# The EVR model for sustainability
## *A tool to optimise product design and resolve strategic dilemmas*

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**Product designs for the future will need a high value: costs ratio and need to incorporate high levels of eco-efficiency. Therefore, a new model has been developed to assess the sustainability of products, the 'EVR model'. This model comprises two concepts:**
- **'virtual eco-costs' which is a LCA-based single indicator for environmental impact;**
- **EVR (eco-costs : value ratio), an indicator which shows the de-linking of economy (value) and ecology (eco-costs) of a product or a service.**

**In this article, the advantage of combining analyses of eco-costs and value is considered, and it is shown how the EVR model can support decision making processes. The following subjects are analysed:**
- **the optimisation of a product in the design stage through use of the EVR model (the 'EV Wheel')**
- **optimisation strategies for the production and distribution chain of a product (Case: a TV)**
- **the strategic dilemmas relating to marketing of products with low environmental impact (Case: a 'low energy TV')**
- **an investment policy which lowers the environmental impact of systems, analysed by use of the 'eco-payout time'**
- **the EVR model applied to consumer spending: the lifestyle of consumers, and the so called 'rebound effect'**

**At the end of this article the consequences are summarised for product development and marketing strategies.**

### Introduction: value, costs, and eco-costs

In the transition towards a sustainable society there is a need for products with a low environmental burden (lower

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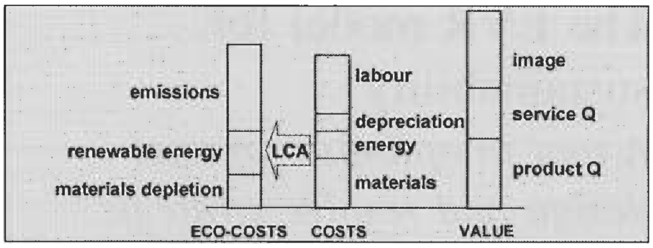


Figure 1: The costs, the eco-costs and the value of a product: the basis of the EVR model (Q = Quality)

emissions and lower use of energy and materials). But we need a strong economy as well, to support this transition. Such a need for "a new era of economic growth" is described in the preface of "Our Common Future" (Brundtland et al., 1987), see Note 1. For industry it means that products must create 'value' for customers, whilst producing a low environmental burden. This has been defined as eco-efficiency by the WBCSD (see Annex 1, Figure 13). The value aspects of sustainability, and the consequences for design and marketing, have been forgotten so far by many environmentalists (Note 2). Hence the quest for a new approach.

At the Delft University of Technology, a model has been developed to assess the so called 'eco-efficiency' of products and services. In this model the ecological burden is monetarised and expressed in one single indicator, the so-called 'virtual eco-costs' (Note 3). The product life cycles are analysed for three main aspects: the eco-costs, the (economic) costs, and value. The key indicator for sustainability in the model is the 'eco-costs : value ratio' – the EVR (Vogtländer et al., 2001a). The basis of the EVR is depicted in Figure 1. The background of the model is summarized in Annex 1.

In its broadest sense, the EVR is an indicator which describes the level of de-linking of the economic value and the eco-costs of a product. A high level of prosperity can only be combined with a low level of pollution and material depletion, when products (and services) are used with a low EVR, since such products combine a high value with a low level of burden for our earth.

In terms of EVR, the 3 stakeholders of a sustainable society each have their specific roles:

- industry must develop products and services with a low EVR
- consumers/citizens should have a life style with preferences for products and services with a low EVR (e.g. they should spend their money on other activities than travelling by air)
- governments should encourage products, processes and lifestyles with a low EVR (e.g. labour intensive activities) and should restrict products, processes and life styles that have a high EVR (e.g. energy intensive activities, activities with high toxic emissions).

But what does it mean for the decisions the stakeholders have to make? How do they know they have made the right choice in terms of sustainability?

### The EV Wheel for product design

In the United Nations Publication Paper "*Ecodesign – A promising approach to sustainable production and consumption*", (Brezet, Van Hemel, 1997), the LiDS wheel (LiDS stands for Life cycle Design Strategy) is proposed as a tool to define the design strategy for sustainable products. This LiDS wheel is a qualitative tool, and at the Delft University of Technology many attempts have been made to make it quantitative. The EVR model provides the opportunity to do so. The concept of the wheel has been adapted to incorporate the main aspects of the value (product quality, service quality, and 'image & design') of a Product Service System (PSS). A new name has been chosen: the Eco-costs & Value Wheel, in short the EV Wheel.

The EV Wheel is depicted in Figure 2 and will be explained later.

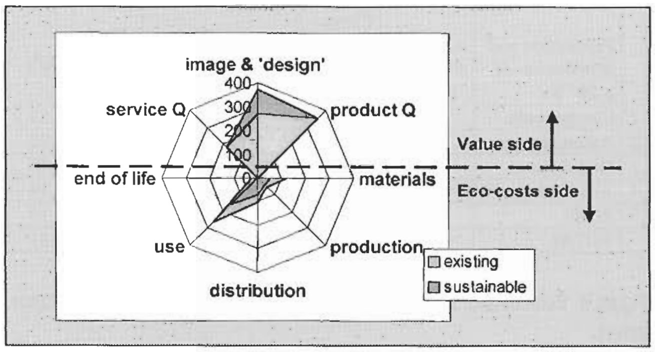


Figure 2: The Eco-costs & Value Wheel (EV Wheel). The value and eco-costs are given for a 28″ television (tentative) in Euro: 400 Euro at the outer ring and 0 Euro at the centre (Q = Quality)

The EV Wheel is meant to provide a quantitative overview of the eco-efficiency of a product, a service or a combination of both (a PSS).

The value side of the EV Wheel is based on the three main elements of value (product quality, service quality, and 'image & design'). These main elements can be derived from the '8 dimensions of quality' of Garvin (Garvin, 1988):

1. Performance or the primary operating characteristics of a product or service.
   *Example:* for a car: it is speed and acceleration; for a restaurant: it is good food.
2. Features or the secondary characteristics of a product or service.
   *Example:* for a restaurant: it is linen tablecloths and napkins.
3. Conformance or the match with specifications or pre-established standards.
   *Example:* for a component: it is whether this component is the right size; for a restaurant: it is whether the meat is cooked according to your request (e.g. 'medium, rare').
4. Durability or product life.
   *Example:* for a light bulb: it is how long it works before the filament burns out.
5. Reliability or the frequency with which a product or service fails.
   *Example:* for a car: it is how often it needs repair; for an airline: it is how often flights depart on schedule.
6. Serviceability or the speed, courtesy and competence of repair.
   *Example:* for a car: it is how quickly and easily it can be repaired; for a mail order house: it is the speed and the courtesy with which an overcharge is corrected.
7. Appearance / aesthetics or fits and finishes.
   *Example:* for a product or service: it is its look, feel, sound, taste or smell.
8. Image or reputation.
   *Example:* for a product or service: it is the positive or negative feelings people attach to any new products, based on their past experiences with the company.

For the purpose of the EV Wheel, we group the 8 dimensions as follows in 3 aspects of value:

i. the **'product quality'** including 4 'core quality' dimensions: 1. Performance;
   3. Conformance; 4. Durability; 5. Reliability;
ii. the **'service quality'** including 3 'extra' dimensions: 2. Features; 6. Serviceability;
iii. the **'image & design'** including: 7. Aesthetics and 8. Image.

For a distinct group of customers, these 3 aspects of value can be determined in terms of money (a 'fair price', see Annex 3), where

[1] (total value) = ('fair price' of the 'product quality')
+ ('fair price' of the 'service quality')
+ ('fair price' of the 'image')

The value side of Figure 2 depicts the 'fair price' for each aspect in Euro. The sum of the three fair prices in the EV Wheel equals the total value of the PSS for the total life cycle.

The three main options to enhance product value are:

· enhance the functionality of a product during the use phase
· extend the use phase
· change the design to give the product a positive (or

| Compo-nents of a 28" TV | Added Eco-costs (Euro) |
|---|---|
| CRT | 35,30 |
| speakers | 10,20 |
| enclosure | 11,80 |
| chassis | 44,30 |
| packaging | 3,40 |
| TOTAL | 106,00 |

Figure 3: Eco-costs of Components 28" TV

| | Production and distribution of a 28" TV | Added ΔValue (Euro) | Cumu-lative Value (Euro) | Added Δ Eco-costs (Euro) | Cumulative Eco-costs (Euro) | EVR |
|---|---|---|---|---|---|---|
| 1 | Components | 200 | 200 | 106 | 106 | 0,53 |
| 2 | Assembly | 150 | 350 | 33 | 139 | 0,22 |
| 3 | Distribution | 50 | 400 | 36 | 175 | 0,72 |
| 4 | Advertising, etc | 50 | 450 | 10 | 185 | 0,20 |
| 5 | Retail | 225 | 675 | 23 | 208 | 0,10 |
| | TOTAL | 675 | | 208 | | 0,31 |

Figure 4: Eco-costs of the production and distribution chain of a 28" TV (tentative).
Note: excludes the use phase and the 'end of life' phase

less negative) value at the 'end of life'.

The eco-costs side of Figure 2 depicts the eco-costs (in Euro) of the PSS for the five aspects of the total Life Cycle:
- materials
- production
- distribution
- use
- end of life

The EV Wheel is basically a communication tool: it shows in one picture the advantages (and disadvantages) of a specific design in comparison with other designs. The upper part of the wheel shows if, and in which aspects, a PSS is attractive to customers. The lower part shows if, and in which aspects, the product has a low ecological burden. A sustainable product combines a big shaded area in the upper part and a small shaded area in the lower part.
The wheel makes it clear where to focus so as to improve the design.

The EVR of a total PSS is the sum of the eco-costs of the five aspects (the lower part of the wheel) divided by the sum of the fair prices (the upper part of the wheel).

## Design strategies in the business chain of a product: the case of a TV

How to optimise a production and distribution chain through the use of the EVR model, can be explained by use of a simple example of a 'standard' television with a 28" CRT (data is given for a typical configuration, slightly rounded off, for confidentiality reasons). See the tables in Figure 3 and 4.

The table in Figure 4 shows that:
- the eco-costs of the components are approximately equal to the eco-costs caused by the assembly, distribution, advertising and retail of the television set. Note that the eco-costs for 'use phase' and 'end of life' will be dealt with later in the 'low energy' TV case, Figure 6.
- the EVR gets lower towards the end of the production and distribution chain. This is because of the higher labour content of service and image, which is added to the product at the end of the production and distribution chain.

Figure 5 depicts the development of the value and the eco-costs in the production and distribution chain. From Figure 5 it is clear that the distribution step requires extra attention from the environmental point of view: the increase of the costs (value) is low, but the increase of the eco-costs is relatively high.

The two dimensional approach of the eco-costs : value ratio seems to be crucial in calculating as well as understanding the elements of the eco-efficiency of a product, a service or a PSS. It reveals the fundamental differences between environmental strategies in each step of the chain:
- making production processes 'cleaner'(lowering the eco-costs at often a *constant* cost level)
- environmental material selection (lowering the eco-costs at often a *higher* cost level)

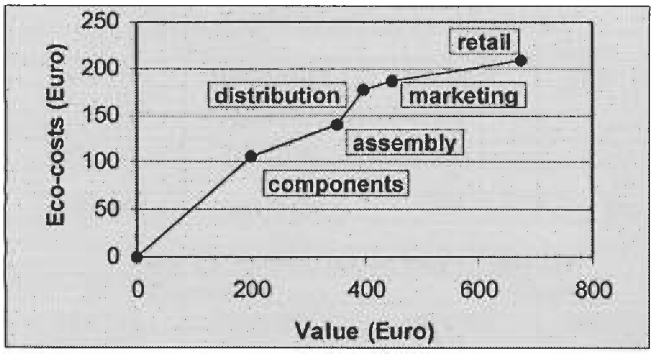


Figure 5: The value and the eco-costs cumulative along the production and distribution chain

- 'savings' in e.g. transport (lowering both costs *and* eco-costs)
- improvement of the perceived value (*enhancing the value* without adding considerable extra eco-costs)

Only a good understanding of value, costs and eco-costs along the total chain can lead to the required improvements in design (Design for Sustainability). It is important here to mention that the EVR method also accommodates a system for quick estimates of the eco-costs (instead of a laborious full LCA), applying tables of eco-cost per Kilogram for materials and eco-costs per Joule for energy sources (Vogtländer et al., 2001a).

With regard to the strategic level of product portfolio management, it is essential to understand the chain (Note 4) in order to manoeuvre a corporation into a position which is suitable for a sustainable future.
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 1 in future (since stricter governmental regulations on the environment will result in the virtual eco-costs becoming part of the 'internal' cost-structure), so there is no market for such a product.

Since the success of a PSS in the market depends whether or not consumers will buy the product, it is important that consumers can understand the concept of eco-costs. The perceived value is what they feel and think about the product, the cost is what they pay for it, but the concept of eco-costs is new for them. *This means that companies face a new challenge in the marketing of eco-costs.*

### Dilemmas on strategies for marketing and pricing. Case: a 'low energy' television

In the previous chapters, the first steps in the chain have been analysed only. In this chapter we will analyse the total chain, especially the aspects of the 'Use phase' of a product.

Equivalent to the Total Costs of Ownership [TCO] (Life Cycle Costing) approach of financial evaluation, the Total Eco-Costs of Ownership [TECO] is defined and applied to a 28" television. See the table of Figure 6 for two cases:

- 'the American family' in Europe, watching 6 hours per day on average
- 'the European young bachelor', watching 1,5 hour per day on average

It is assumed that the life time of the television is 10 years, and that the energy consumption is 100 W during 'watching' and 2,5 W during 'stand by' (at a renewable electricity price of 19,60 Euro per GJ).

The data of Figure 6 on the standard 28" TV are derived from two confidential studies on the subject: one study for Philips (1997) and one study for Sony (1995). These data are tentative and tend to be different for each specific design.
The data on the 'low energy' TV are of a more hypothetical character: the energy consumption of the standard TV could be reduced by a more advanced system design (there are several options), however, at a higher level of production costs.
Suppose that a new 'low energy' type of television will be launched with the following characteristics

| All prices in Euro | Watching 6 hours per day (average in a year) | | | |
|---|---|---|---|---|
| | *standard 28" TV* | | *"low energy" 28" TV* | |
| | Value (costs) | Eco-costs | Value (costs) | Eco-costs |
| Purchase | 675 | 208 | 776 (+15%) | 239 (+15%) |
| Energy "watching" | 174 | 239 | 130 (-25%) | 179 (-25%) |
| Energy "stand by" | 13 | 18 | 10 (-25%) | 13 (-25%) |
| "End of Life" | 30 | 3 | 30 . | 3 . |
| **TCO and TECO** | **892** | **468** | **912 (+2%)** | **434 (-7%)** |

| All prices in Euro | Watching 1,5 hour per day (average in a year) | | | |
|---|---|---|---|---|
| | *standard 28" TV* | | *"low energy" 28" TV* | |
| | Value (costs) | Eco-costs | Value (costs) | **Eco-costs** |
| Purchase | 675 | 208 | 776 (+15%) | **239 (+15%)** |
| Energy "watching" | 44 | 60 | 33 (-25%) | 45 (-25%) |
| Energy "stand by" | 16 | 22 | 12 (-25%) | 16 (-25%) |
| "End of Life" | 30 | 3 | 30 . | 3 . |
| **TCO and TECO** | **765** | **293** | **840 (+10%)** | **303 (+3%)** |

Figure 6: The Total Costs of Ownership [TCO] and the Total Eco-Costs of Ownership [TECO] of a standard 28" TV and a 'low energy' 28" TV, for two consumer market segments

- the price and related eco-costs are 15% higher;
- the energy consumption is 25% lower (for watching as well as stand by).

The first question now is whether this new television is attractive from the environmental point of view. The answer is:

- *yes* when we watch the TV for more than 6 hours per day on average, see 5th column Figure 6;
- *no* when we watch for less than 1,5 hours, since the extra eco-costs in the production chain is more than the savings of eco-costs during the use- phase, see 5th column Figure 6.

From governmental point of view it seems to be attractive to stimulate the low energy television by subsidising (or differentiating through taxation), to influence the purchasing decision of the consumer in the retail shop (remember that the purchase price is 15% higher without subsidy). However, when the low energy television is purchased by people who watch less than 1,5 hours per day, the government is *subsidising eco-costs* ! The only solution is to design a separate marketing strategy for each of the market niches. In all circumstances the issue has to be clearly communicated to the market (the consumers).

The second question is whether or not the government should stimulate the replacement of old televisions by the new low energy televisions. From a governmental point of view this seems to be attractive since it results in less energy consumption. However, then televisions are recycled at an earlier (premature) stage than is required from the durability point of view. This dilemma can be resolved by calculating the effects of replacement of the old type television (see the table of Figure 6):

- assuming that the life time of a TV is 10 years, the related eco-costs per year of the depreciation of the standard TV is 20,8 Euro per year.
- the savings of the eco-costs of energy is 65 Euro over a period of 10 years, so 6,5 Euro per year.

The conclusion is that, from an environmental point of view, it is not reasonable to throw away the old TV when it is still working: the energy savings are not enough to counterbalance the negative effect of throwing away the old TV before its optimal lifetime.

The question whether or not to invest in a system which has a lower environmental impact, is not only an issue in the market of appliances. It is one of the major issues with regard to investment strategies

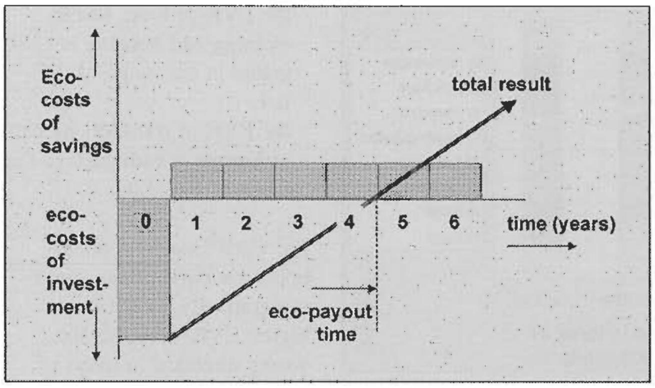


Figure 7: The eco-payout time

of industries and governments on the road towards sustainability. The policy with regard to investments in new 'cleaner production' systems is dealt with in the next section.

### The eco-payout time for investments

It is important for companies and governments to know which investment is the best choice on the road to sustainability. Analogous to the 'pay-out time' as an investment criterion in financial evaluations, the concept of the eco-payout time is introduced:

[2] eco-payout time =

$$\frac{\text{eco-costs of the investment}}{\text{eco-costs of the savings}}$$

The meaning of this formula is depicted in Figure 7. This figure shows that only after the pay-out time period, the savings are bigger than the expenditure at the start. So after the pay-out time period we have a positive balance on eco-costs.

In practice, it would be a major step forward towards sustainability if companies not only base their investment decisions on the pay-out time (or other economic criteria), but also consider the eco-payout time. In doing so, these companies will position themselves step by step better in the competitive world of future sustainability, since they will move towards production systems with low eco-costs (towards 'cleaner production').

Formula 2 can be transformed to:

[3] eco-payout time =

$$\frac{[(\text{value of investment}) \times EVR_{investment}]}{[(\text{value of savings per year}) \times EVR_{savings}]}$$

or:

[4] eco-payout time =

$$\text{pay-out time} \times \frac{EVR_{investment}}{EVR_{savings}}$$

When a company bases the investment decisions on such a double criterion (pay-out time as well as eco-payout time), investments in savings of energy or material will prevail (before, for example, savings in labour) since the EVR of labour is lower than the EVR of materials and energy.

There are types of investments that enable cost savings which are normally abandoned *directly* after the depreciation period (= the pay-out time). In such cases one should be certain that the eco-payout time is shorter than the pay-out time, otherwise a negative balance of eco-costs is left. In these cases one should fulfil the following criterion:

[5] $EVR_{investment}$ 'less or equal' $EVR_{savings}$

For investments in computer software for instance, this criterion is no problem: labour is replaced by labour. However, for investments in computer hardware this criterion is a problem: the EVR of a computer is higher than the EVR of the labour it replaces. In this case one should keep the hardware longer than the depreciation period from the environmental viewpoint!

In the case of replacement of production facilities (investments without additional savings), the ecological balance is always negative: one should always consider here the alternatives of maintenance and/or renovation. This also applies for office buildings.

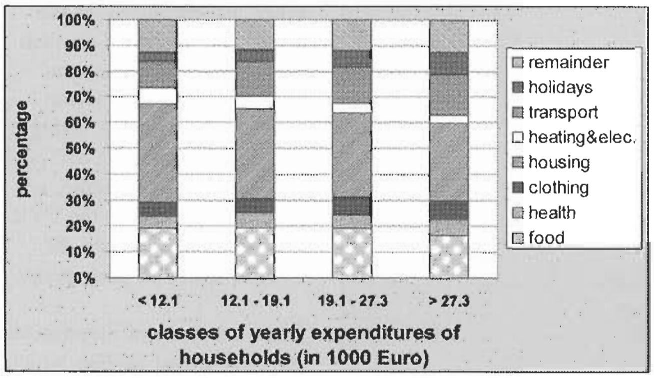


Figure 8: Preferences of expenditures of households (households in The Netherlands, 1995). Source CBS, The Hague

**The EVR model and the buying pattern of consumers. The 'rebound effect'**

De-linking of economy and ecology is also related to the lifestyle of consumers. Under the assumption that most households spend what they earn in their life, a low level of EVR of the household expenditure is the key towards sustainability. Then, the virtual eco-costs will be low, even at a high total value of the expenditures. There are two levels of achieving this:

1. at the product level: the delivery of eco-efficient ('low EVR') products and services by the industry
2. at the consumers level: the change of lifestyle in the direction of 'low EVR' consumption patterns

At the product level, our society is heading in the right direction: gradually industrial production is achieving higher levels of the value : costs ratio and is at the same time means it is becoming 'cleaner'.

At the consumers level, however, our society is suffering from the fact that the consumers preferences are heading in the wrong direction: towards products and services with an unfavourable EVR (like bigger cars, more kilometres, intercontinental flights for holidays). These unfavourable preferences can be concluded from Figure 8.

Figure 8 shows that people in The Netherlands (and probably in the other EC countries) spend relatively more money on cars and holidays when they have more money available. Other studies (Kramer et al., 1998) show that people tend to have intercontinental holidays when they can afford it.
It is obvious that these preferences will become a big problem when people become richer, since the EVR of food, health, clothing and housing is much lower than the EVR of transport and (inter)continental holidays by plane (voy Händer et al., 2001a):

- the EVR of food, health, clothing and housing is estimated in the range of 0.3–0.4
- the EVR of transport by car in Europe is estimated in the range of 0.8–1.0

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

Consumer preferences are relevant for the design of products and services due to the so called 'rebound effect'. See Figure 9. When eco-costs are reduced by 'savings', the economic value (costs to the consumer) is reduced as well, so the consumer will spend the money somewhere else. In the example of Figure 9, savings on product type 1 have a positive effect on the eco-costs, if the money is spent on products with a lower eco-costs: value ratio (e.g. product type 2). Example: savings on travel costs are spent on housing. However, savings on product type 2 may result in higher eco-costs if the money is spent on products with a higher EVR (e.g. product type 1). Example: savings on housing costs are spent on travel. The conclusion is that 'savings' are only positive for the environment when savings are achieved in areas with a high EVR.

A typical example of the 'rebound effect' relates to the efficiency increase of light bulbs: when consumers spend

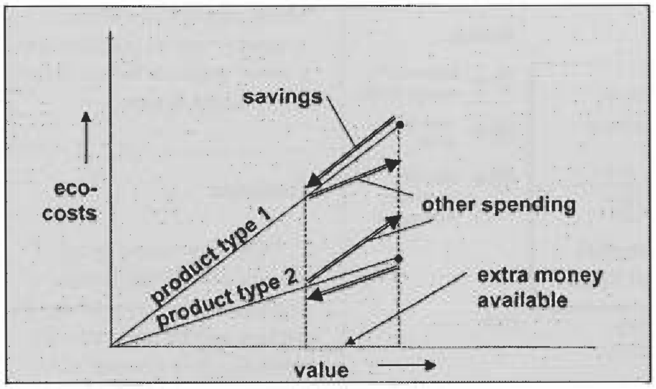


Figure 9: The 'rebound effect' of consumer spending

the saved energy on more light (e.g. in their gardens) or on electricity for other domestic appliances, this doesn't help much in terms of sustainability.

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] (Vogtländer et al., 2000b)) in comparison with other expenditures. Savings on luxury goods (generally a low EVR because of the high labour content: 0.2 ... 0.4, which might be negative since the 'rebound' might relate to the use of more energy (in the form of travel).

In product design, savings in energy often require higher product costs. An example of such a saving relates to making cars lighter (in order to reduce fuel consumption). Figure 10 shows the result of calculations for middle class German cars and for European fuel prices (Saur, 1999).

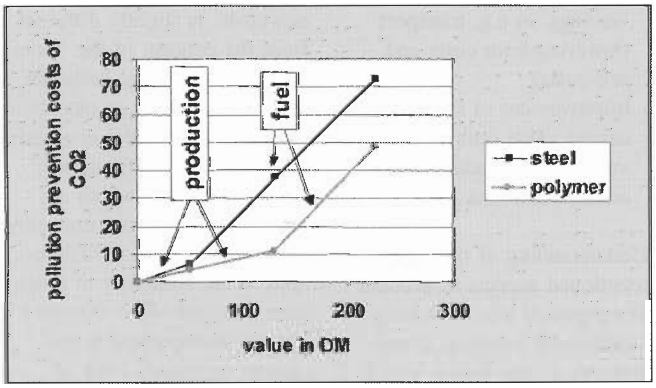


Figure 10: The Total Costs of Ownership (TCO) and the pollution prevention costs of CO2 for two alternative designs for a part of the coach-work of a middle class German car

The left hand side of the two lines relates to the production (the end-of-life phase included) of a specific part of the coach-work of the car. The right hand side of the two lines depicts the effect of the fuel consumption on that specific part of the coach-work (0.305 litre fuel per 100 km per 100 kg). At a total life time of 250,000 km, SMC (a polymer) is break even with steel from the economic point of view, but much better from the environmental point of view. This is an example where there is no 'rebound effect', since the economic savings on the fuel equal the extra costs of the coach-work.

It is good to mention here that the change in cost structure (from energy costs towards product costs) may have a serious impact on the marketing of the product. When the aforementioned example of coach-work is applied to the total car (a hypothetical case), the price of the car will go up with nearly a factor two-and-half, which may only be marketed via total lease concepts (for the *total* life time of the car!).

### Conclusions

The development of a sustainable society needs a combined approach:

- by the industry: the delivery of eco-efficient ('low EVR') products and services

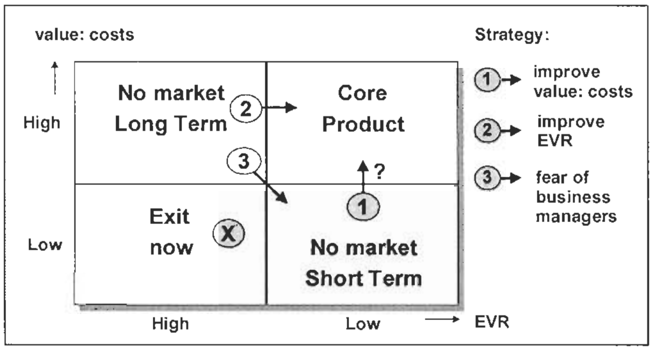


Figure 11: Product portfolio matrix for product strategy of companies

· by the consumers: a change in life-style towards 'low EVR' consumption patterns

Governments should lead industry in the right direction (e.g. by regulations), and should stimulate consumers to make the right choices in terms of the EVR.

With regard to product portfolio management of companies, the EVR model shows the clear implications in the matrix for PSS of Figure 11.

The basic idea of this product portfolio matrix is the fact that each PSS is characterised 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 4 strategic directions:
1. enhance the value : costs ratio of a sustainable design with a sound EVR to make it fit for short term introduction in the market
2. enhance the EVR of current successful products to make it fit for future markets
3. be careful that direction 2 doesn't result in a lower value costs ratio
4. abandon products with a low value : costs ratio and a high EVR as well

There appears to be four fundamentally different opportunities to enhance the eco-costs : value ratio:
· making production processes 'cleaner'(lowering the eco-costs at the same value)
· better materials selection (lowering the eco-costs at often higher cost levels)
· 'savings' in e.g. transport (lowering both costs and eco-costs)
· improvement of the perceived value (enhancing the value without adding considerable extra costs)

Understanding of the aforementioned aspects of product development and marketing strategies is essential to manoeuvre a corporation into a position which is fit for a sustainable future. Furthermore, the eco-payout time should play a role in the decision taking process to manoeuvre a company and its products into a better position for the future (i.e. a lower EVR).

### Footnotes

1. "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."(Preface of "Our Common Future" (Brundtland,1987), page xii).
2. In a previous article in this Journal, "Customers – the forgotten stakeholders" (Prentis et al., 1999), the issue of lack of 'customer focus' in environmental analyses is dealt with.
3. The concept of the 'virtual eco-costs' is slightly different from the concept of the 'external costs'. External costs are related to *damage* to our environment. The virtual eco-costs are related to the (marginal) *prevention* costs, which are required to bring our economy into a state which is sustainable. What both type of costs have in common, is that they are not incorporated in the current economic costs of products and services.
4. For a PSS, the bundle of business activities is called the 'profit pool', rather than the

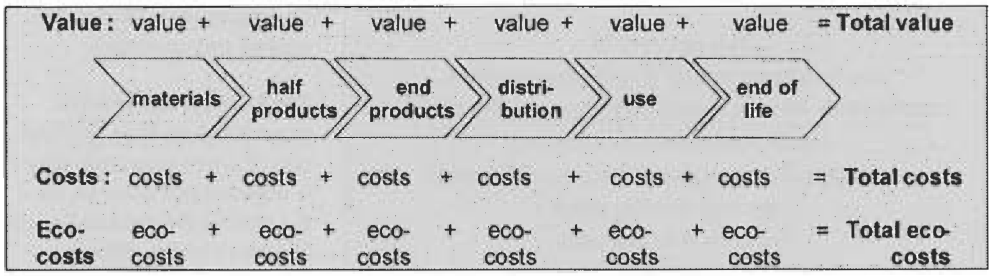


Figure 12: The basic idea of combining the economic and ecological chain: 'the EVR chain'

product chain (Gadiesh et al., 1998).

5. Within the production chain, 'value' equals the sales price. At the end of a production chain, where the consumer buys the product, the way the 'value' has to be assessed is slightly different (Vogtländer et al., 2001a): from the consumers point of view the value equals the 'fair price' (Gale, 1990), see Annex 3. For a short description of the 'costs-price-value' model see Annex 2.

### Annex 1. The virtual eco-costs and the EVR model

The basic idea of the EVR model is to link the 'value chain' (Porter, 1985) 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 as well, the so called eco-costs. See Figure 12.

The eco-costs are 'virtual' costs, resulting from a 'what if' calculation on 'marginal prevention costs': they are a norm for the costs of measures which have to be taken to make (and recycle) a product "*in line with earth's estimated carrying capacity*" (ref. Figure 13). These costs have been determined on the basis of technical measures to *prevent* pollution and resource (energy) depletion to a level which is sufficient to make our society sustainable (Vogtländer et. al, 2000, 2001a)

Since our society is yet far from sustainable, the eco-costs are 'virtual': they have been estimated on a 'what if' basis. They are not yet fully integrated in the current costs of the product chain (the current Life Cycle Costs). The ratio of eco-cost and value, the so called eco-costs : Value Ratio, EVR, is defined in each step in the chain as:

[6] EVR = eco-costs : value

For one step in the production and distribution chain, the eco-costs, the costs and the value (see Note 5) are depicted in Figure 1.

To determine the eco-costs, five components of the eco-costs have been defined, being 3 'direct' components plus 2 'indirect' components:

- virtual pollution prevention costs, being the costs required to reduce the *emissions* of the production processes to a sustainable level (Vogtländer et al., 2000);
- eco-costs of *energy*, being the price for renewable energy sources;
- *materials* depletion costs, being (costs of raw materials) $\times$ $(1 - \alpha)$, where $\alpha$ is the recycled fraction; for more information see (Vogtländer et al., 2001b);
- eco-costs of *depreciation*, being the eco-costs related with the use of equipment, buildings, etc.;
- eco-costs of *labour*, being the eco-costs related to labour, such as commuting and the use of the office (building, heating, lighting, electricity for computers, paper, office products, etc.).

Based on a detailed cost-structure of the product, the eco-costs can be calculated, by multiplying each cost element with its specific eco-costs : value ratio, the EVR. These specific EVRs have been calculated on the basis of LCAs.

**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
- through the life cycle -
to a level in line with
earth's estimated carrying capacity**

Figure 13: The definition of eco-efficiency (WBCSD, 1995)

Tables are provided in (Vogtländer et al., 2000a).
The EVR model has been based on the definition of eco-efficiency, as developed by the WBCSD, see Figure 13.
The part of this definition above the dotted line is describing the value of a product, the part under the dotted line is defined by the eco-costs. In the EVR model Eco-efficiency is defined as:

[7] eco-efficiency =

$$\frac{\text{value} - \text{eco-costs}}{\text{value}},$$

or eco-efficiency = 1 − EVR

Note that the eco-efficiency is:

- negative when the eco-costs are higher than the value, or where EVR > 1
- 0% when the eco-costs are equal to the value, or when EVR = 1
- 100% when there are no eco-costs, or when EVR = 0

## Annex 2. The costs-price-value model

In elaborating the concept of eco-efficiency as defined by the WBCSD and the basic idea of the EVR model as depicted in Figures 1 and 12, it is essential to understand the differences between costs, price and value as they are defined in modern management theories (like Total Quality Management and/or Continuous Improvement).

The classical management paradigm describing the function of costs, price and value is depicted in Figure 14. In the eyes of the producer, profit is a result of the difference between the costs of a product and its price. Managers try to reduce the costs as much as possible and get a price as high as possible.
However managers know that the end user (consumer) will buy the product only when, in his or her eyes, the perceived value is higher that the price.

In the classical management paradigm, the manager has no choice: when the price gets too high, there will be no buyers, so the only thing he can focus on is reducing costs. In this paradigm, measures for environmental protection add costs, so must be kept to a minimum.

In modern management, the strategic focus is on the *ratio* of value and costs, as is depicted in Figure 15. A big difference between value and costs creates a variety of strategic options for setting the right price (more profit by optimisation of margin per product versus sales volume).

In classical management, higher value ('quality') leads always to higher costs. In modern management that is not the case: there are many management techniques that lead to a better value : costs ratio. Examples are: logistics (better delivery at lower stock

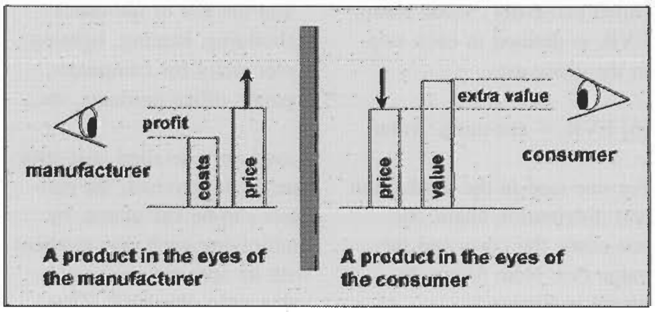


Figure 14: The classical paradigm is 'price driven', which leads to 'cost cutting'

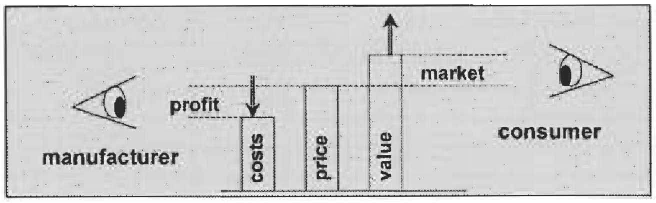


Figure 15: The new management paradigm is about enhancing the value/costs ratio"

levels), complaint management (satisfied customers with less claims), waste and quality management (less materials better quality). All these examples – there are many more in the field of Total Quality Management and Continuous Improvement – lead to more value at less costs. This is called 'the double objective' for managers (Vollmann, 1996) and opens new perspectives to support eco-efficiency (it supports the first part of the eco-efficiency definition of the WBCSD). See also (Porter et al., 1995). Note that this modern management philosophy is much more than just 'adding services' to existing products. It is about carefully improving the quality of products and services (as perceived by the customer!) by eliminating the 'non value added' energy, materials and work.

The question is now whether these modern management techniques *always* lead to better eco-efficiency. The answer is no (e.g. the use of pesticides in agriculture results in a better value/costs ratio but not in a better level of environmental protection). That is why the aforementioned definition of eco-efficiency of the WBCSD adds: "....*while progressively reducing ecological impacts* .....". For this reason, the 'virtual eco-costs' as a single indicator for sustainability has been introduced in the EVR model of Figure 1. In this way the 'cost structure' of a product (including services) is linked to the related ecological impacts and material depletion.

## Annex 3. The dimensions of Quality and the Fair Price

The quality dimensions of Garvin (see main text) can only be judged by the customers ('as perceived by the customers', measured by customer panels or customer surveys). These quality dimensions can be expressed in terms of the 'fair price' (Gale, 1990).

The technique is that the customer is asked to estimate the value the total product-service system in terms of the (total) 'fair price'. The 'fair price' is the highest price at which a customer is prepared to buy a product and/or service. When the price of a product is higher than the 'fair price', the product is considered by the customer as too expensive. When the price is lower than the fair price, the customer considers a purchase as attractive. So the fair price equals the value as depicted in Figures 1, 14 and 15.

In addition to the assessment of the fair price, each quality dimension can be rated:

- in terms of the quality (=value) of each dimension (ranging from 'very poor' to 'excellent')
- in terms of importance of each dimension (ranging from 'not important' to 'very important')

The fair price for the 'product quality', the 'service quality' and the 'image' can be determined then by calculating the weighed averages of the ratings of the quality dimensions, and assigning the corresponding portions of the total fair price to the quality aspects. An example for an easy, linear, situation is given in the table of Figure 16. A distinct group of customers (customers within one market niche or one market segment) is asked to assess the total fair price (= total value), the score of importance, column (1), ("how important is this value aspect for you?" 1 = 'of no importance' to 5 = 'very important), and the rating of the value, column (2), ("what is the quality aspect for you?" 1 = 'very poor' to 5 = 'excellent').
The fair price for the value aspects is calculated then according to the scheme in this table.

| | Value aspect | Importance Score (1) | Value Rating (2) | (3) = (1) x (2) | (4) = (3) / 'total (3)' | 'fair price' = (4) x 'total value' |
|---|---|---|---|---|---|---|
| a | Product Q | **4** | **3** | 12 | 0,40 | 360 Euro |
| b | Service Q | **2** | **3** | 6 | 0,20 | **180 Euro** |
| c | Image | **3** | **4** | 12 | 0,40 | 360 Euro |
| d | Total | | | 34 | 1,00 | **900 Euro** |

Figure 16: Calculation scheme for assessment of the fair price for value aspects (example)

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