

## THE ECO-COSTS/VALUE RATIO: A TOOL TO DETERMINE THE LONG-TERM STRATEGY FOR DELINKING ECONOMY AND ENVIRONMENTAL ECOLOGY

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### ABSTRACT

Looking at the dynamic changes in our world, the ever-growing economy seems to be one of the major root causes of the continuing deterioration of our environment. The question is: what can be done? Stopping economic growth is not a realistic option; so the solution must be found in a better eco-efficiency of our systems for production and consumption ('delinking of economy and ecology'). Future products and services need to have a high value/costs ratio combined with a low burden on our environment. At the Delft University of Technology, a model based on life cycle analysis has been developed to assess the eco-efficiency of products, services, houses, buildings, etc. The model is also applied for the environmental impact assessment of urban and rural planning. It is called the model of eco-costs/value ratio (EVR). The basic idea of the EVR model is to link the 'value chain' to the ecological 'product chain'. In the value chain, the added value (in terms of money) and the added costs are determined for each step of the product 'from cradle to grave'. Similarly, the ecological impact of each step in the product chain is expressed in terms of money, the so-called eco-costs. The ratio of 'eco-cost' and 'value' is defined in each step in the chain as:  $EVR = \text{eco-costs}/\text{value}$ . The 'eco-costs' have been defined in terms of marginal prevention costs ('end of pipe' as well as 'system integrated') for pollution and materials depletion. The eco-costs are 'virtual' costs: these costs are related to measures which have to be taken to make (and recycle) a product 'in line with earth's estimated carrying capacity'. These eco-costs are estimated on a 'what if' basis (what technical measures are required to lower the *current* pollution and resource depletion to sustainable levels?). The 'value' in the model is the market value: the 'fair price' as perceived by customers. The advantage of such a definition of eco-efficiency (instead of using 'costs') is that the consumer behaviour is incorporated in the model. This makes the model suitable for strategic design of the transition towards an environmentally sustainable society: green products and services will only survive in our free market economy when they have a good value for the consumers.

*Keywords:* eco-costs, life cycle analysis, value, prevention, land use, materials and pollution.

### 1 INTRODUCTION

In the Preface of *Our Common Future* of the World Commission on Environment and Development's 1987 report, G.H. Brundtland wrote:

The downward spiral of poverty and environmental degradation is waste of opportunities and of resources. In particular it is a waste of human resources. These links between poverty, inequality, and environmental degradation formed a major theme in our analysis and recommendations. What is needed now is a new era of economic growth – growth that is forceful and at the same time socially and environmentally sustainable [1].

But what does such a rather philosophical statement mean to governmental authorities, business managers, designers and engineers in terms of the practical decisions they take? What are the right products to develop? What is the right governmental policy?

With regard to urban developments, there is a need to resolve questions like: What is the best architectural design in terms of ecological impact? What is the best concept of buildings in a city in terms of sustainability? What is the best spatial planning?

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<sup>†</sup>Prof. Charles F. Hendriks had already prepared this article before he passed away on the 13th of November 2004.

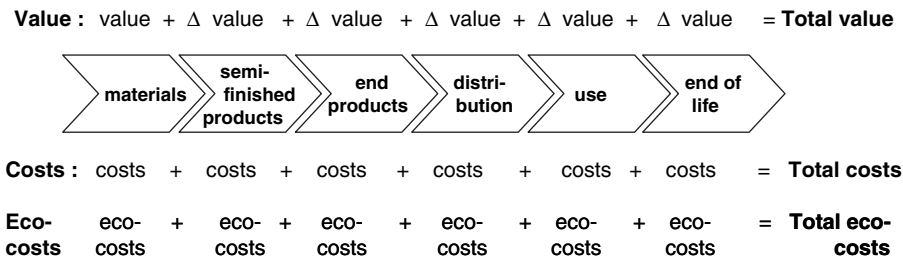


Figure 1: The basic idea of combining the economic and ecological chain: 'the EVR chain'.

For that reason, the Delft University of Technology developed the eco-costs/value ratio (EVR) model as a practical tool for decision-making, based on the life cycle analysis (LCA) methodology, and comprising the following features:

- One single indicator for the three major groups of environmental impacts (materials depletion, fossil energy consumption, toxic emissions) and land use.
- a relatively simple and well-defined allocation model to cope with the typical LCA difficulties in the service and building industry. (In the building industry, LCAs are characterized by many 'indirect' environmental impacts; issues are the environmental impact of the manufacturing of building equipment and the recycling of building materials.)
- An indicator which shows the degree of delinking of economy and ecology, which can be applied when a designer is asked to design a product (a house, a road, a city) within a given budget. The issue is then to create maximum value for the end-user at a minimum of environmental burden (eco-costs).

The basic idea of the model is to link the 'value chain' [2, 3] to the ecological 'product chain'. In the value chain, the added market value (in terms of money) and the added costs are determined for each step of the product 'from cradle to grave'. Similarly, the ecological impacts of each step in the product chain are expressed in terms of money as well: the so-called eco-costs (Fig. 1).

The eco-costs are 'virtual' costs: these costs are related to measures which have to be taken to make (and recycle) a product 'in line with the earth's estimated carrying capacity'. These eco-costs are the sum of the 'marginal prevention costs' of each 'class' (type) of pollution (Section 3.1) and the costs of measures for prevention of material and energy depletion (Sections 3.2 and 3.3).

Since our society is yet far from sustainable, the eco-costs are 'virtual': they have been estimated on a 'what if' basis. The costs of the required prevention measures are not yet fully integrated in the current costs of the product chain (the life cycle costs). It is expected that, *in future*, the eco-costs will become a part of the product costs (by means of 'eco-tax', 'tradable emission rights' or other governmental measures), since our society will not continue to accept the consequences of unsustainable situations in the long term.

## 2 THE VALUE, COSTS AND ECO-COSTS OF A PRODUCT

Now we look into one step of the production chain.

The market value ('fair price') of a product is determined by [4]:

- product quality;
- service quality;
- image.

These three components of value are described in more detail by the 'eight dimensions' of Garvin [5].

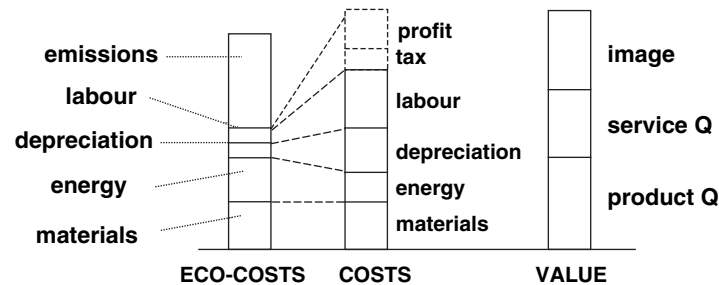


Figure 2: The decomposition of 'virtual eco-costs', costs and value of a product.

The cost-structure of a product comprises:

- the purchased materials (or components);
- the required energy;
- depreciation (of equipment, buildings, etc.);
- labour.

For each company in the production chain, the tax + profit equals the value minus the costs.

The direct eco-costs have been defined as the sum of the following elements:

- virtual pollution prevention costs, being the costs required to reduce the emissions in the product chain (from cradle to grave) to a sustainable level;
- eco-costs of energy, being the price for sustainable energy sources;
- eco-costs of materials depletion, being  $(\text{costs of raw materials}) \times (1 - \alpha)$ , where  $\alpha$  is the recycled fraction of materials to *make* a product.

The indirect eco-costs are:

- eco-costs of depreciation, being the eco-costs related to the use of equipment, buildings, etc.;
- eco-costs of labour, being the eco-costs related to commuting and the use of the office (building, heating, lighting, electricity for computers, paper, office products, etc.).

This is depicted in Fig. 2.

Along the production chain, the value, the costs and the eco-costs can be added up, as depicted in Fig. 3.

The ratio of the value and the eco-costs is characteristic for each process, product or service. We can define this EVR at every aggregation level of the production chain.

The two-dimensional approach of the EVR seems to be crucial in calculating as well as understanding the elements of the eco-efficiency of a product. The example in Fig. 4 reveals the fundamental differences between environmental strategies in each step of the chain:

- improvement of production processes (lowering the eco-costs at *constant* cost level);
- environmental material selection (lowering the eco-costs often at *higher* cost levels);
- 'savings' in, for example, transport (lowering both costs and eco-costs);
- improvement of the perceived value (*enhancing the value* without adding considerable extra eco-costs), often by adding services to the product.

With regard to the required sustainable strategies, it is essential to understand the chain. A low EVR indicates that the product is fit for use in a future sustainable society. A high EVR indicates that the value/costs ratio of a product might become 'less than one' in the future (since 'external'

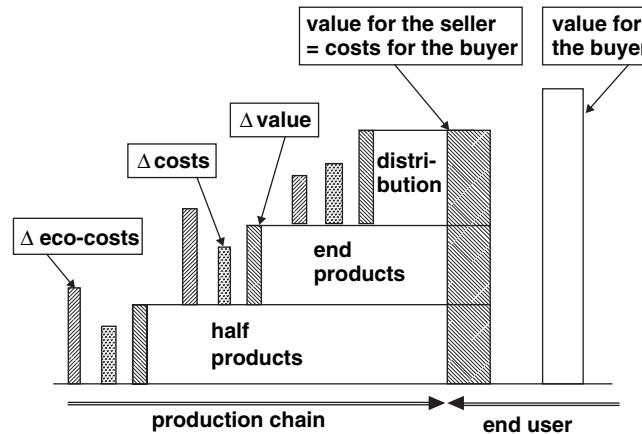


Figure 3: The decomposition of the value in the chain.

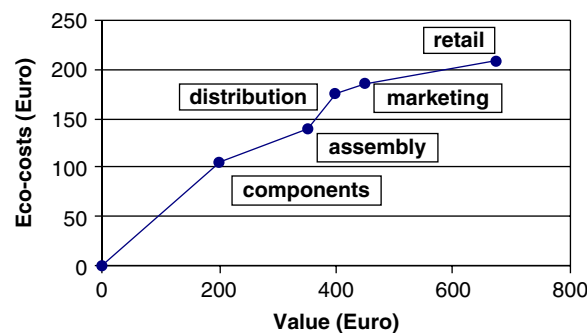


Figure 4: The value and the eco-costs cumulative along the production and distribution chain (data for a 28-inch CRT television).

costs will become a part of the ‘internal’ cost-structure), so there is no market for such a product in the future. Later in this article, we will show how we can apply the EVR model to determine the long-term strategies for delinking economy and environmental ecology, but first we will define and describe the eco-costs.

### 3 THE COMPONENTS OF THE ECO-COSTS

As mentioned in Section 2, we define the eco-costs as the sum of three direct (toxic emissions, energy and materials depletion) and two indirect elements (depreciation and labour). All these elements are calculated according to the LCA method, as defined in ISO 14041.

#### 3.1 The virtual pollution prevention costs

For toxic emissions, the marginal prevention costs are assessed for seven emission effect classes on the basis of prevention measures which are based on readily available technologies. The costs of the required marginal prevention measures are based on West European 1998 price levels [6]:

- 6.40 euro/kg SO<sub>x</sub> equivalent for acidification;
- 3.05 euro/kg PO<sub>4</sub> equivalent for eutrophication;
- 3.00 euro/kg VOC equivalent for summer smog (revised in 2002);
- 12.3 euro/kg fine dust PM10 for winter smog;
- 680 euro/kg Zn equivalent for heavy metals;
- 12.3 euro/kg PAH equivalent for carcinogens;
- 114 euro/1000 kg CO<sub>2</sub> equivalent for global warming.

### 3.2 The eco-costs of energy

The calculation method to determine the eco-costs of energy is based on the assumption that fossil fuels have to be replaced by sustainable energy sources (for details see [7]). The ‘eco-costs of energy’ is equal to the costs of the renewable energy system which has to replace the current system.

### 3.3 The eco-costs of materials depletion

With regard to the depletion of materials, the main approach in the model is:

- the eco-costs of materials depletion are set equal to the market value of the raw materials when the materials are not recycled;
- when a fraction  $\alpha$  of the sourced material is recycled, a factor  $(1 - \alpha)$  is applied to the market value of the raw material for the new product to calculate the eco-costs of materials.

Therefore

$$\text{Eco-costs of materials depletion} = \text{Market value of the raw material} \times (1 - \alpha). \quad (1)$$

The underlying assumption is that the (average) market value of the virgin material for *metals* reflects whether the material is scarce or hard to find and/or mine (e.g. platinum, gold, silver), or whether that will happen in the foreseeable future. The fraction  $\alpha$  has to be applied to the materials used for the new product (and not as a fraction of materials from the old product at the end of life), after the upgrading process (if applicable).

For *plastics*, however, the situation is different, since its source is crude oil. It is more in line with the general philosophy of this model to avoid the use of fossil fuels and use biomass instead as the source material for plastics. Therefore, in the EVR model the price of feedstock for plastics based on biomass has been chosen for the eco-costs of materials depletion. This price is estimated at 0.6 euro/kg.

### 3.4 Indirect eco-costs: the eco-costs of labour

The eco-costs of labour are indirect eco-costs, since labour as such hardly results in any environmental burden. However, there is some environmental burden related to labour, such as the environmental impacts of heating, lighting, use of computers, commuting and so on. The calculations of these eco-costs are specific for the type of labour.

A good guess for offices is that the eco-costs for labour are approximately 10% of the costs. Calculations for labour outside offices (shop floor personnel in factories, sales people, truck drivers, etc.) show that the eco-costs will vary in a range of 5%–15% of the costs, where the eco-costs of commuting and the use of electricity play a rather dominant role. Therefore, it is recommended that an LCA assessment is carried out in each typical case.

### 3.5 Indirect eco-costs: the eco-costs of depreciation of production facilities

The eco-costs related to the fact that fixed assets are used to make a product are indirect eco-costs. The issue of the 'eco-costs of depreciation' is that the eco-costs of the production equipment (or production facilities) have to be allocated to the products which are made using this equipment or in these facilities. For a proper choice of allocation rules, in line with LCA ISO 14041, see [7, 8].

The allocation rules are equivalent to the normal economic accounting rules for the allocation of depreciation costs to the life cycle costs of a product. This results in a very simple calculation method. A simple example: when 3 euro of the costs of a product is related to depreciation of the production equipment, and the EVR of the equipment is 0.4, the eco-costs of depreciation is  $3 \times 0.4 = 1.2$  euro.

Calculations have yielded the following values for the EVR of different materials:

• complex machines	0.3
• luxurious buildings (offices)	0.3
• low cost offices	0.4
• processes in stainless steel	0.4
• refineries	0.5
• steel structures	0.6
• warehouses	0.6

## 4 THE ISSUE OF LAND USE

The increasing use of land (urban areas, industrial areas, road infrastructure, etc.) is a major cause for the degradation of our environment. In the last decade there has been a growing concern about this negative aspect of a growing population and increasing economic wealth. So, most of the designers feel the need for incorporating the negative aspects of 'land use' in spatial planning. But how?

The so-called 'eco-costs of land conversion' is proposed as a single indicator, being the marginal costs of prevention (or compensation) of the negative environmental effects of change of land use. These 'eco-costs of land conversion' are based on four sustainability characteristics of land (before and after the conversion):

1. the botanical aspects (the species richness and the rarity of ecosystems and vascular plants);
2. the aspect of 'scenic beauty';
3. the aspect of production of food and biomass;
4. the aspect of the H<sub>2</sub>O cycle.

For the situation in The Netherlands (and the western part of Europe), the eco-costs of aspects 1 and 2 appear to be dominating. In this article, we will describe only the first aspect.

'Habitat for plants, animals and other species' is a major aspect with regard to conversion of land. The issue here is that biodiversity is degraded by the expansion of urban areas.

Although both flora and fauna are affected, flora has been widely accepted to classify the subject of land use [9], since it is easier to characterize than fauna (indicators for fauna are still under development), and since it is argued that there is a link between both types of biodiversity [10].

Species richness is characterized by the number of species of vascular plants in a certain area,  $S$ . It is one of the most applied measures for characterizing the botanical aspects of land in LCAs [9]. Data for  $S$  are available for many Western European countries. For The Netherlands, field data are available on a grid of 1 km<sup>2</sup>.

In the EVR model, land use is expressed in terms of the quality of land before and after the change. The quality factor is defined as the counted total number of vascular plant species,  $S$ , divided by the quality norm for it,  $S_{\text{ref.}}$ , where  $S_{\text{ref.}}$  is the number of species for 1 km<sup>2</sup> of nature.

The category indicator for species richness of land, species richness indicator (SRI) is introduced, which is expressed as the product of the area,  $A$  ( $\text{m}^2$ ), and the quality factor,  $S/S_{\text{ref}}$ .

$$\text{SRI} = A \times S/S_{\text{ref}}. \quad (2)$$

So SRI is expressed in terms of 'equivalent  $\text{m}^2$  of nature'.

The environmental effect of the change of land use is then described as

$$\Delta \text{SRI} = A \times \Delta S/S_{\text{ref}}, \quad (3)$$

where  $\Delta$  denotes the difference of  $S$  and SRI before and after the change.

For the quality norm of  $S$  in The Netherlands,  $S_{\text{ref}}$ , a value of 250 vascular plant species for  $1 \text{ km}^2$  is proposed.  $S$  is more than 250 for 9% of the total area of The Netherlands (areas above 300 are very rare: 3.5%; areas above 200 are quite common: 21%).

For Germany, England and the northern part of France, the same quality norm of 250 species for  $1 \text{ km}^2$  is proposed, since the species richness in these countries is of the same order of magnitude as in The Netherlands [10]. For species richness of other countries, see [11].

The total costs of compensation, the eco-costs of species richness, are:

$$\text{Eco-costs of species richness} = \Delta \text{SRI} \times 4 \text{ (euro)}, \quad (4)$$

where  $\Delta \text{SRI}$  is the difference between SRI before and after the conversion.

A much more subtle method of botanical characterization based on the counting of species (vascular plants) is a methodology developed by Witte [12]. This methodology takes the rarity of plants and ecosystems into account.

Although species richness is an indicator for botanical value ('when there are many species, there are normally valuable species as well'), it is a logical step forward to distinguish between species which are important and species which are less important. In this system, 'rarity of eco-systems' is the main measure of importance. Since this method is operational in The Netherlands only, it is not described in this article. For a description of the method and a comparison with species richness, see [11, 13].

## 5 DELINKING OF ECONOMY AND ECOLOGY

In the previous sections, the reader may have thought only about the product(ion) side of the problem of eco-efficiency. However, there is a consumer's side of the delinking of economy and ecology as well.

In fact, there are two ways of achieving environmental sustainability:

1. on the supply side of the economy: the delivery of eco-efficient (low EVR) products and services by the industry;
2. on the demand side of the economy: the change of lifestyle of the consumers in the direction of low EVR consumption patterns.

### 5.1 The EVR model and the buying pattern of consumers: the rebound effect

Assuming that most households spend what they earn in their life, the total EVR of the expenditures of households is the key towards sustainability. At a low EVR, the eco-costs will be low, even at a high total value of the expenditures.

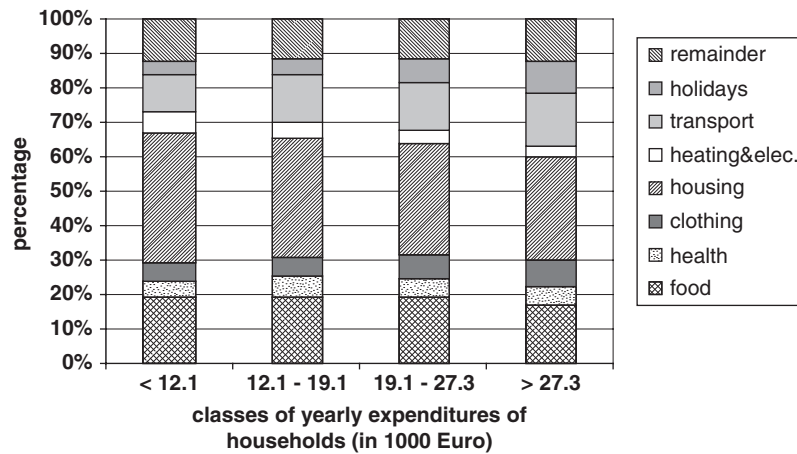


Figure 5: Preferences of expenditures of households (households in The Netherlands, 1995).

On the supply side, our society in the EU is heading in the right direction (often under governmental pressures): gradually industrial production is achieving higher levels of the value/costs ratio and is at the same time becoming 'cleaner'.

On the demand side, however, our society is suffering from the fact that consumer preferences are heading in the wrong direction: towards products and services with an unfavourable EVR (like bigger cars, more kilometres and intercontinental flights for holidays). These unfavourable preferences are evident from Fig. 5.

Figure 5 shows that people in The Netherlands (and probably in the other EU countries as well) spend relatively more money on cars and holidays when they have more money available. Other studies [14] show that people tend to have intercontinental holidays the moment they can afford it.

Although not enough data is available yet to make an eco-cost calculation on the spending patterns of households, it is obvious that these consumer preferences will become a big problem in the near future, since the EVR of food, health, clothing and housing is much lower than the EVR of transport and (inter)continental holidays by plane:

- the EVR of food, health, clothing and housing is estimated to be in the range 0.2–0.3;
- the EVR of transport by car in Europe is estimated to be in the range 0.8–1.0.

So, as the European households get richer, their spending will gradually increase in the direction of a higher EVR, which is the wrong direction in terms of eco-efficiency and sustainability.

Consumer preference is relevant to the design of products and services with respect to the so-called 'rebound effect' (Fig. 6). When eco-costs are reduced by 'savings', the economic value (costs for the consumer) is reduced as well, so the consumer will spend the money somewhere else. In the example of savings on product 1 in Fig. 6, the net result is positive, since the money which is saved is spent on another product (product 2) with a lower EVR. In the example of savings on product 2 in Fig. 6, however, the net result is negative, since the money saved is spent on a product (product 1) with a higher EVR.

The conclusion is that 'savings' are positive for the environment only when they are achieved in areas with a high EVR.

A typical example of the rebound effect is related with the efficiency increase of light bulbs: when consumers spend the energy saved on more light (e.g. in their gardens) or on electricity for



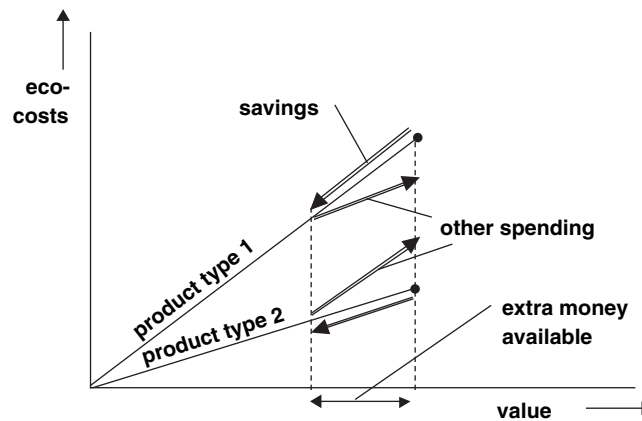


Figure 6: The 'rebound effect' of consumer spending.

other domestic appliances, it does not help much in terms of sustainability. Another example is the fuel savings in cars by using better aerodynamics: in countries where it is permissible to drive fast (e.g. Germany), better aerodynamics is used to drive faster instead of cheaper.

In general, however, one may conclude that savings on energy can have a positive effect in terms of sustainability, since the EVR of energy is relatively high (1.2, ..., 1.8) [7] in comparison with other expenditures.

Savings on luxury goods (generally a low EVR because of the high labour content: 0.2, ..., 0.3), might be negative since the 'rebound' might be in the area of more energy (in the form of travel).

## 5.2 Green products

The road towards sustainability is much more complex than just creating products and services with a low EVR for the supply side of our economy. There has to be a demand for such products as well, i.e. consumers have to buy them, otherwise there will be no delinking of economy and ecology.

In general, individuals are neither prepared to pay more for 'green' products nor are they prepared to give up their 'freedom' in terms of less travel. However, people (in The Netherlands) are quite aware of the importance of the issue of sustainability and their responsibility in this respect [15]. An example of this awareness is that a Dutch enquiry (1995) on the subject revealed a surprisingly high score on the question: 'people behave irresponsibly when they do not take environmental effects into account'. The average score was 4.3 on a scale of 1 (totally disagree) to 5 (totally agree).

The question now is: what has to be done? The fact that people are positive about the issue of sustainability has to be converted into a situation where people buy sustainable products, but how?

Environmentalists in Europe seem to be more and more disappointed that the market share for 'green' products stay marginal (2%–6%), irrespective of the many efforts which have been taken in the recent past [15–17]. The question is, however, whether the right measures have been taken up to now.

In this respect, it is important to realize that [18]:

1. the required transition is rather a process than a quick fix;
2. the system to be changed is characterized more by complex circular interrelationships than by simple linear cause–effect relationships;

3. the harder the environmentalists push, the harder the existing system will push back;
4. small changes in the dynamic system can produce big results – but the areas of highest leverage are often the least obvious.

To analyse the problem (or rather, the opportunity), a new approach is proposed, beginning with a system description of the interaction between the three main stakeholders: the consumers/citizens, the government(s) and the companies. This interaction is summarized in the ‘three stakeholders’ model’.

### 5.3 The three stakeholders’ model

In the transition towards sustainability, each of the stakeholders has to play its own role:

- consumers/citizens have to shift their expenditures towards a lower EVR, i.e. they should buy ‘green’ products and services;
- companies have to create product–service combinations with a lower EVR, i.e. they should offer ‘green’ solutions to the market;
- governments have to create regulations and new systems for tax, subsidies and tradable emission rights, i.e. they should create a business environment that gives ‘green’ solutions a fair chance in competition with the current products and services.

It is obvious that when one of the stakeholders fails to play the right role, the transition towards sustainability will not happen. What triggers each of the stakeholders of the system to go in the right direction? Who triggers the transition process?

Designers tend to believe in ‘technology push’: when the green products are on the market, they will be bought in the long run, but the reality seems different.

The general business opinion is inclined to ‘market pull’: the consumers have to trigger off the demand. Why should they do so? In reality, they tend to go for the best price/value proposition in the market instead of the proposition with the lowest environmental burden, since the latter is normally slightly more expensive. Advertising campaigns to make people buy the slightly more expensive ‘green’ option have so far been unsuccessful. Apparently, the government should do something as well: level the playing field in the market, i.e. create a system in which the ‘green’ solutions have a fair chance.

The key to the solution of the problem is to realize that the consumer is an individualist, reacting instantly and in the short term to offerings on the market. Sustainability, however, is a long-term issue for the citizen. We have to realize that each individual is a consumer as well as a citizen.

The interactions of the consumer/citizen with companies and governments are depicted in the three stakeholders’ model of Fig. 7. The validity of the model was checked in three computer decision room sessions with consumers, business representatives and governmental representatives [19].

The three stakeholders have three different interactions with each other:

- the citizens interact with their governments via politics: citizens want to have a sustainable future, are aware of the fact that the required transition can succeed only when we put our shoulders under it *together*, and therefore ask the government to take action;
- the government interacts with the companies: governments take action via regulations, taxes, subsidies, ‘covenants’, etc., and force companies to react;
- companies interact with consumers: companies try to offer consumers ‘best value for money’ and gain market share by satisfying the short-term customer (individual) needs.

The predominant direction to trigger the required transitions in the circle in Fig. 7 is counter clockwise, as described above. In some business areas, the industry is acting proactively (instead of

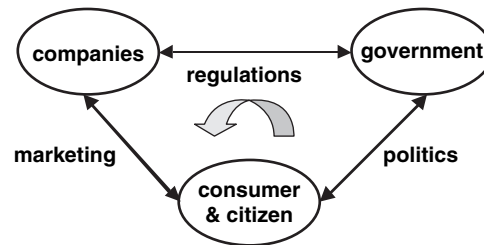


Figure 7: The three stakeholders and their main interactions.

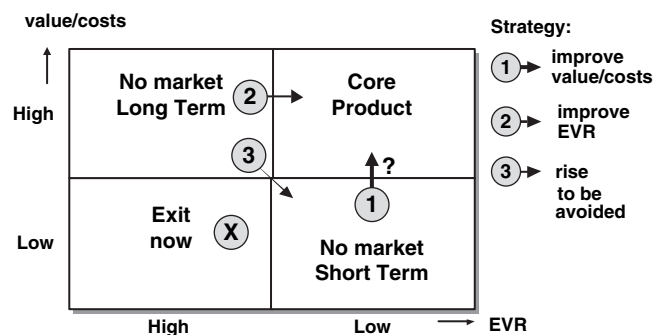


Figure 8: Product portfolio matrix for product strategy of companies.

reactively), for instance in the automotive industry. However, most businesses act only when they are forced by governmental regulation (the argument is that ‘a level playing field’ is required).

#### 5.4 Product portfolio strategies

The eco-costs as a single indicator for environmental burden are also a yardstick for imminent business problems in the field of sustainability.

Products with a high level of eco-costs (in comparison with their value) have a problem in that their costs might increase sharply in the future, caused by measures taken by governments. The costs of a product might even rise above the level of its value to customers (then there is no market for that product). So it makes sense to take action in advance.

To analyse the short-term and the long-term market prospects of a product or product–service combination (product service system, PSS), each PSS can be positioned in the portfolio matrix of Fig. 8.

The basic idea of the product portfolio matrix is that a product is characterized by:

- its short-term market potential: the value/costs ratio;
- its long-term market requirement: the EVR.

In terms of product strategy, the matrix results in four strategic directions:

1. enhance the value/costs ratio of a sustainable, low EVR, product to make it fit for short-term introduction on the market;
2. enhance the EVR of current successful, high value, products to make it fit for future markets;

3. be careful that direction 2 does not result in a lower value/costs ratio;
4. abandon products with a low value/costs ratio combined with a high EVR.

For a 'green' product, the usual problem of strategy 1 is that it has a low current value/costs ratio (in most cases, the production costs are higher than the production costs of the classic solution). Usually, this is related to two causes or a combination of both:

- there is no market volume for that green product, and therefore no 'economies of scale';
- the classic solution has lower costs since higher levels of pollution are tolerated.

Such a situation is not easy to tackle. Only when the government sets limits to the environmental pollution or introduces green tax or tradable emission rights, the second part of the problem will be solved (the playing field is levelled), but the economies of scale problem still persists. The best solution is then to integrate the new sustainable product in the production and distribution systems of classic products, to eliminate the economies of scale problem.

For a product which has a good present value/costs ratio, but a high EVR, the opportunity of strategy 2 is to enhance the EVR of the product by process redesign (lowering the eco-costs). This road towards sustainability is far more promising than the first strategy. The reason is that the economies of scale for production and distribution are available, and that the new product is marketed to an existing client base which is used to the brand name, the quality standards, the service system, etc.

## 6 CONCLUSIONS

In March 1995, the World Business Council for Sustainable Development defined eco-efficiency as: 'the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity, throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity.' This definition links modern management practice ('the delivery of competitively priced goods and services ... quality of life') to the need of a sustainable society ('while progressively reducing ... to ... earth's carrying capacity'). The first part of the sentence asks for a maximum value of the business chain. The second part of the sentence requires that this is achieved at a minimum level of ecological impact, i.e. minimum eco-costs.

The model of the EVR provides the translation of this challenging mission statement to a system with facts and figures, which is required to support the decision-taking processes in practice.

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