of results refers mainly to stocks and their use, instead of flows (Giarini & Stahel 1993).

Social and cultural ecology: the industrial economy has been largely technology focused, using monetarized values as its main yardstick. A sustainable society is result focused and based on social and cultural values (non-monetary assets), integrated with economic values. Changing course towards a more sustainable society means taking into account social and cultural factors as peers to economic ones.

A service economy is fundamentally different from the industrial economy in that its main objective is to maintain or increase total wealth and welfare, i.e. the monetary and non-monetary assets of society, over long periods of time. Its focal point is the optimization of use, i.e. of the performance and the results achieved with goods, rather than the goods themselves. The central notion of economic value in the service economy is the value of usage over time, in contrast to the momentary value of exchange at the POS (point of sale) in the industrial economy (the added value system is only a subsystem of a larger economic concept). Similarly, quality in the service economy is defined as long-term optimization of system functioning, not as a momentary quality at the POS.

The invisible hand of the free market prefers junction 2 to the economically more advantageous junction 1 (figure 2), if mandatory recycling legislation is introduced. The reason for this 'wrong' choice lies in industry's familiarity with throughput optimization, as well as in incomplete legislation. The economic optimization of the loops in figure 2 only becomes an objective for manufacturers if legislation imposes closed liability loops (product take-back and product stewardship 'from cradle to the next cradle' by manufacturers), in addition to closed material loops. These liability loops are 'invisible' in a techno-economic vision and thus easy to overlook.

In case of the mandatory or voluntary take-back of goods, the new economic objective for industry now becomes to maximize profits through the reuse of components and goods, instead of the old minimization of costs in recycling and disposal of goods. In some cases, manufacturers may need to develop strategies of 'retained ownership' (operational leasing, renting, selling results instead of goods) in order to guarantee the return of their goods after each cycle. Xerox's marketing strategy of selling

† It has been calculated that industrialized countries need to reduce their resource flows by a factor of ten in order to enable the less developed countries to multiply their per capita resource input within a sustainable level of world resource flows (Shmidt-Bleek 1994).

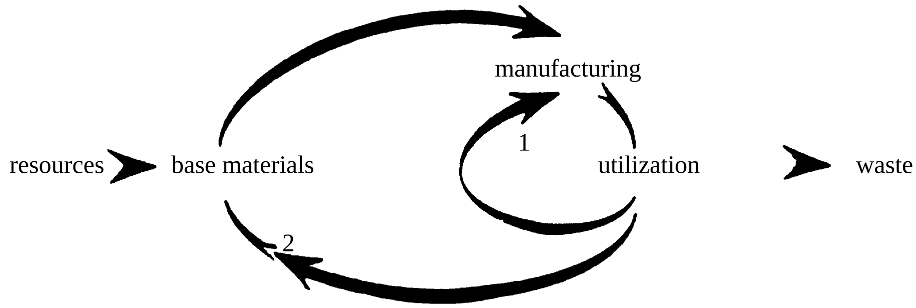

Figure 2. Closing the material loops: the loops of a self-replenishing, more sustainable service economy (or 'lake' economy) and the junctions between these loops and a linear economy (after Stahel & Reday 1981). Junction 1: product-life extension versus new goods; cost advantage product-life extension. Junction 2: virgin materials versus recycling materials; cost advantage virgin materials. Loop 1: reuse of goods, repairs of goods, reconditioning of goods and technological/fashion upgrading of goods. Loop 2: recycling of materials.

customer satisfaction in addition to its technological life-cycle design strategy is a brilliant example of asset management (for stock equals wealth).

A transition from a resource flow based industrial economy to a wealth management based service economy will be greatly facilitated if a majority of people and nation states can agree on a common vision of sustainability. Such a vision, however, is almost by definition more cultural than technological; it further needs a clear structure to avoid misinterpretations.

2. The pillars of a sustainable society

The concept of sustainability is based on several techno-economic pillars, each of which is essential for the 'survival' of the natural ecosystem—of which humanity is part—on Earth. It is of no use to argue on priorities, or speculate on which of these pillars can be lost first; society cannot take the risk of losing any single one of them.

(1) *Nature conservation*, or the ecosupport system for life on the planet. This pillar contains global aspects (e.g. oceans and atmosphere as global commons, biodiversity), as well as regional ones (e.g. drinking water, the carrying capacity of nature with regard to populations and their lifestyle).

(2) *Health and safety* (non-toxicology, qualitative): a danger mainly related to the health of people and animals, resulting increasingly from man's own activities (e.g. (accumulation of) toxic substances in the environment: DDT, mercury, thalidomide).

(3) *Reduced flows of resources*, or higher resource productivity (quantitative, e.g. CO_2): a potential of radical change for the planet (towards a reacidification and/or climate change) and thus a threat to man's life on Earth. Also a factor of disequilibrium between economies in North and South.

The 'quest for a sustainable society', however, must be much broader and include the longevity and sustainability of our non-techno-economic structures.

(4) *Social ecology*, the fabric of societal structures: this pillar includes issues such as democracy, peace and human rights, employment and social integration, security and safety.

(5) *Cultural ecology* includes education and knowledge, ethics and culture, as well as values of national heritage at the level of the individual, the corporation and the state: 'show to others that you are able to care, by looking after your car, your

house (instead of buying a new one)' (J. P. Kusz, personal communication 1995); 'good engineering and industrial design has always also been ecologically responsible' (Siemens PC engineers, 1985); 'only people, not robots, can permanently improve product quality' (Toyota's president on opening the labour-intensive assembly lines in the RAV4-factory (1995)); 'waste is inefficient and therefore un-Japanese' (report on waste management by the Japanese Ministry for International Trade and Industry, 1995).

Historic examples of sustainability, such as the Native Americans' rule of 'everything you do should have positive repercussions on the next seven generations' and the Prussian management rules for sustainable forestry, both at least 200 years old, were based on communities and their traditional values, i.e. a socio-cultural, not technological, ecology. The precautionary principle, one of the key principles agreed upon in the Rio declaration, is also primarily based on socio-cultural values—but it has hardly been put into practice so far. The question therefore arises if modern society, based on legal frameworks and penal systems, can find a recipe for sustainability in areas where precaution is the most efficient (or only) strategy, such as the global commons, without falling victim to 'the prisoners' dilemma' (where each individual fares better than his or her inmates by ruthlessly exploiting his or her personal advantage, but where the prisoners as a whole are better off by cooperating with each other).

The holistic vision of a sustainable society was already at the base of the movement that coined the English term 'sustainability' in the early 1970s (the Woodlands Conferences in Houston, Texas, and the related Mitchell Prize Competition (Coomer 1981)). In order to understand the necessity for changing course towards a more sustainable economy, it is vital to keep the wider reference of a sustainable society (including subjects such as full and meaningful employment, quality of life) in mind.

3. Sustainable society as a common global vision

The vision of sustainability should be based on a global consensus and, like the concentric waves in a lake after a stone is thrown into the water, develop from a few abstract key issues or principles towards a multitude of increasingly concrete and regionally adapted applications: vision; objectives; industrial policy; business strategies and management tools; industrial design for ecological solutions (goods and services).

The following structure is a more detailed example of these concentric waves, focused on the objective of a higher resource productivity (i.e. pillar 3).

The common vision: sustainability.

Objective: to build and improve all pillars of a sustainable society, including a considerably higher resource productivity.

Industrial policy: to promote a self-responsibility of economic actors through, for example, closed liability and material loops, an extended result-focused product responsibility by economic actors, free-market safety nets† (e.g. mandatory insurance

† 'Free-market safety nets' are economic actors which can give a guarantee that financial losses resulting from innovators' mistakes do not have to be borne by the state: pools such as P&I clubs in shipping, insurance companies (including captive insurers, reinsurers), 'Berufsgenossenschaften' in Germany. These losses can arise from environmental or product liability, workers safety and compensation, etc.

Table 1. *Demand and supply strategies for a higher resource productivity*
(Source: adapted from Giarini & Stahel (1989, 1993).)

	type of strategies	
increased resource productivity through:	closing the material loops (technical strategies)	closing the liability loops (commercial/marketing strategies)
sufficiency solutions (demand side)	near *zero-options* ploughing at night, loss prevention (vaccination)	*zero-options* towels in hotels, non-insurance (rear-end accidents CA)
system solutions reducing *volume and speed* of the resource flow (supply side efficiency)	*system solutions* Krauss–Maffei PTS plane transport system, skin solutions, accessibility	*systemic solutions* lighthouses, selling results instead of goods, selling services instead of goods
more intensive use of goods reducing the *volume* (supply side efficiency)	*ecoproducts* dematerialized goods, multifunctional goods	*ecomarketing* shared use of goods, selling use instead of goods
longer use of goods reducing the *speed* of the resource flow (supply and demand side efficiency)	*remanufacturing* long-life goods, service-life extension of goods and of components, new products from waste	*remarketing* discurement services, away-grading of goods, marketing of fashion upgrades for goods in the market

cover) and a legal framework (including taxation) fostering sustainable solutions (goods and services).

Business strategies: to develop innovative technical and marketing strategies which identify and optimize sustainable and economically viable solutions 'from cradle to the next cradle', with the aim to provide customer satisfaction over long periods of time, interpreting quality as a long-term optimization of system functioning.

Management tools: to optimize asset management, resource productivity and risk management, including relevant controlling instruments, and to define benchmarks and methods to measure improvements towards sustainability.

Design for ecosolutions, goods and services: zero-options (sufficiency), system solutions and usage optimization through a longer and more intensive use (efficiency), dematerialized solutions (ecoproducts). Details of business and design strategies which lead towards more sustainable solutions are given in table 1.

Reality, i.e. short-term business optimization, has led to the opposite trend of creating concentric waves from the outside inwards: first on the market were 'green' products (each with its own reference frame), followed by services for 'greening businesses' promoted by consulting firms (ecolabels and ecoaudits), even before an agreement on a common vision is in sight.

4. Wealth without resource consumption: facing new risks in a service economy

The objective of 'wealth without resource consumption' is obviously of little interest to the industrial (river) economy, as it will lead to 'economic disaster' (as measured in resource throughput). There is therefore a considerable untapped potential of technical innovation and economic activity ahead for proactive entrepreneurs that recognize and successfully develop this potential. The key to 'wealth without resource consumption' is the service economy: if customers pay an agreed amount per unit of service (and service equals customer satisfaction), service providers have an economic incentive to reduce resource flows, as this will increase their profits doubly: by reducing procurement costs for materials and energy and by reducing waste elimination costs (Giarini 1993). Examples for this are the Xerox life-cycle design programme for photocopiers, the retreading of tyres, the elevator business, Speno's railgrinding services, DuPont's voluntary programme to retake and recycle nylon carpets and remanufacturing activities in general.

The main benefits for proactive entrepreneurs are a higher long-term competitiveness through reduced costs, as well as higher product quality and customer loyalty, in addition to a 'greener' image; the main risk is the increased uncertainty due to the introduction of the time factor into the economic calculation. The latter can, however, be substantially reduced by appropriate design strategies, such as modular system design for interoperability and compatibility between product families, component standardization for ease of reuse, remanufacture and recycling, loss and abuse prevention built into products.

Sufficiency is one strategy for higher sustainability and wealth without resource consumption. Witness a hotel: by suggesting its guests 'save the environment' by reusing towels for several days, the hotel does indeed reduce the consumption of water, detergents and washing machines. But it also reduces its laundry costs and extends the useful life of towels and washing machines, thus increasing its profit margin. Zero-options, or sufficiency, are among the most ecologically efficient solutions—and they also offer the highest savings.

Systems solutions and the shared usage of goods are also very effective efficiency strategies of higher resource productivity. Several people sharing in the use of a pool of goods can draw the same usage value through a more intensive use of a substantially reduced number of goods, thus achieving a higher resource productivity per unit of service. Examples for this are, besides public infrastructures such as lighthouses, roads, concert halls and railways, the Lufthansa car pool for flight crews, the 'charter way' concept by Mercedes for trucks and the textile leasing of, for example, uniforms, towels and hospital linen.

A shared usage is possible in the (monetarized) economy through rental services and the sale of services instead of goods (laundry and dry cleaning), but also within communities (non-monetary) through lending and sharing. The former takes place within the legal framework of society, the latter's principles of sharing and caring are based on community values (trust and tolerance) which are part of socio-cultural ecology. Some of the issues involved in the sharing of immaterial and material goods are open to misinterpretation because they incorporate values of both society (law) and community (trust). Distrust leads to increased individual consumption, conflict or failure†. A shared usage of *immaterial* goods has two major advantages: a great number of people can profit from the goods simultaneously—in contrast to material goods—and immaterial goods are by definition dematerialized. The technology shift from analogue to digital or virtual goods will further enhance shared use, even

† This dilemma might partly have been the reason for the failure of the initiatives to develop 'terotechnologies' (tero = caring) in the UK in the 1970s.

if the main reason for the change to virtual goods is competitiveness, not ecology. Product life extension services of analogue (mechanical) goods lead to a regionalization of the economy, whereas digital and virtual goods enable producers to stay global, by providing solutions (for example, the technological upgrading of goods) through do-it-yourself activities. This gives producers direct access to the customer; it also eliminates distributors and distribution costs. The coming change to digital television, accompanied by long-life hardware combined with later technological upgrading through software, is an example of this trend—pushed by the novel German take-back legislation for electronic goods.

Wealth with less resource consumption is further possible by substituting maintenance-free long-life products which deliver high-quality results for disposable products. Modern examples include music CDs (compact discs) and supercondensors instead of batteries in electrical goods. CDs are also a point in case for the resulting shift in income from manufacturers to distributors (secondhand sales and rental shops), if the manufacturers themselves do not become service providers (e.g. selling music instead of CDs), which would have demanded a structural change from global manufacturing to local rental services.

A longer use of goods through product-life extension services (loop 1 in figure 2), as well as dematerialized product design, also increases resource productivity, but needs to be promoted as it goes against the logic of the linear economy. Doubling the useful life of goods reduces by half the amount of resource input and waste output, and in addition reduces the resource consumption in all related services (distribution, advertising, waste transport and disposal) by 50%. Furthermore, product-life extension services are often a substitution of manpower for energy, and of local workshops for (global) factories, thus enhancing social ecology. Economic success comes through an understanding of the logic inherent in a 'lake economy' based on services: to optimize usage demands a proximity to the customer and thus a regionalization of the economy. As the stock of goods in the marketplace is the new focus of economic optimization (the assets), these goods become the new 'mines' for resources. They cannot economically be centralized—an efficient service economy has to have a decentralized structure (service centres, remanufacturing workshops and minimills). Service centres are ideally accessible 24 hours a day, such as the emergency department of a major hospital.

5. Benefits for the user/consumer

'Service is the ultimate luxury', according to publicity by the Marriott hotel group. The shift to a service economy (e.g. product rental instead of purchase) encounters few problems of acceptance on the demand side. The consumer-turned-user gains a high flexibility in the use of goods (something ownership can never give him), as well as guaranteed satisfaction at a guaranteed cost per unit of service. Furthermore, there is no loss of status: the marketing of the industrial economy has wrongly created the idea that status symbol value is linked to ownership—in reality, it has always been linked to leasehold. The driver of a red Ferrari gets the same attention from bystanders if he has bought, rented or stolen the car. Ownership therefore only makes economic sense in cases where durable goods increase in value, normally through an increase in rarity, such as antique furniture, vintage cars, real estate.

Also, ownership only makes ecologic sense for individuals interested in asset management. In many countries, an increasing portion of individuals live mentally in a multioption society: they do not want to commit themselves medium- or long-term, neither to goods nor people (Gross 1995). They want new toys all the time—and can afford them. Only a service economy can fulfil their needs without creating an avalanche of waste, by selling them results and services instead of goods, flexibility of usage instead of bondage by property.

Most of these strategies of a higher resource productivity also offer the customer a reduction in costs. Sufficiency solutions based on a better (scientific) understanding of a problem reduce resource flows and costs: ploughing at night, for instance, reduces weeds and thus herbicide costs by 90%; remanufactured goods costs on average 40% less than equivalent new goods of the same quality; sharing goods also means sharing costs. However, sufficiency and efficiency solutions often demand that the users/customers develop a new relationship with goods and/or people—knowledge and community become substitutes for resource consumption.

6. Innovation and an industrial policy for sustainability as the keys to higher resource productivity

A fundamental change in actors and issues occurs when society evolves down the 'sustainability pillars', from 'health and safety' to 'resource productivity' (table 2). In the past, biologists and chemists have been the driving force through command and control regulations in order to conserve nature and limit toxicology, in the name of nation states. Now, engineers and industrial designers, marketeers and businesspeople will take the lead through innovation, in order to achieve an increase in resource productivity by a factor of ten. 'Innovation by enterprises' and 'an industrial policy to promote sustainability' become the future key strategies not only towards a sustainable society, but also towards competitiveness! (Innovation strategies open to economic actors are summarized in table 1.)

This corresponds to a fundamental change in political thinking, from ecology versus economy (and state versus industry) towards ecology with economy (and state with enterprises). The new industrial policy can best promote sustainability by removing obstacles which hinder, and by creating incentives which foster, innovation towards more sustainable solutions. The state still has to determine the need for safety barriers to protect people and the environment. However, the state should not provide this protection itself, nor carry the costs of accidents, but foster free market safety nets such as mandatory insurance (e.g. environmental impairment liability, product liability)!

At a time when tax authorities increasingly leave it to the stock exchanges to define valid accounting guidelines (because banks and stock exchanges have a prospectus liability and therefore a self-interest to verify the figures they are given), the state should define the aim of, but not the strategies to, a higher resource productivity (e.g. ecoproducts). However, the state should make sure that the economic actors which innovate get rewarded and promoted and that those caught cheating (or their safety net) will pay up. By doing this, the state could become considerably leaner and more efficient. The principle of 'insurability of risks' would automatically introduce the precautionary principle into the economic mechanisms to chose between possible technologies, present and future.

The fundamental change in actors and issues occuring when society evolves down the 'sustainability pillars', from 'health and safety' to 'resource productivity', is summarized in table 2.

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Table 2. *Key actors and issues in each of the five pillars of sustainability*

pillars of sustainability (values)	actors which can			monetary costs and benefits
	define objectives	identify solutions	deal with abuse	
1. nature conservation (natural assets)	states, preventative legislation (asset management)	nature itself (scientists)	precaution (avoid 'non-repairable' damages)	lost opportunity costs
2. safety and health (non-toxicology)	states, legislation to limit damages (after scientific proof)	scientists and MDs	financial compensation to victims, fines and prison sentances	additional costs
3. higher resource productivity	consumers enterprises	sufficiency better business solutions through innovation	change supplier free-market financial safety nets, e.g. insurance	savings savings in procurement and waste disposal
	states	new industrial policy based on incentives for innovation and sustainability	transfer	savings through lean administration and risk
4. social ecology (invisible fabric)	parents, communities, corporations, states	education and knowledge	feed-back loops to peer groups (punishments)	savings in social costs
5. cultural ecology	individuals, corporations, states	education and ethics	loops of virtue	savings in social costs

Some of the key issues of an industrial policy for sustainability can be summarized as follows.

(1) Introduce the factor 'time' into the legislation governing the economy: (i) develop and use methods to measure sustainable competitiveness over long periods of time, e.g. GPI or ISEW instead of GNP†; (ii) define and legislate the minimum quality of goods for sale in function of their service life, by requiring a long-life warranty (e.g. in accordance with the ten years in the EC safety directives), instead of the present exclusion of the use of used components in new goods; (iii) focus funding on R&D, as well as education, and training on prevention and precaution methods instead of process technologies: long-term behaviour of materials, components and goods (wear and tear versus fatigue), technical risk management, industrial design for system thinking, ways to popularize sustainability in terms of socio-cultural ecology.

(2) Increase the self-responsibility of economic actors: (i) through a product responsibility 'from cradle to the next cradle'; (ii) by replacing mandatory technical

† GPI general progress indicator (US), ISEW index of sustainable economic welfare (European), GNP gross national product; for details of GPI and ISEW please refer to van Dieren (1995)

standards by mandatory free market safety nets, thus introducing the insurability of risks as the main criterion for an economic choice between technological options; (iii) by eliminating subsidies and incentives for economies of scale which often hide diseconomies of risk.

(3) Use industrial policy as a locomotive for economic competitiveness: change industrial policy ahead of the economic development in order to increase innovation towards sustainability.

(4) Sustainability is a holistic principle; the requirement of 'unity of matter' in legislation has become an obstacle to problem solving (e.g. levying taxes on resource consumption in order to finance old age and unemployment).

(5) Introduce self-correcting taxation loops in the economy: tax resource consumption and waste instead of labour, thus rewarding all sufficiency and efficiency solutions (and eliminating the discrimination of 'voluntary work', 'moonlighting' and 'non-productive work' at the same time).

Few incentives and little know-how have been developed under the present economic or industrial policy to develop and apply strategies of sustainability or a higher resource productivity in practice. A society which 'saves the environment' by replacing ('destroy and produce new') millions of vehicles in working order when a 'cleaner' technology becomes available (e.g. unleaded petrol, lean burning engines, catalytic converters), based on industry's claim that existing engines cannot be upgraded or converted, does not act efficiently, neither with regard to its engineering development nor the environment, and acts on short-term assumptions (the proof for this was delivered by a handful of skilled Swiss mechanics converting the engines of their fleet of vintage Junkers Ju-52 aircraft to unleaded petrol).

7. Benchmarks for sustainability

Experience has shown that the resource efficiency of existing solutions can be improved by up to a factor of four (e.g. water use through drip irrigation in Israel, use of herbicides by railways). For an increase in resource productivity well beyond a factor of four, however, innovative strategies for new solutions are needed, attacking problems on a systems instead of a product level, or departing from a new understanding of the underlying need, or using new technology (table 1) (Stahel 1995).

The discussion on resource productivity which was started recently by Schmidt-Bleek and others (Schmidt-Bleek 1994, 1996) has shown the need to measure old and new solutions not against alternatives but against optimums. Otherwise, most of the praise might go to the worst actors of the past, whereas existing ecologically optimal solutions will go unnoticed, or even be forced out of the market by aggressive new-green marketing. Many traditional solutions have indeed reached a high degree of sustainability: an Austrian cabinet maker that uses timber from the local forests to produce furniture and toys for the regional market, repairs products when broken and heats his workshop in winter with waste timber, can hardly improve the sustainability of his activity even by a factor of four. The same goes for a local brewery in Wales which buys its raw material from local farmers and sells barrels of beer to the local pubs. The fact that these firms can hardly improve their ecological efficiency does not mean they are working in an unsustainable way—quite the contrary! However, it does show the necessity to establish benchmarks in order to define priorities and objectives in the quest for a higher resource productivity.

Benchmarks are easy in domains where people can be used as a yardstick, such as mobility. 'Sustainable mobility' can be defined as any method of mobility which enables a person to move faster and with less energy input than by walking, such as the bicycle for horizontal and the elevator for vertical mobility. The chances, however, that improvements to the motorcar will ever reach the human yardstick are low. In other cases, such as the coffee brewed by different coffee machines, the optimum benchmark is the quality of the result achieved. During the last coffee tasting competition organized by the EU consumer associations, one of the best results was achieved by the Bialetti espresso machine, an early ecoproduct designed and first produced in 1930 which is still on sale—together with hundreds of other coffee machines, all more expensive, more recent and more material intensive. Benchmarks can therefore also be used to indicate areas of ecomature solutions.

References

Coomer, J. C. (ed.) 1981 *Quest for a sustainable society* (published in cooperation with The Woodlands Conference). Oxford: Pergamon.

Dieren, W. van 1995 *Taking nature into account*. Basel: Birkhäuser.

Giarini, O. & Stahel, W. R. 1993 *The limits to certainty, facing risks in the new service economy*, 2nd edn. Dordrecht: Kluwer.

Gross 1995, *Die multi-options-gesellschaft (the multi-option society)*. Frankfurt: Suhrkamp.

Gruhler, W. 1990 *Dienstleistungsbestimmter strukturwandel in deutschen industrieunternehmen*. Deutscher Instituts Verlag.

Schmidt-Bleek, F. 1994 *Carnoules declaration of the Factor 10 club 1994*. Wuppertal Institute.

Schmidt-Bleek, F. 1996 *The fossil makers—Factor 10 and more (Wieviel umwelt braucht der Mensch? MIPS—das mass für ökologisches Wirtschaften)*. Basel: Birkhäuser.

Stahel, W. R. 1984 The product-life factor. In *An inquiry into the nature of sustainable societies: the role of the private sector* (ed. S. G. Orr). The Woodlands, TX: HARC.

Stahel, W. R. 1985 Hidden innovation, R&D in a sustainable society. In Science and public policy. *J. Int. Sci. Policy Foundation* **13**. (Special issue: The hidden wealth.)

Stahel, W. R. 1992 Re-use and recycling, waste prevention and resource savings in utilization. Conference manuscript, Guildford.

Stahel, W. R. 1994 The impact of shortening (or lengthening) of life-time of products and production equipment on industrial competitivenes, sustainability and employment. Research report to the European Commission, DG III, 1 November.

Stahel, W. R. 1995 *300 examples of higher resource productivity in today's industry and society (Intelligente Produktionsweisen und Nutzungskonzepte)— Handbuch Abfall 1-Allg. Kreislauf und Rückstandswirtschaft*, band 1 und 2. Karlsruhe: Landesanstalt für Umweltschutz Baden-Württemberg (Hrsg.).

Stahel, W. R. & Reday, G. 1981 *Jobs for tomorrow, the potential for substituting manpower for energy*. Report to the Commission of the European Communities, Brussels. New York: Vantage.

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