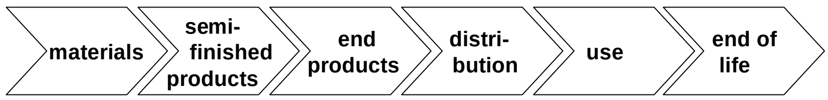
Summary

The Eco-costs / Value Ratio, ERV

The basic idea of the EVR (Eco-costs/Value Ratio) 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, the so called eco-costs. See Figure A.

Value : value + Δ value + Δ value + Δ value + Δ value + Δ value = **Total value**



Costs : costs + costs + costs + costs + costs + costs = **Total costs**

Eco-costs eco-costs + eco-costs + eco-costs + eco-costs + eco-costs + eco-costs = **Total eco-costs**

Fig. A: The basic idea of combining the economic and ecological chain: “the EVR chain”.

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*” [a]. These costs have been estimated on the basis of technical measures to *prevent* pollution and resource depletion to a level which is sufficient to make our society sustainable.
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:

EVR = eco-costs / value

For one step in the production+distribution chain, the eco-costs, the costs and the value[b] are depicted in Figure B.

---

[a] In 1995, the World Business Council for Sustainable Development (www.wbcsd.ch/eurint/eeei.htm) described the role for industry in their definition of 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, through the life cycle, to a level at least in line with earth’s carrying capacity.”
[b] Within the business chain, the value equals the market price. From the consumers point of view the value equals the ‘fair price’ (Gale, 1994). Note: in the business chain, the cost for the buyer is the value for the seller.

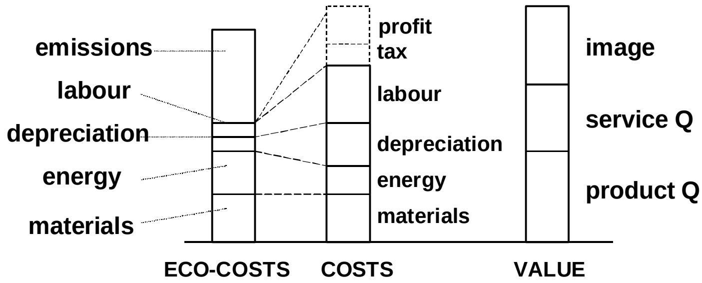


Fig. B: The decomposition of "virtual eco-costs", costs and value of a product

The five components of the eco-costs have been defined as 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., 2000b)
- ✓ eco-costs of *energy*, being the price for renewable energy sources
- ✓ *materials* depletion costs, being (costs of raw materials)x(1-α), where α is the recycled fraction
- ✓ 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 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 bases of LCAs. Tables are provided for materials, energy and industrial activities.

In the EVR model Eco-efficiency is defined as:

$$\text{eco-efficiency} = (\text{ value } - \text{ eco-costs }) / (\text{ value }), \text{ or eco-efficiency} = 1 - EVR$$

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.

(See section 3)

The pollution prevention costs

The aforementioned pollution prevention costs are being calculated in four steps:
1. LCA calculation according to the current standards (ISO 14041)
2. Classification of the emissions in 7 classes of pollution
3. Characterization according to characterization multipliers as used in e.g. the Eco-indicator '95, resulting in "equivalent kilograms" per class of pollution
4. Multiplication of the data of step 3 with the 'prevention costs at the norm' ,being the marginal costs per kilogram of bringing back the pollution to a level *"in line with earth's carrying capacity"*.

The following 'prevention costs at the norm' are proposed for The Netherlands and Europe:

- prevention of acidification:	6.40 Euro/kg (SOx equivalent)
- prevention of eutrophication:	3.05 Euro/kg (phosphate equivalent)
- prevention of heavy metals:	680 Euro/kg (calculation based on Zn)
- prevention of carciogenics:	12.3 Euro/kg (PAH equivalent)
- prevention of summer smog:	50.0 Euro/kg (calculation based on VOC equivalent)
- prevention of winter smog:	12.3 Euro/kg (calculation based on fine dust)
- prevention of global warming:	0.114 Euro/kg (CO2 equivalent).

These 'prevention costs at the norm' are based on the so called 'marginal prevention costs' of emissions. The way these marginal prevention costs are determined is depicted in Figure C. For each type of emission, the costs and the effects (in terms of less emissions) are accumulated for several prevention measures to be taken (a 'what if' calculation). At a certain point on the curve, the 'norm for sustainability' is reached. The marginal prevention costs are defined by the costs per kg reduction of the 'last' measure, depicted as line b.
The 'norms for sustainability' are based on the 'negligible risk levels' for concentrations (in air and in water) and the corresponding 'fate analyses', being the link between concentration and emissions.

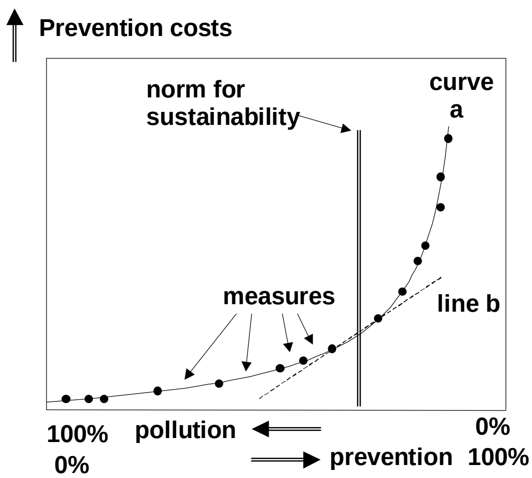


Fig. C: The way the marginal prevention costs are calculated from emission prevention measures for a certain region.

(See Section 2)

The End of Life stage

The End of Life systems are rather complex. For complex products, like buildings, there are many different system opportunities to make the solution more sustainable (from recycling to enhancement of the durability).

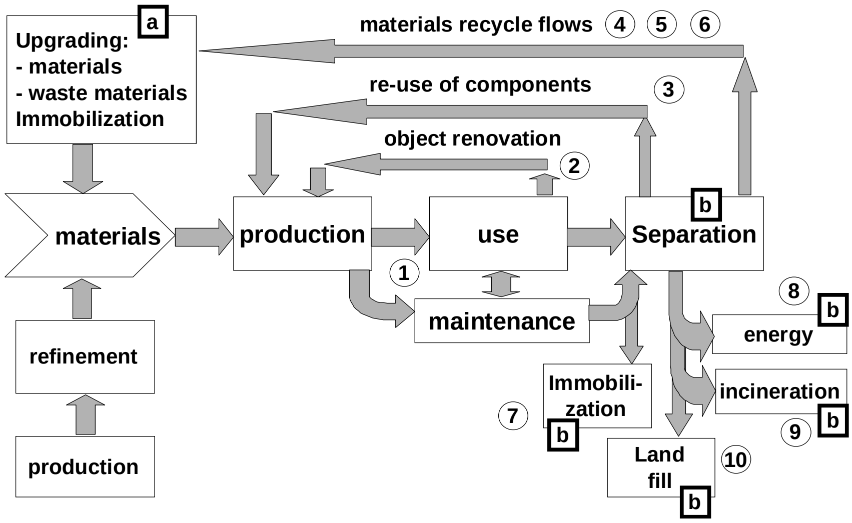


Fig. D: The flow of materials in the Life Cycle

Figure D depicts the major types of End of Life treatment and types of recycling. It is developed to describe and analyse the various kinds of complex modern life cycles of consumer products, buildings, manufacturing plants, civil structures, etc.

The numbers in Figure 5 relate to the "Delft Order of Preferences", a list of the 10 major systems for End of Life used for structured and systemized analyses of (combinations of) design options:
1. Extending of the product life
2. Object renovation
3. Re-use of components
4. Re-use of materials
5. Useful application of waste materials (compost, granulated stone and concrete, slag, etc.)
6. Immobilization with useful appliances
7. Immobilization without useful appliances
8. Incineration with energy recovery
9. Incineration without energy recovery
10 Land fill.

It is important to realize that for big, modular objects (like buildings), there is not "one system for End of Life" but in reality there is always a combination of systems.
Two basic rules for allocation in the EVR model are:
- Costs and eco-costs of all activities marked with 'b' are allocated to the End of Life stage of a product (transportation included).
- Costs and eco-costs of all activities in the block marked with 'a' are allocated to the material use of the new product (so are allocated to the beginning of the product chain).

In line with the aforementioned allocation strategy, the 'bonus' to use recycled materials is taken at the beginning of the product chain, where the new product is created. Material depletion is caused here when 'virgin' materials are applied, material depletion is suppressed when recycled materials are applied.

(See Section 4)

The EVR as an indicator for de-linking economy and ecology

Product designs for the future will need to combine a high value/costs ratio as well as a high eco-efficiency.
The advantage of the EVR model is that it can reveal how the de-linking of economy and ecology can take place in practical situations.

For designers, the EV Wheel has been developed, showing the strength and weakness of a certain design on the value side as well as the eco-costs side. See Figure E. A sustainable design is characterized by high scores at the value side and low scores at the eco-costs side.

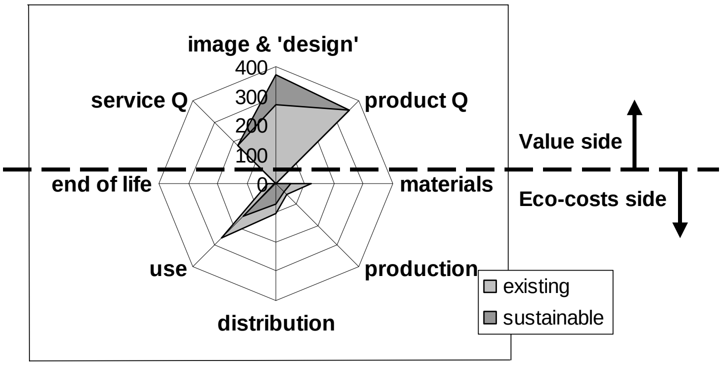


Fig. E: The Eco-costs & Value Wheel (EV Wheel), with value and eco-costs (Euro).

Another powerful instrument to analyse a product is an eco-costs value chart of the manufacturing, assembly and distribution chain.
In the production chain, the value as well as the eco-costs gradually increase from the raw materials to the point of sales. This is depicted in the example of a 28" television in Figure F.

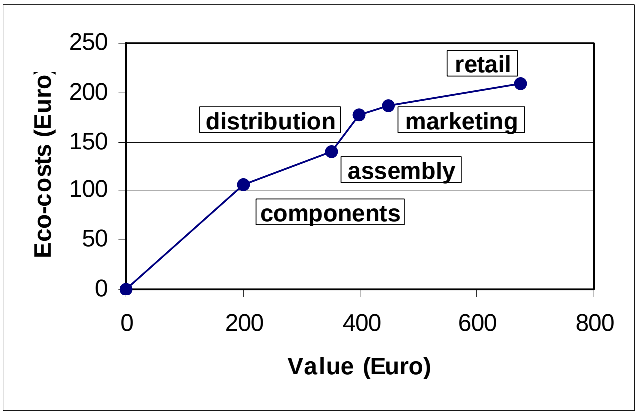


Fig. F: The value and the eco-costs cumulative along the production and distribution chain. (data for a 28" television)

The EVR is also a good indicator of the sustainability of consumers expenditures. The so called "rebound effect" is depicted in Figure G, showing that 'savings' are sometimes not a good solution for sustainability.
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 product 1 of Figure G, the net result is positive, since the money which is saved, is spent on another product with a lower

EVR. In the example of product 2 of Figure G, however, the net result is negative, since the saved money is spent on a product with a higher EVR.
The conclusion is that "savings" are only positive for the environment when savings are achieved in areas with a high EVR (and spent in areas with a low EVR).

A typical example of the rebound effect is related to the efficiency increase of light bulbs: when consumers spend the saved energy on more light (e.g. in their gardens) or on electricity for other domestic appliances, it does not 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) in comparison with other expenditures.
Savings on luxury goods (generally a low EVR because of the high labour content: 0.2 – 0.4), might be negative since the "rebound" might be in the area of more energy (in the form of travel).

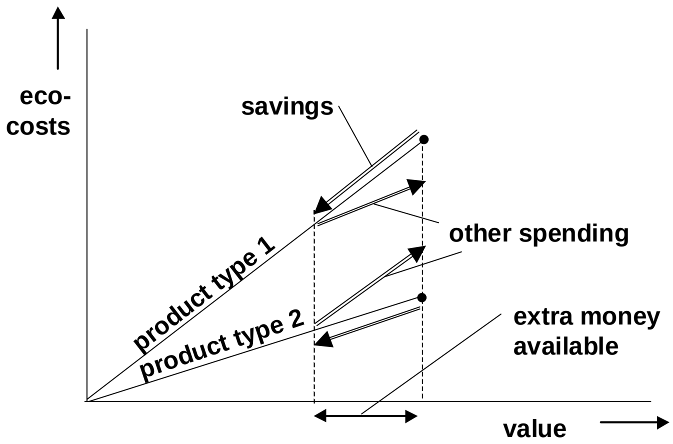


Fig. G: The "rebound effect" of consumer expenditures

(See Section 5)

Case: the transport function

To illustrate the advantage of the EVR model in cases where service plays an important role, a transport chain has been analysed: vegetables from the Dutch greenhouse to the retail shops in Frankfurt. The chain has been analysed for two transport packaging systems: returnable crates and ‘one way’ solid board boxes. See Figure H.

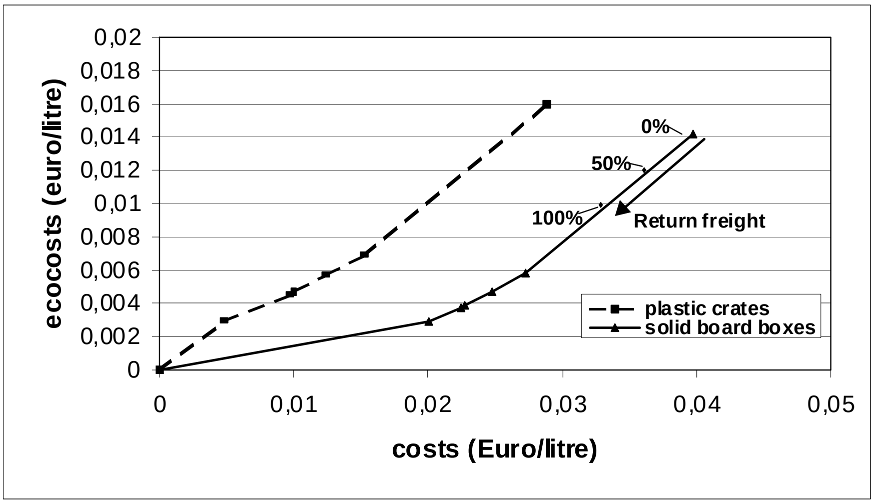


Fig. H:. Costs and eco-costs per litre net transport volume for the total chain (total distance 500 km) as function of the percentage return freight

For the design of transport systems an integral LCA approach of the total transport chain (cycle) is required to minimize eco-costs. This is because of the high interaction of the system components: the packaging system, the transport system and the storage system. Efficient use of volume (of the truck as well as of the transport packaging) plays a key role as well as the re-use of packaging materials.

The eco-costs for the solid board box system appeared to be lower for all cases (also for shorter distances), especially when the truck can be used for other freight on the return trip. The EVR (and therefore the eco-efficiency) of the solid board box system is in all cases considerably better as well. So there is no reason from the environmental perspective to prefer plastic re-usable crates, which is an embarrassing conclusion in the light of the discussions in The Netherlands that started in the early nineties: ‘durable’ does not go hand in hand with ‘sustainable’ in this case, because the use of energy appears to be rather predominant in those transport systems.

(See Section 6)

The eco-costs of land conversion

Although it is argued that land-use cannot be integrated in the LCA of industrial mass products, a characterization system has been developed for conversion of land. This system might be used in:
- LCAs of one-off products like buildings, roads etc.
- rural and urban planning, to determine the best option and to assess possibilities of compensation (e.g. in the Dutch MER system).

The calculation system for the eco-costs of land conversion is summarized in Figure I.
In the calculation scheme of Figure I it is shown that two category indicators can be used for the endpoint category 'habitat for plants': either SRI (for species richness) or ERI (for rarity of vascular plants and their ecosystems). Both SRI and ERI have the dimension of 'equivalent m^2 of nature'. For ERI a threshold value has been built in: when ERI/A is more that 1 conversion should be forbidden (A is the area in m^2).

For the endpoint category 'H_2O cycle', a category indicator has been developed for the specific case of the Dutch polders. For other cases a category indicator is still to be developed (for the conversion from green areas to built-up areas. These eco-costs tend to be low, however, in comparison to the eco-costs of scenic beauty.

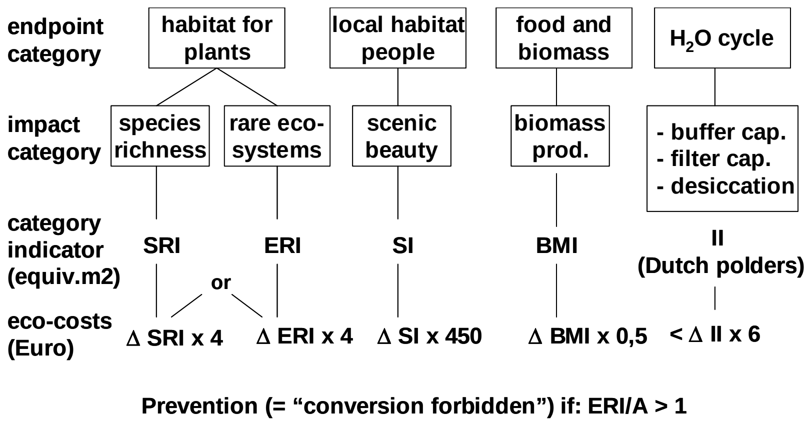


Fig. I: Characterization system for land conversion, and the corresponding eco-costs

In calculations of eco-costs, two aspects seem to be dominating:
a. the botanical valuation of nature, in situations where a green area is converted to a green area of an other type
b. the scenic beauty, in situations where green land in urban areas is converted to built-up land.

The calculations on eco-costs can be used in order to determine measures for compensation in spatial planning. Such a compensation has to be done within each endpoint category separately (e.g. negative effects on the H_2O cycle must be compensated by positive measures in the field of the H_2O cycle, and not in the field of botanical value or scenic beauty).

(See Section 7)

Aspects of communicating the eco-costs and the EVR

It has been tested whether or not the EVR model leads to a good understanding of the eco-efficiency of a product-service combination. In an experiment, 3 separate groups of 8-11 people were asked to rank four alternative solutions of a product-service system (the after sales service and the maintenance service of an induction plate cooker) in terms of sustainability. The 3 respective groups were:

- customers (among whom representatives of consumer organizations)
- business representatives from the manufacturing company of the induction plate cookers
- governmental representatives (employees of the Dutch ministries of environmental affairs and economic affairs, and of the Dutch provinces as well as consultants involved in governmental policies), all experts in the field of sustainability.

The question was to rank the proposed alternatives in terms of "best sustainability" as well as in terms of "best choice in general", and to give arguments for the chosen answers. Furthermore it was asked what information was missing to make "the right" decision on the ranking (as it was perceived by the participants).
At the end it was asked whether the eco-costs and the EVR were perceived as good criteria on which to base decisions.

From the experiments it can be concluded that:

- The concept of Eco-costs was accepted by the majority of the non-experts, better than LCA output on which to base their ranking
- The concept of the EVR was understood by the majority of the non-experts, but the consequences of it in terms of life style were not easily accepted (especially the consumers group rejected the idea to judge on *their* life style by an eco-efficiency parameter)
- The environmental experts in the governmental group did not directly accept the concept of eco-costs model (they wanted in depth information first); they tend to stick to their existing knowledge of LCA data, which is in line with Rogers' theory of diffusion of innovation.

The experiment indicates further that:

- the aspect of sustainability plays hardly any role in the decision when a consumer has a strong preference (based on other aspects, like the cost/benefit ratio) for a certain product type
- however the aspect of sustainability can play a quite important role in the decision when there is no preference on other grounds.

This way of selection of products and services is depicted in Figure J

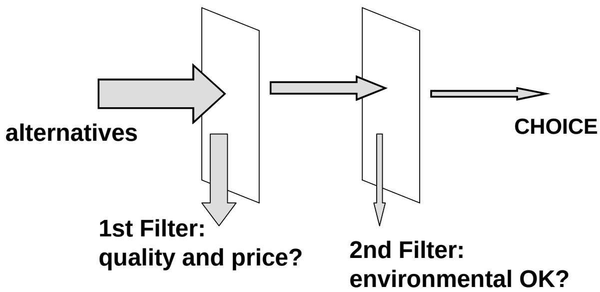


Fig. J: The Double Filter Model : environmental data serve only as a second order filter in the decision of consumers.

(See Section 8)

The road towards sustainability

The combined approach of eco-costs and value reveals new opportunities to reach "the factor 4" in eco-efficiency (or even more). The required transformation , however, is far from easy.
In order to describe the mechanism of the required transition, the 'three stakeholders model' has been introduced. See Figure K. This model provides the main interactions between business, government and consumers/citizens with regard to the issue of sustainability:
- citizens ask the government to care for their long term interest and to create sustainability
- the government defines restrictive rules and has to create an even playing field for the industry
- the industry satisfies short term consumers needs in terms of maximum value for money.

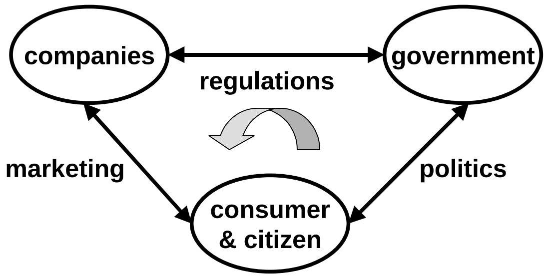


Fig. K: The 'three stakeholders model' and their main interactions

With regard to the introduction of green products, the EVR model reveals two important issues:
- in the product portfolio management strategy companies have to enhance the EVR of products with a high value/costs ratio (rather than try to enhance their cost/value ratio of products with a low level of eco-costs, as many environmentalists propose). See Figure L.
- marketing strategies need to be differentiated:
  - for commodity products (products where it is hard to differentiate on price/value), make the low eco-costs of a product a competitive edge, but keep the price/value at the same level
  - make the eco-costs part of the image for special products and high quality products, but do not stress the sustainability issues too much, since consumers go for the best price/value.

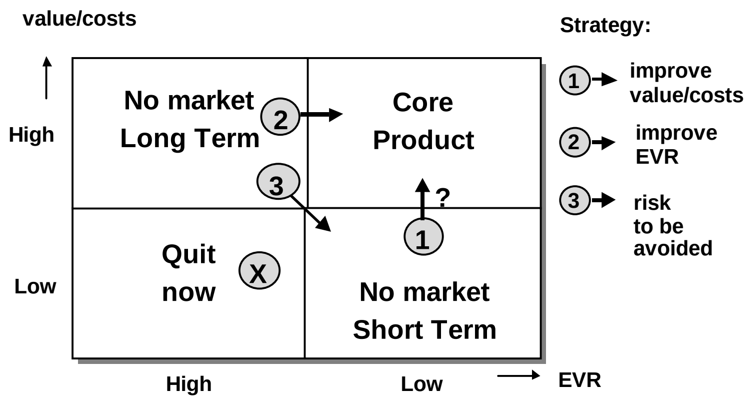


Fig. L: Product portfolio matrix for product strategy of companies

It is shown why it is so difficult for governments to force the industry in the direction of sustainability, and keep an even competitive playing field at the same time. Gradually increasing tax on pollution would work in a closed economy, but has the adverse effect of 'exporting environmental pollution' in an open, global, trade.
Tradable Emission Rights systems for the industry, in which the government take part, seem to be the most promising solution on national level.

On global level a Tradable Emission Rights system between governments might become the right tool to freeze the CO_2 emissions to its current level. Drastic and fast reduction of the emissions, however, cannot be expected from such a system. The goal can only be reached step by step.

Systems of subsidies (or tax relief) on consumer products are suitable to facilitate the market introductions of innovative products, but only in market niches, and only for products with a high EVR. General subsidies (or tax relief) for other than these products have to be avoided.

(See Chapter 9)