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Strategic sustainable development — selection, design and synergies of applied tools

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Abstract

The number of tools and approaches to develop sustainability is growing rapidly. Sometimes they are presented as if they are contradictory or in competition. However, a systems approach consistent with basic principles and the requirements of sustainability shows that these tools are complementary and can be used in parallel for strategic sustainable development. In fact, it is only when using these approaches outside of the systemic context of sustainability that they become contradictory. This paper is a collective effort of scientists who have pioneered some of these tools and approaches.

The paper maps essential elements for developing sustainability and documents how these elements relate to the application of the respective tools. The objective is to show how these tools and approaches relate to each other and build on each other when used for planning for sustainability.

Keywords: Sustainable development; Sustainability; Systems thinking; Backcasting; Upstream thinking; Strategic planning; Factor X; Factor 10; Ecological footprinting; ISO 14001; EMAS; EMS; System conditions; Life cycle assessment (LCA); The natural step (TNS); Zero emissions (ZE); Cleaner production (CP); Sustainable technological development (STD); Natural capitalism

1. Introduction

A growing number of tools for management and monitoring of sustainable development have gained worldwide acceptance in the last decade, like ISO 14001, Life Cycle Assessment (LCA) [1,2], Ecological Footprinting [3], Factor 4 [4,5], Factor 10 [6,7], Sustainable Technology Development [8], Natural Capitalism [9], and The Natural Step Framework [10,11,30]. They have been supported by a number of organizations and programs. This variety has led to some confusion regarding the qualities, differences and linkages between various tools, and, consequently, questions on how best to apply them.

The intent of this study is to develop a systems perspective to investigate:

(i) the relationships between various tools and organizational perspectives for advancing strategic sustainable development and to that end
(ii) the utility of having access to a diversity of tools and programs.

For comprehensive planning in any complex system, we have previously described the value of delineating five hierarchically different system-levels and in main-

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taining the distinction between the levels when planning. Their interrelatedness can then be utilized in a deliberate and methodical fashion [11]. The five levels are:

1. Principles for the *constitution* of the system (e.g. ecological and social principles).
2. Principles for a favorable *outcome* of planning within the system (e.g. *principles for sustainability*).
3. Principles for the *process* to reach this outcome (e.g. *principles for sustainable development*).
4. *Actions, i.e. concrete measures* that comply with the principles for the process to reach a favorable outcome in the system (e.g. recycling and switching to renewable energy).
5. *Tools* to monitor and audit (i) the relevance of actions with reference to principles for the process (e.g. indicators of flows and key-figures to comply with principles for sustainability), and/or monitoring (ii) the status of the system itself, and impacts (e.g. ecotoxicity and employment), or reduced impacts, as a consequence of strategically planned societal actions.

In the present study, we have further elaborated the levels of this hierarchy and better defined the interdependencies of the essential components in a systems model. The model has been applied to study various concepts and programs, thereby presenting a unified whole.

In section 2, the model is developed.

In section 3, the model is applied to demonstrate the *primary* focus of the following Tools and Initiatives: The Natural Step Framework (TNSF); Factor 10; Ecological Footprinting (EF); Sustainable Technological Development (STD); UNEP/Cleaner Production; Zero Emission; and Natural Capitalism.

In section 4, the result is discussed.

2. A systems model of essential elements for sustainable development

The previously described hierarchical 5-level model for planning in complex systems [11] is further elaborated and displayed in Fig. 1.

2.1. The overall system — the ecosphere

Level 1 represents the overarching system that we are focusing on, i.e. the societies and the surrounding ecosystems. This system, also referred to as the *ecosphere*, occupies the full space above the lithosphere (earth's crust) to the outer limits of the atmosphere. Hierarchically different levels of principles for planning within this system must be based on an understanding of the constitutional principles of the functioning of this system (e.g. thermodynamics; the biogeochemical cycles; the ecological interdependencies of species; the societal exchange with, and dependency on, the ecosphere) [for references, see 10].

2.2. Principles for sustainability

Level 2 defines the goal, i.e. the *state* sustainability within the ecosphere. The Brundtland commission provided a philosophical definition: "To meet the needs of the present without compromising the ability of future generations to meet their own needs" [12]. Claims to maintain biodiversity not only for the productivity of the ecosystems but also for its own sake, belong to this level.

2.2.1. The Four System Conditions

This philosophical overall goal can be spelled out in more specific terms. For example, The Natural Step developed such a framework of complementary, non-overlapping conditions for social and ecological sustainability — the Four System Conditions [for references, see 10,11].

The System Conditions for *ecological* sustainability are derived from the three basic mechanisms by which natural life sustaining systems can be destroyed, followed by inserting a "not" to create the converse of those mechanisms. The System Condition for *social* sustainability is simply stated as the requirement to meet human needs (within the frame set by the three System Conditions for ecological sustainability):

In the sustainable society, nature is not subject to systematically increasing…

1. Concentrations of substances extracted from the Earth's crust.[1]
2. Concentrations of substances produced by society.[2]

[1] The societal influence on the ecosphere due to accumulation of lithospheric material is covered by this principle. The balance of flows between the ecosphere and the lithosphere must be such that concentrations of substances from the lithosphere do not systematically increase in the whole ecosphere, or in parts of it. Besides the upstream influence on this balance through the amounts of mining and choices of mined minerals, the balance can be influenced by the quality of final deposits, and the societal competence to technically safeguard the flows through recycling and other measures. Due to the complexity and delay mechanisms in the ecosphere, it is often very difficult to foresee what concentration will lead to unacceptable consequences. A general rule is not to allow societal-caused deviations from the natural state that are large in comparison to natural fluctuations. In particular, such deviations should not be allowed to increase systematically. Therefore, what must at least be achieved is a stop to systematic increases in concentration.

[2] This principle implies that the flows of societally produced molecules and nuclides to the ecosphere must not be so large that they can neither be integrated into the natural cycles within the ecosphere nor be deposited into the lithosphere. The balance of flows must be such that concentrations of substances produced in the society do not systematically increase in the whole ecosphere or in parts of it. Besides the upstream influence on this balance through production volumes and characteristics of what is produced, such as degradability of the produced substances, the balance can be influenced by the quality of final deposits, and the societal competence to technically safeguard the flows through measures such as recycling and incineration.

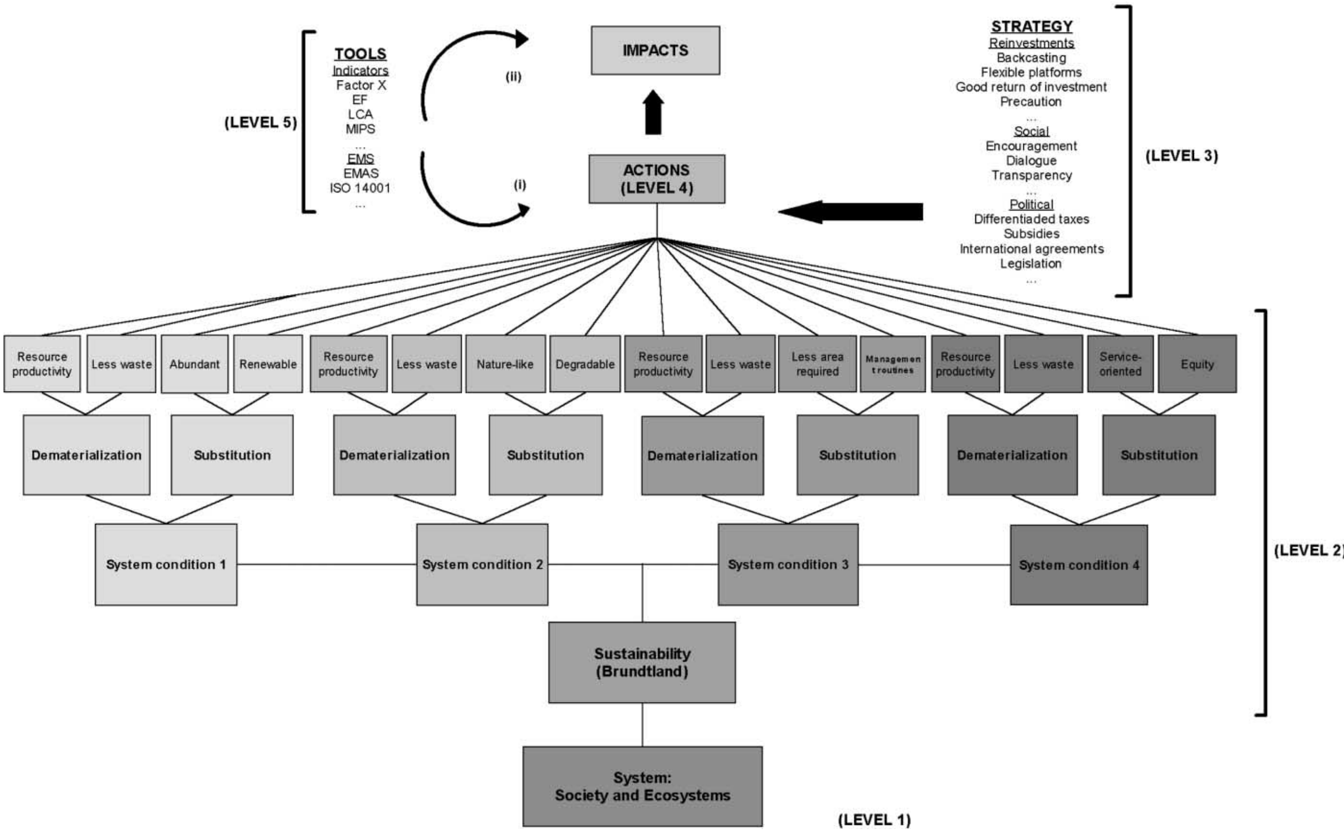


Fig. 1.

3. Degradation by physical means.[3]
4. And, in that society human needs are met worldwide.[4]

By utilizing a successful outcome in the future as the starting point for planning (backcasting — see below, section 2.3.1.1), objectives in relation to the system conditions can be formulated:

Our ultimate sustainability *objectives* are to:

1. Eliminate our contribution to systematic increases in concentrations of substances from the Earth's crust. This means substituting certain minerals that are scarce in nature with others that are more abundant, using all mined materials efficiently, and systematically reducing dependence on fossil fuels.
2. Eliminate our contribution to systematic increases in concentrations of substances produced by society. This means systematically substituting certain persistent and unnatural compounds with ones that are normally abundant or break down more easily in nature, and using all substances produced by society efficiently.
3. Eliminate our contribution to the systematic physical degradation of nature through over-harvesting, introductions and other forms of modification. This means drawing resources only from well-managed eco-systems, systematically pursuing the most productive and efficient use both of those resources and land, and exercising caution in all kinds of modification of nature.
4. Contribute as much as we can to the meeting of human needs in our society and worldwide, over and above all the substitution and dematerialization measures taken in meeting the first three objectives. This means using all of our resources efficiently, fairly and responsibly so that the needs of all people on whom we have an impact, and the future needs of people who are not yet born, stand the best chance of being met.

[3] The societal influence on the ecosphere due to manipulation and harvesting of funds and flows within the ecosphere is covered by the third principle. It implies that the resource basis for: (i) productivity in the ecosphere such as fertile areas, thickness and quality of soils, availability of fresh water, and (ii) biodiversity is not systematically deteriorated by over-harvesting, introductions, mismanagement or displacement.

[4] Human needs refer to not only the basic needs to sustain life, but all needs to maintain health — including emotional and social needs [13]. These needs should not be confused with the cultural means by which we satisfy them — this will be further discussed as a need to change societal focus from commodities to services — see below.

2.2.2. Dematerialization and substitution

Each of the sustainability *objectives* described by the System Conditions can be further divided into two basic mechanisms: *dematerialization,* i.e. reduction of material flows, and *substitution,* i.e. exchange of type/quality of flows and/or activities. These two aspects of sustainability can be used in parallel and on different scales, e.g from changing amounts *and* types of fuel in the same process (e.g. from petroleum fueled to more efficient bio-fueled vehicles), through a more radical change of the whole process (e.g. from combustion engines to more efficient and cleaner fuel cells), to completely new and less resource demanding and more ecologically and socially sound ways of satisfying the same human need (e.g. from a road-transport dependent business model that does not integrate social costs in developing countries, to licensing and fair trade utilizing information technologies).

Both dematerializations and substitutions can be further subdivided. *Dematerialization* can be further subdivided into various means of increased *resource productivity,* e.g. more efficient engines, and *less waste,* e.g. recycling, or to allow waste from one process to be raw material for another. The subdivision of substitutions differs from system condition to system condition.

2.2.2.1. System conditions 1 and 2. Dematerialization of certain flows, i.e. reduced resource-throughputs per utility unit may be enough to avoid increased concentrations of certain compounds in nature, e.g. NO_x. However, this will most likely not be enough for others that are either so scarce in nature that even relatively small societal flows pose substantial risks for increased concentrations due to leakage from society, e.g. Cadmium and CFCs. Such flows need to be phased out, i.e. *substituted*:[5] for by:

- Other materials from the earth's crust that are more abundant — or renewables (System Condition 1).
- Other compounds that are either naturally occurring, or easily degradable into such compounds (System Condition 2).

2.2.2.2. System condition 3. In the same way, the sustainable society must meet the third System Condition partially by *dematerialization* to phase out destructive interference with functions and evolution of ecosystems from over-harvesting of forests, croplands and fisheries to sustainable levels. However, this will not be sufficient since certain activities should be substituted for by others, some by moving to less area-consuming activities (e.g. exchanging road transports for boat traffic), or by exchanging certain management routines for others that are more cognizant of ecosystem impacts and utilization (e.g. recycling of micro-nutrients to soils, or reducing the weight of tractors in agriculture and forestry to reduce the compression of soils).

2.2.2.3. System condition 4. Dematerializations and substitutions must not only be regarded from an ecological perspective (the first three system conditions), but also from a social perspective (the fourth system condition). This includes a number of health aspects that are related to ecological pollution. In this respect humans are part of ecosystems and run risks just like all other species when the first three system conditions are violated. Understanding the health aspects of pollution is an increasingly demanding scientific field, particularly since traditional "toxicology" will not be sufficient when it comes to elucidating the epidemiology of long-term exposure to very low concentrations of compounds that interact with biological systems. Examples include endocrine disruption, chemical sensitization and increased autoimmune diseases.

Another social aspect is the availability and distribution of resources. In this respect, industrialized and newly industrializing societies are challenged on three fronts. First, we must reduce the total material resource flows to within ecologically sustainable levels (System Conditions 1–3), second, we must cooperate to increase the affluence of poor people on Earth, and third, we have an increasing number of people on the planet. A culture recognizing the role and need for dematerialization is necessary so that supplies — after the dematerializations and substitutions required by ecological realities have been performed — will be enough for the people on Earth. *Cultural* substitutions will also play an essential role, e.g. by changing focus from commodity to *services* in order to find completely new ways of meeting the same human need. Surpluses that can be generated by the combined dematerializations and service oriented substitutions, must then be used to take responsibility for all people on earth, i.e. a global culture where *equity* is the norm. From a global perspective, there are alternatives to slash and burn agriculture of rain forests for feeding people in the developing world. "Fare trade," i.e. fair ways of recruiting the developing world into the world's economy, such as paying social costs for raw materials goods and services, is one example.

The possibility cannot be excluded that a successful transition to a more equal global economy would substantially improve the psychological life quality in the affluent world as well. This could be true before the indirect effects from such a transition would be a fact. The indirect ecological and social costs from inequity will continue to grow in the affluent world until the situation is resolved [12].

[5] An alternative is to find a completely new way of providing the same service, see below, system condition 4.

2.3. Principles for sustainable development

Level 3 focuses the process to reach the goal. To move society in the direction of sustainability, i.e. towards all the dematerializations and substitutions needed to comply with the four system conditions, the actions should be fostered through a set of principles for the process.

2.3.1. Principles for strategic investments

Investments should be planned strategically. Here a step-by-step approach can be used to bring operations closer to principles for ecological sustainability (see "reinvestment in natural capital", section 3.7) in parallel with improvements in social and economic performance, thereby empowering the extension of the process. Investments should be selected by four principles [10,11]:

2.3.1.1. Backcasting. Without first defining a future "landing place" on the systems level, reaching sustainability is an unlikely outcome of any effort. Each investment should bring practices closer to the overall objective of complying with the system conditions. This requires backcasting [10,11,14,15], which means that the starting point of the planning is an envisioned successful future outcome of the planning. Based on this outcome the strategic paths are designed. This is an essential planning methodology when the system is complex, and when current trends, actions and planning are part of the problem [16].

An example of the need to apply backcasting is that dematerializations and substitutions do not always walk hand in hand towards sustainability. Certain important substitutions may actually lead to an *increased* material intensity and/or costs, particularly in the early stages of development. Examples of such trade-offs include the relatively poor energy-output per resource input (and concurrent pay-back times) in wind-power only a couple of decades ago and that the first generations of low-energy light bulbs had relatively higher concentrations of mercury.

In general, it is important to have an informed vision of one's goal in order to strategically deal with potential trade-offs from different decisions. However, this is often omitted in sustainability efforts. Today's short term and acute effects arising from various alternative products and processes are generally given greater weight in decision making than determinations of which of the alternatives best serves as a stepping stone on a strategic path to a future where the trade-off is no longer needed. That strategic thinking is not always the case can be highlighted by many examples from the current debate — for instance, regarding "traditional vs. sustainable energy systems". Rather than discussing various options (nuclear power, fossil fuels, wind power, biofuels, solar energy, hydro power, etc.) from a *sustainability perspective* (such as compliance with the four system conditions), the public debate often focuses on the short term consequences and problems from alternative energy sources, and then projects those full scale into the future, without consideration of the goals or the full potential for the alternatives. This also ignores the "learning curve," i.e. the positive aspects that will follow from development of the sustainable energy sector such as societal and technical development, growth of scale, and more efficient end-uses of energy. This more limited perspective leads to assessments such as: "We would have to cover the whole country with windmills, at enormous costs, if we turn to wind-power, and if we turn to bio-fuels, all forests will be over-harvested and destroyed". Moreover, a tenfold dematerialization of the present western wealth producing machine would in itself lead to roughly a fivefold decrease in energy needs [7].

In fact, the word "strategy" implies backcasting, that is to have a sufficiently well defined outcome, the "future landing place". This means that today's trends (i.e. customer's preferences) should only influence the *pace* and the *initial scale* of the transition, not its *direction*. That is the essence of backcasting, which should be followed and complemented by the more commonly applied methodology of *forecasting*. Forecasting is based upon the recognition of current problems and trends for planning. Thereafter, "getting rid of the problems" in combination with estimates of what is considered "realistic" determines the planning process. If forecasting is the sole planning strategy, there are substantial risks that "fixing the problems" will retain the principle mechanisms from which the problems arose. This will create additional problems in the future [10,17].

2.3.1.2. Flexible platforms. It is not sufficient to undertake investments that approach compliance with the system conditions in the short term. A neglected principle is that the steps taken must also avoid dead ends in the future. This means that each investment should provide technically feasible stepping-stones, or "flexible platforms," to link to future investments in the same direction. An example is to produce a new car engine that is not only more fuel efficient (a dematerialization aspect of system condition 1), but that has future potential to run on other fuels (substitution aspect of system condition 1). This is particularly important when investments are large, and consequently tie up money and resources for extended periods of time [10,11].

2.3.1.3. Good return on investment. Of all "flexible platforms" that can be considered, priority should be given to those that stand a relatively good chance of yielding *a good return on investment* (i.e. relatively inexpensive, and/or meeting a growing market demand, and/or foreseeing coming regulatory changes, etc.).

Good return on investment can seed the subsequent “flexible platforms” with money. The combination of these three re-investment principles, backcasting, flexible platforms and good return on investment provides the overall strategy for sound investments [10,11].

Due to society’s systematic violation of the system conditions for sustainability, the resource-potential for health and economy is systematically decreasing. At the same time, Earth’s population is increasing and since the efficiency of fulfilling human needs is relatively low the average demand for resources are increasing. Non-sustainable development could be visualized as entering deeper and deeper into a funnel, in which the space becomes narrower and narrower. To the individual company, municipality, or country — wanting to make intelligent investments, the crucial thing must then be to direct its investments towards the opening of the funnel, rather than into the wall. In reality this means that the smart investors make themselves less and less economically dependent on being a relatively large contributor to the violation of the system conditions as best they may, even given short-term incentives to do otherwise.

The wall of the funnel will increasingly superimpose itself into daily economic reality in the following ways: increasing numbers of environmentally concerned customers, tightening legislation, ever increasing costs and fees for resources and pollution, and tougher competition from competitors who invest skillfully towards the opening of the funnel. To take a step-by-step approach towards compliance with principles for success, rather than simply “fixing problems”, creates a relatively lower risk of being hit by such foreseeable, but highly unpredictable, consequences of non-sustainable operations.

2.3.1.4. Precautionary principle. Being cautious is another way of avoiding mistakes and their often costly consequences. The precautionary principle is mostly applied when there is uncertainty regarding the ecological consequences of a specific activity. However, since good return on investment is another strategically essential element of sustainable development, the precautionary principle should also be applied when there are serious economic doubts. Sometimes a hitherto unexplored “proactive” path may turn out to be a dead end, or may be more costly than another option.

A rational application of the precautionary principle requires a strategic approach. However, “greening initiatives” in industry are not always based on backcasting, where a successful outcome and the self-benefit from a successful outcome, as well as the consequences of failing, are made explicit upfront in the planning procedure. Hence short-term economic arguments are often used to justify an unwillingness to change established routines. In this context, it is important to point out that to not do anything is also, in reality, a decision. There is no rational reason to allow the burden of proof for decisions of inaction to be lower than the burden of proof to justify proactive decisions [10]. Or in other words — the precautionary principle should be applied also on inactive attitudes.

2.3.2. Social principles

Other principles for the process may be more obvious, though sometimes not taken into account.

2.3.2.1. Dialogue and encouragement. The principle of dialogue and encouragement is essential for teamwork and community building. For instance, management teams taking a clear stand, implementation of a listening and respectful working environment, celebration of steps forward, and using effective means for communicating and reporting are all characteristics of an encouraging leadership for sustainable development 18. It must also be pointed out that an elegant application of the previously described aspects of strategic principles — principles for reinvestments — also serves the social aspects. Backcasting from a starting point that is sufficiently large in time and space, is a way of avoiding frustrating moral conflicts in the economy between the benefit of the relatively few, at the expense of the secure future of all stakeholders.

2.3.2.2. Transparency. In addition to being an indirect aspect of dialogue and encouragement, the democratic principle of *transparency* allows peers to see, understand and correct mistakes. Sometimes intelligent moves towards future market opportunities are considered business secrets. This may be perceived as being in conflict with the transparency principle, and, indeed, this may be true, particularly in the short run. Counter balancing this in the long run, transparency opens up avenues of possibilities that would be difficult to achieve without it. Transparency creates trust, helps in recruiting the entire supply chain and all stakeholders onto the same playing field, and opens up possibilities for business agreements and cooperation — sometimes even with competitors — in creating new market opportunities.

2.3.3. Political means

Political action can be the leading and cutting edge. This may be needed when role models in society have exhausted the full potential of their individual strategies, and when the pace of their joint leaps forward turns out to be insufficient from the whole society’s point of view. *Political means* are then designed to protect our commons.

2.3.3.1. “Differentiated taxes”. In order to stimulate reduction of material flows into the economy — such as fresh water, copper, cadmium, or fossils — “material added taxes” or other tax forms on inputs can be effective. Input factors can be considered as a base for tax rates.

Moreover, those output flows we may wish to remove or replace, for instance net technology-based emissions of CO_2 into the atmosphere (from fossil fuels, system condition 1), can be taxed at *relatively* higher rates than flows that are aligned with sustainability principles, for example CO_2 from carbon neutral energy sources. At the present time, this is perhaps the most debated of all governmental options to support sustainable development. Four aspects of this debate are essential: (i) Increasing public demands on the "polluter pays principle", and increasing demands from the market on resources as such due to the material development of presently lesser industrialized countries like China, India and Indonesia, will very likely cause a shift to higher costs of the resources. From this perspective, taxes can be perceived as an attempt at early correction of the course and to avoid "hitting the wall" in the future. (ii) If higher taxes are successful at decreasing ecologically deleterious flows, economic benefits will follow indirectly from the ecological benefits. (iii) Taxes on unwanted flows being *relatively* higher than other flows, say nothing about the total tax. It may be higher or lower, and other areas of the tax system, such as tax on labor, can be changed in a compensatory way, or not. Thus taxes on more sustainable flows can be increased or decreased, the important aspect is that they are *relatively* lower than unwanted flows. "Differentiated taxes" is a more constructive term for this way of taxation, than "green taxes". It is also unloaded in the public debate. (iv) Any changes of the tax system to induce substantial societal changes, should be designed in dialogue with those who are going to be called upon to act and pay — firms within the energy and transport sectors for instance, and people whose expense structure may be particularly affected by changes.

One option is to have an escalating scale of the tax over a time period that is realistic for the technical transition, and that can be foreseen. The latter aspect is probably the most difficult, but still essential, aspect to consider. For industry to take future tax changes into serious economic account in their business strategies, it is important to be able to trust the decisive power, and the political endurance, behind the tax agreements. To that end dialogue — based on backcasting from success — should be a key element, possibly the most essential.

2.3.3.2. Subsidies. It could be argued that subsidies of proactive measures should be applied much more often. However, subsidies in general, particularly if they are long lasting, create many problems. Besides the problems of designing them in a way that is perceived as "fair" to the market, and building up bureaucracies to control how they are applied and utilized, they often miss the target. In an ideal sound market economy, built on a balanced full-cost accounting system, taking the necessity of long-term future investments into account, no subsidies should be needed. Therefore, to implement them even for temporary periods has a tendency to cement the problems they are there to compensate for. Over time, they may even run in the face of new, and even more demanding objectives of the current economy. Thus many complicated and incomprehensible subsidies are supporting activities that don't have to apply a full-cost accounting system in the ecosphere. Examples are the agricultural system, where politically decided subsidies divert farmers away from the sound objective of providing clean and healthy foods by sustainable practices, and today's non-sustainable energy systems, that don't have to pay for the steps needed to make them comply with the system conditions. Not even insurance is paid for by sound market incentives. Getting rid of "perverse" subsidies is probably more important than to bring in new subsidies [19].

However, subsidies probably have to play a certain role — for instance in case of investments in long lasting sustainable production oriented research and development. These fields comprise too many uncertainties and risks to be fully covered in the private sector.

2.3.3.3. Traditional privileges. Traditionally, there are little or no public charges on the extraction and use of natural materials and soils by owners of land or waterways. Authorities also continue to grant rights to extract or harvest at relatively low rates on public land (with the exception of hunting rights which tend to be costly in industrialized countries). Fishing and mining in international waters, while restricted in some cases by international agreements, are nevertheless cost free with the exception of the cost of harvesting. As a consequence, the extent of water withdrawal, the use of commons for economic activities, the mining of minerals, the harvesting of timber, the fishing in open waters and many other activities for profits bears little or no relation to the three first system conditions outlined above.

2.3.3.4. Norms and standards. For many good reasons, industrialization has spawned a host of standards and norms. Standards and norms often also contribute to the preservation of natural resources. However, standards, norms and building codes can — and frequently do — require excessive energy, material and space for their implementation. Reviewing this situation, particularly as regards developing countries, may help to reduce the distance from the overall objective of complying with the system conditions for sustainability.

2.3.3.5. International agreements. Examples of intergovernmental agreements include the Rio conference's generation and description of an overall political framework for sustainable development — the Agenda

21 Protocol— the protocols covering reduction of CFC's (Montreal, Copenhagen and Vienna) and the Kyoto protocol addressing reduction of greenhouse gases. The scale of such work is enormous. However, the results are often criticized for not being proactive enough or concrete enough at the operational level. Yet, such agreements have had great enough impact to justify this strategy — if only from the perspective that international cooperation of this magnitude helps to put the various objectives on the global business agenda. The CFC agreements, for instance, have been helpful in stimulating voluntary market changes. These, in turn, have further accelerated the pace of CFC-phase-outs.

2.3.3.6. International trade and economic development. Freeing the international flow of goods from barriers such as tariffs is rightfully considered one important means to increase the prosperity of people around the world. However, as current processes, transports, products and services are excessively resource intensive and frequently subsidized without full cost accounting including ecological concerns, increasing the availability and use of these technical artifacts worldwide increases continuously the distance from the overall objective of complying with the system conditions for sustainability. For this reason the GATT agreements must be urgently reviewed and adjusted to reflect conditions for reaching economic and ecological stability.

It has been widely acknowledged that the wealth of all nations cannot be based upon the western model of resource intensity. This being the case, exports to and the internal development strategies for some 5 to 8 billion people will necessarily shift towards favoring dematerialized processes, infrastructures, goods and services. Long term trade and economic aid policies of western countries may soon begin to reflect this situation.

2.3.3.7. Legislation. Law enforcement to protect our global commons should be applied when all other possibilities are exhausted. Since many sustainability problems are international, this requires a further development of the international agreements from their current status as recommendations to constituting law in the participating countries.

2.4. Actions

The *process principles* described in the previous paragraph (level 3), are applied to foster concrete *actions* (level 4) to eventually comply with the system conditions for sustainability (level 2) within the ecosphere (level 1). It is important not to confuse actions with the principles that underpin them. Actions such as *turning to renewable energy, recycling, and turning to more resource-efficient engines* can sometimes be of value to approach compliance with the system conditions. However, since renewable energy, for example, may lead to destruction of forests through over-harvesting (thereby violating system condition 3), since recycling of cadmium as an alternative to phasing it out (e.g. large flows of cadmium in batteries between industry and households) may lead to increased concentrations of this metal in ecosystems (thereby violation of system condition 1), and since more efficient car-engines may lead to *increased* use of fossil fuels through rebound effects, rather than to savings which — within the same or even reduced global use of fossil fuels — would allow a more equitable distribution to the developing world (thereby violating system conditions 1 and 4) [10,20], it is important that activities are chosen and examined from a complete sustainability perspective. Compliance with all system conditions is the strategic starting point for planning. To that end, tools and metrics should be selected and designed from the same perspective [11].

2.5. Tools

It follows from the above, that the next level to be described (level 5), i.e. the monitoring of the process, should utilize tools and metrics that are designed from a total systems perspective to indicate and audit progress towards sustainability. There are two levels to consider [11].

(i) The first focuses on evaluating how the actions comply with the overall plan and objectives, i.e. to monitor if the selected path of transition is actually bringing societies and the manufacturing sector closer to the objectives (compliance with the system conditions). Were specified flows actually reduced or phased out, and were the planned substitutions actually put into place? This is the crucial level to monitor from a strategic point of view, also for the individual firm, since the monitoring of steps towards compliance with basic principles of success allows one to not only "fix" problems, but to avoid them. This includes problems that we are not yet aware of. For instance, products and services can be systematically dematerialized, and persistent compounds that are foreign to nature can be phased out without knowing their critical thresholds in nature, or even what specific harm they will do once such thresholds have been exceeded.
(ii) The second level to monitor is the actual impacts in the system we want to protect. This focus is essential, since it is the direct target of the planning. In the end, society as a whole needs to see success on this level — i.e. was unemployment reduced or not? Did the birds of prey, and the otters, make it or not? Have the forested areas, topsoil levels, and fish stocks, been maintained, or not?

While it is important not to confuse the levels of the hierarchical model with each other, a clear understanding and synergistic application of the differences is not always the case in concrete planning. In their strategic planning, firms need to take into account the current acute problems from violations of the system conditions (sub-level ii), since the market reflects these problems right now. However, firms often focus on specific and known effects in nature from various compounds and activities — looking myopically downstream along cause–effect chains — so that they lose sight of (sub-level i) the principle levels for long term *solutions* — based on upstream thinking and prevention [10,11].

The focus on specific impacts (sub-level ii) is often so dramatic and generates so much turbulence in the market, that the urge to "fix" all the detailed problems can disguise temporarily the underlying systems-errors creating them. There are numerous examples of how the same mistakes are repeated over and over again, ignoring principles of sustainability and sustainable development. CFCs were believed — at the time of introduction — to be harmless since they were "non-toxic and non-bioaccumulative". Today, persistent compounds foreign to nature are still introduced, and accumulate towards their unknown eco-toxic thresholds since the public debate, and our authorities, have not drawn the principle conclusions from previous mistakes. Thus, to avoid incomplete solutions all activities that will directly or indirectly contribute to the violation of the system conditions should be phased out — whether the impacts from those problems are as yet known or not [10,21]. In conclusion, strategic tools should not only focus on current downstream problems (sub-level ii), but also apply a sustainability perspective so that the long-term course will not culminate in unsustainable activities (sub-level i).

2.5.1. Applying the model to some selected tools and metrics

2.5.1.1. Factor X. The Factor X concept is a direct way of utilizing metrics on various activities that can reduce the throughput of resources and energy in a given process: "By what factor can — or should — certain flows, or material flows in general, be reduced?" This makes the Factor X concept a very useful and flexible approach for monitoring activities aimed at meeting the dematerialization aspect of each system condition.

From the presentation in section 1.3 it can be deduced that the following aspects should be considered when the Factor X concept is applied under systems conditions [22]:

- The best possible answer to the following question must be found: By what factors should present technology-induced flows of natural materials be reduced *as a minimum* in order to stay within the capacity of the eco-cycles?
- Any answer found to this question should be considered preliminary, to be improved as experience with dematerialization grows.
- Taking equity aspects into account, by what factor should material flows in the affluent parts of the world be reduced in order to allow sufficient ecological space for decent living conditions for the poor (system condition 4)?
- The Factor X concept should encourage engineers, managers, politicians and NGOs to "think big" from the beginning. When paradigmatic changes are in the making, timid steps without an envisioned overall "landing place" can be frustrating, expensive, and even lead in the wrong direction. Moreover,
- Once new signals are given to the market that encourage increasing resource productivity, dematerialization becomes a strategy for gaining market shares;
- One-dimensional technological solutions are rarely appropriate. Technical options for reducing flows must be systematically related to social, economic as well as ecological aspects of economic/ecological sustainability (system conditions I–IV).
- If back-casting (looking back at the present situation from the desired "landing place", the explicit ultimate sustainability objectives) is employed, then the design of transition steps linked to the goal of achieving sustainability follows naturally.

2.5.1.1.1. Qualitative aspects

- The factors by which certain flows need to be reduced in order to stay within the assimilation capacity of the ecosystems may differ widely due to differences in their respective ecological functions before their eradication, extraction or displacement from their natural places, e.g. water, soil or forests (system condition 3).
- The persistence, abundance, and eco-toxicity of metals and compounds are important considerations (system conditions 1 and 2).
- Certain aspects are not quantitative at all. In line with the discussion in section 2, there is a need to phase out certain flows altogether (system conditions 1 and 2), or to introduce more balanced management routines in forestry, agriculture or fisheries (system condition 3).

2.5.1.1.2. Dynamic aspects

- Various flows can influence one another. In order to reduce certain flows, other flows may need to be (temporarily) *increased*. For instance the mining of certain materials will need to be increased in order to build up a societal pool of products that are helpful for dematerialization, e.g. recyclable IT equipment or recyclable photo-voltaic cells;

— Rebound effects create a similar problem. A certain flow within a system may *increase* as a rebound effect, or in reaction to reduced flows within a subsystem. For example, our relatively more efficient car engines have contributed to a higher use of petroleum, not the other way around 20.

2.5.1.2. Life cycle assessment, rucksacks and MIPS. When we look at a specific product, we only see a small part of the total material flows that have been mobilized for its production. The “hidden” flows, e.g. material flows like fossil fuels in mining and transports, can be regarded as the product’s “rucksack” [23].

It has therefore been generally acknowledged that life-cycle-assessment (LCA) methods must be applied if errors of unknown magnitude are to be avoided in the assessment of the ecological stress potential of human activities, products and services. The term LCA [1,2] refers to the evaluation of the total life cycle of a product, “from the cradle to the grave”, i.e. from extracting basic resources, through production, transportation, to use and disposal of the product itself. LCA is often used to compare products with equivalent functions, or to determine “hot spots”, i.e. aspects of the life cycle that are critical to the overall environmental impact.

The perspective of this evaluation can differ with regard to the objective of the LCA. This means, the term “LCA” refers to the overall objective of evaluating all parts of the life cycle of a product. It does not explicitly say how this is done, what is the overall scope, or for what purpose.

LCA can be based on backcasting from the system conditions, to cover the qualitatively important aspects of a production process from a sustainability perspective [24]. The qualitative perspective can then be complemented with quantitative aspects, for instance aiming at reaching a total reduction of material flows by a Factor of 10 (section 3.2). To move beyond being an ecological assessment tool and become a sustainability assessment tool, the substitution aspects of the first three system conditions, as well as the fourth system condition, must also be taken into account. It is therefore essential to relate the flows, as well as the aspects and impacts of the LCA, to the utility unit of service. This is the rationale behind the concept Material Input Per unit Service (MIPS) [23,25]. Similarly, the specific area need per unit of service (per unit utility or per unit extracted value) can be given in FIPS, where the “F” stands for the German word Flaeche for area. [23, English translation availble under the title “The Fossil Makers” under <www.factor 10.de >].

Alternatively, LCA can be focused on an ecological impact perspective to deal with some of the most acute problems of today’s industrial activities [1,2,17].

As indicated already, the total (life-cycle-wide) weight of material inputs into a product minus the weight of the product itself can be called its “rucksack”. Typically, the rucksack of current technical products in terms of non-renewable materials is about 30 tons per ton and can reach much higher values, as for instance about 300 for such products as PCs or catalytic converters.

Individual raw materials extracted from nature can differ vastly with respect to their resource intensities, depending upon ecological, geographic, technical and other conditions. Gold for instance requires the extraction and displacement of 540 000 kg of nature per kg of gold, copper 500, aluminum 85, paper 15, and round wood only 1.2. With these factors, the rucksacks of products can be assessed rapidly [25]. In consideration of the differences in ecological impacts from various kinds of flows, it should be noted again that rucksacks give a rough estimate of the resource intensity, whereas a full sustainability analysis also requires qualitative assessments of the respective flows.

2.5.1.3. Total material flow — TMF. On the macro-economic level, knowledge of total material flows (TMF) within a specified period of time and for defined economic areas (e.g. country or region) can be used for monitoring of certain aspects of sustainability (dematerialization) and spot rebound effects before it may be too late.

Imports, losses to the environment, inputs harvested or extracted within the economic area and exports must be considered, as must be the rucksacks of each material flow. For equity reasons, *per capita* flows should be considered when comparing different countries and regions as regards there distance from the overall objective of complying with the system conditions for sustainability. Currently, Vietnamese consume annually about 2 tons of non-renewable resources, Japanese about 40 tons, and Americans some 90 tons [26,27].

2.5.1.4. Ecological management systems (EMS, e.g. ISO 14001 and EMAS). These tools are administrative tools for managing environmental work within businesses. When an EMS is applied as a business tool in a strategic way to avoid draconian measures in the future, the previously described principles, and planned actions and tools/metrics in line with those principles, make up the contents of the plan, while the EMS can be said to be its vehicle. The principles and activities must be put into a relevant administrative context. This allows the principles to guide the planned activities, which in turn are monitored, audited, and, finally, evaluated in order to direct and manage the next iterative cycle of activities captured by the EMS. This means that for an EMS to be useful for sustainable development *and* for business, the objectives for the planning (i.e. complying with the system conditions) and specific activities and associated metrics to meet these objectives need be incorporated into the structure of the EMS [28,29]. ISO 14001 and EMAS are the most commonly described EMS. A framework based on basic principles for sustainability and sustainable development, provides the EMS with direction, and helps firms to align business with the larger context of sustainable development and changes in the market. Conversely, without such an administrative tool, it is difficult, possibly impossible, to implement comprehensive principles in an effective operational way such that transition can occur.

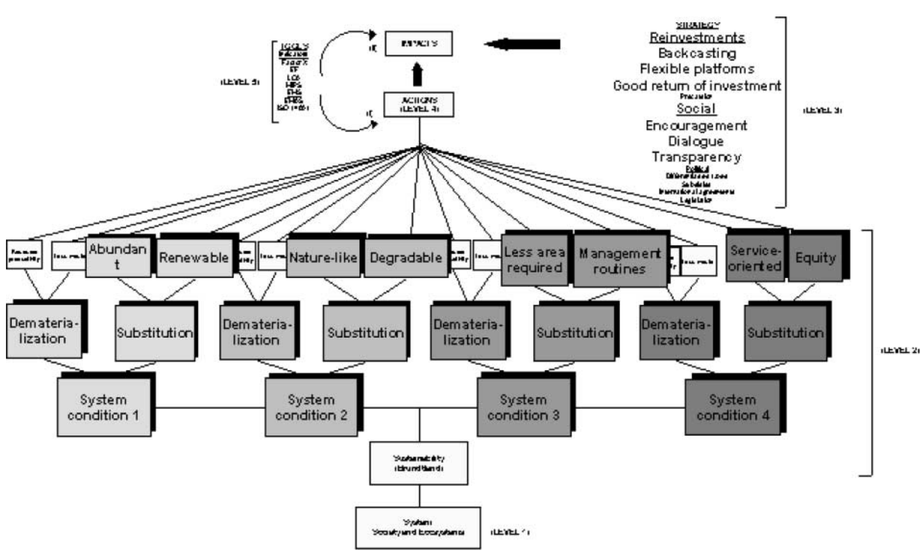
3. Some organizational initiatives studied in relation to the model

In the following section, a number of concepts and associated institutions will be related to the model presented in section 1. All of those institutions are working with sustainability as the ultimate goal, and have elaborated working programs that take a systems perspective of the kind presented in the model into account. However, their “entry points” into the model vary. This means that each has its distinct *primary* focus (highlighted in the respective figures, see below) from which other aspects of sustainability have been elaborated as secondary consequences to the primary focus. This is important to recognize in order to avoid misunderstandings of the presentation. Differences in primary focus should lead, almost per definition, to some important differences in perspectives and experiences. When the different tools are considered, this potential synergy ought to be utilized in conscientious and deliberate ways, rather than being perceived solely as alternatives, or even “competitive” alternatives.

3.1. The Natural Step (TNS) and The Natural Step Framework (TNSF)

The Natural Step (TNS) is an international non-for profit NGO, instituted to facilitate an ongoing dialogue between scientists on the one hand, and decision makers in business and public policy on the other. The objectives of TNS are to (i) identify such overarching principle levels of strategic planning towards sustainable development that can be agreed upon, (ii) based on such principles develop a framework for planning that can serve as a shared mental model — or language — for sustainable development, (iii) support the implementation of the framework in various kinds of firms and organizations and (iv) to study the actual results from this implementation.

This process has led to the development of The Natural Step Framework TNSF [for references, see 10] for decision-making. It is designed for qualitative problem analysis, community building, and for the development of investment-programs in business corporations and municipalities. Its primary focus is on a comprehensive definition of level 2 in the presented model, resulting in the development of the system conditions, and on backcasting and other essential elements for strategic planning in level 3 to comply with level 2 (see figure below). This intellectual approach is dependent on tools developed by others to cover the other aspects of the model. This includes more quantitative assessments of the objective of meeting the system conditions (as provided by other institutions like the Factor 10 Institute, see below), and various tools to monitor the transition, for instance tools for management like ISO 14001 and for indication of progress such as LCA and the Factor concept (level 5). Furthermore, since the whole idea of TNS is to develop and disseminate a framework to guide



concrete actions, the documentation of actions from various role models that are applying the framework is an essential element of TNS (level 4).

3.2. Factor 10 and the Factor 10 Institute

Schmidt-Bleek has cast the Factor X concept (see section 2.5) into concrete and practical policy and management tools for the macro- and micro-economic levels. He estimated that it would take at least a two-fold reduction of world-wide use of natural materials in order to avoid continuing systematic degradation of the biosphere. Since the average *per capita* consumption in OECD countries is at least five times that of developing countries, and further increases in world population are unavoidable, sustainable levels of material flows on a global level will not be reached unless the material intensity of the industrialized countries is reduced by at least a factor of 10. In this way, the Factor X concept (level 5 in the presented model) is turned into a direct "benchmark" for the *dematerialization* of industrialized countries needed to achieve sustainability (23), i.e. belongs to level 2 in the model presented in this paper. The "Factor Ten Club" of prominent environmentalists was founded in 1994, subscribing to this goal, and the Factor 10 Institute was founded in Carnoules, Provence, 1997.

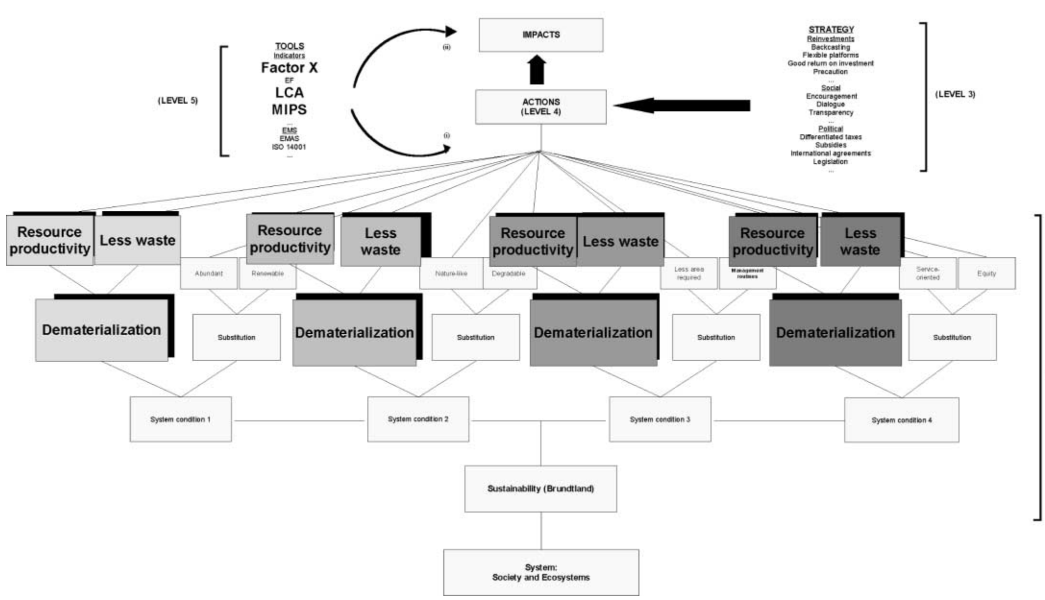
The Factor 10 Institute has also elaborated a number of other concepts that are designed to monitor Society's material intensity. The "Rucksack" factors are assigned to determine the resource productivity of natural materials. In the case of copper for instance, 500 tons of non-renewable nature are used to gain 1 ton of the refined metal. Its "rucksack factor" is therefore said to be 500. For steel, the corresponding figure is about 7.

Efforts have also been done to relate the material intensity to the desired utility, MIPS (material intensity per service unit) as well as relating units of service to the respective land use (FIPS) and total material flow per unit time through an economic unit (TMF) (23). These tools are naturally mapped under level 5 in the model presented in this paper, (see Fig. 1).

The Factor 10 concept — like all concepts for sustainable development — needs be applied in the overall context of the model presented in section 1. Dematerializations should be combined with very deliberate substitutions. The material intensity that can be assimilated in natural cycles is highly different for different materials. Certain material flows — persistent compounds foreign to nature for instance — should not only be lowered but phased out altogether, whereas the flow of certain substitutes — such as new materials that are easier to assimilate in nature's eco-cycles or those that carry lesser "rucksacks" — may need to be increased, at least temporarily, to comply with the system conditions. The need to make subtle distinctions between various materials does in no way contradict the applicability of a rough estimate of the overall need to dematerialize modern society.

3.3. Ecological Footprinting

Ecological Footprinting (EF) [3] is a way of "benchmarking" all dematerializations under the system conditions (level 2 in the model). One of the major differences to Factor 10 is that, with Ecological Footprinting, the outcomes of various activities in society are not determined by factors (i.e. incremental units related directly to the specific materials or material flows). The outcomes are instead measured and aggregated into units of area, i.e. as a reduction or an increase in the ecological area needed to support the activities. This is then related to an estimation of the total life sustaining area of the



biosphere, i.e. the accumulated “footprints” from all activities are related to the total carrying capacity of the ecosphere. Ecological Footprinting provides a tangible way of describing the relevance of improved technologies and less resource intensive lifestyles as means to reduce “footprints” of affluent societies in line with the dematerializations under each system condition. EF also highlights some aspects of the required substitutions under system conditions I–III [30] because qualitative differences in various materials, or crops in agriculture, influence the size of the footprint. For example, the area needed to assimilate CO_2 emissions from fossil fuels can be added to the “footprint”. As with the Factor X concept, there are some qualitative aspects of the system conditions that cannot be described in terms of footprints. For instance, contamination of nature from the use of scarce elements or persistent compounds foreign to nature (system conditions I and II, respectively), cannot be related to an ecological area in a meaningful way. These are aspects that need to be phased out in a sustainable world. The Footprint only includes those activities that are potentially sustainable if not done in excess of the biosphere’s regenerative capacity. The same goes for changes in certain management routines in, for instance, agriculture or forestry (system condition III).

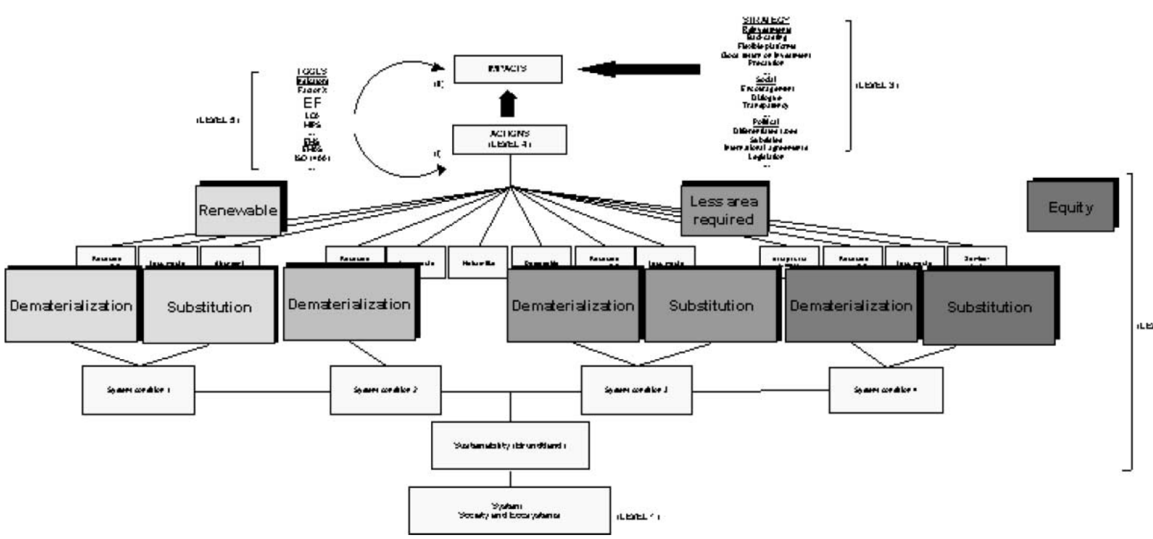
EF is an overall measuring tool to get a tangible overview of our performance with regard to sustainability, and is unique in its capacity to communicate very directly how life style and technical competence relate to such a perspective. EF inherently contains aggregated data concerning dematerializations and certain substitutions under all system conditions. Consequently, it has certain limitations when we are studying isolated flows of society, for instance when various sub-systems are going to be evaluated and compared to each other in a planning procedure. Here, the more flexible Factor concept can be used. Both concepts are relevant for their purposes, and can be successfully applied in a complementary manner.

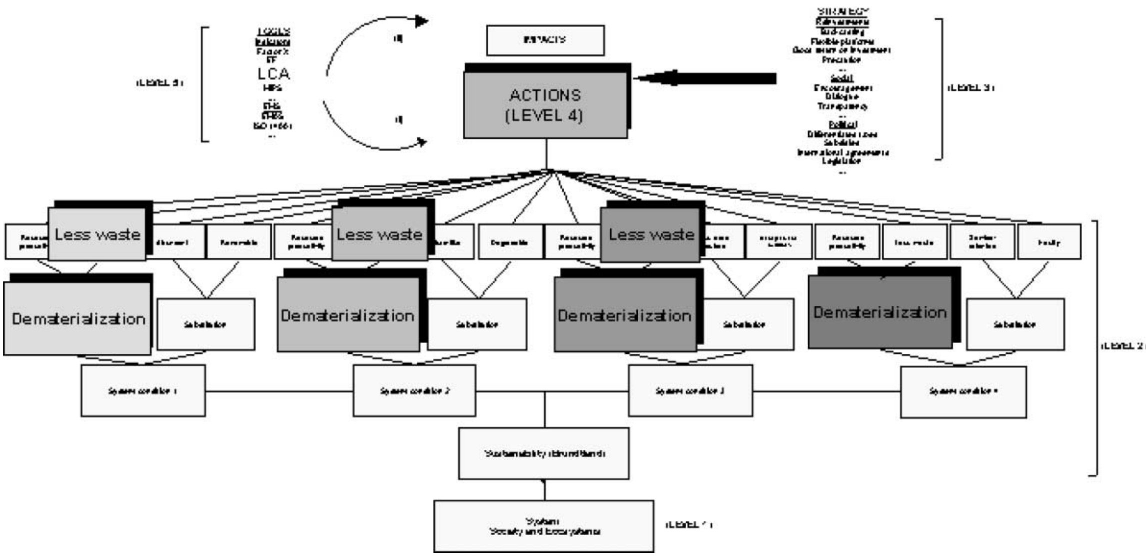
3.4. Zero Emissions

Zero Emissions refers to a combined research and action-based program, launched by the United Nations University (UNU) in 1994 [31]. Following the Zero Emissions Concept total material cycles from intake to emissions should be clarified as a holistic system [32]. Thus, its primary focus is the intake of natural resources within renewable limits and final emissions within acceptable limits. This implies the optimisation through an integrated system of processes and consequently the mimic of the hierarchy of natural ecosystems in the anthropogenic sphere. Thus the concept focused originally on reducing sharply the waste streams generated by industrial and especially agricultural activities through supplementary processes that would turn them into useful products [33,34]. A network on industries through clustering builds integrated systems, in which everything has its use.

In the anticipated “Zero Emissions Society” consumers would preferentially purchase functions instead of material goods and thus be actively involved in the creation of a new service economy, where all materials are automatically sent back to the producers after they lose their functions. The maximization of the residence time of materials/resources in the human activity sphere is another target, since an increased resource productivity is an indirect way of producing less waste. Additionally the design of goods should lead to eradication of the concept of waste [35,36].

In order to avoid misleading conclusions, ZEF seeks to develop Life-Cycle-Analysis (LCA) techniques so that this tool can cover the full aspects of sustainability





and not just arbitrarily chosen data on emissions and energy use [37].

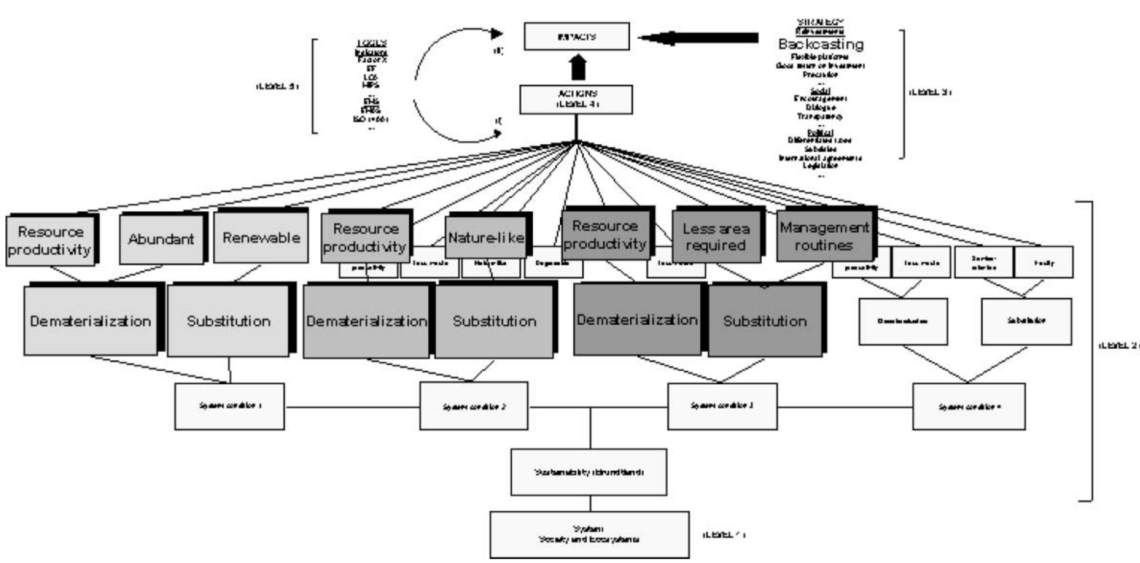
The UNU Zero Emissions Forum — through networking with universities, industry and politics — promotes international multidisciplinary research efforts to analyse trends in society and technology [38]. Thus, Zero Emissions Forum has gathered concrete experience through a number of case studies all over the world [31,34,35,39,40].

3.5. Sustainable Technology Development (STD)

Sustainable Technology Development describes the Dutch National Research programme of the same name, which has sought ways to influence innovative processes and outcomes in favour of accelerating the development of technologies and maximising the contribution that technology can make toward sustainable development. The fact that it takes decades to develop an option for sustainable technology up to a viable product in the market is an essential consideration in the approach of SDT. STD focuses on some well known aspects of sustainability as the primary objectives of planning, and like TNSF, it also puts primary focus on the relation between the objective of planning on one hand (sustainability), and principles for the process to reaching the objectives on the other. More specifically [41]:

- Based on cooperation between public policymakers, business and knowledge institutes
- Bridging the (economic development) gap between business need for "short" term profits and the societal need for research and development on sustainable options for the long term

Thus STD, like TNS, applies backcasting and integrates social tools and objectives as essential elements for planning, and acts as facilitators



- for firms solving their own problems with tools provided by STD and
- for policy makers designing sustainability oriented policies and connected policy oriented research and development programs in cooperation with business and knowledge institutes [42].

The focus of STD has allowed the organization to gather experience as a facilitator and negotiator in many sensitive issues in Dutch industry and environmental policy. Additionally, STD has gathered profound experience regarding technologies in general and also in other aspects of sustainability, for instance higher efficiency and ecologically sensitive land use.

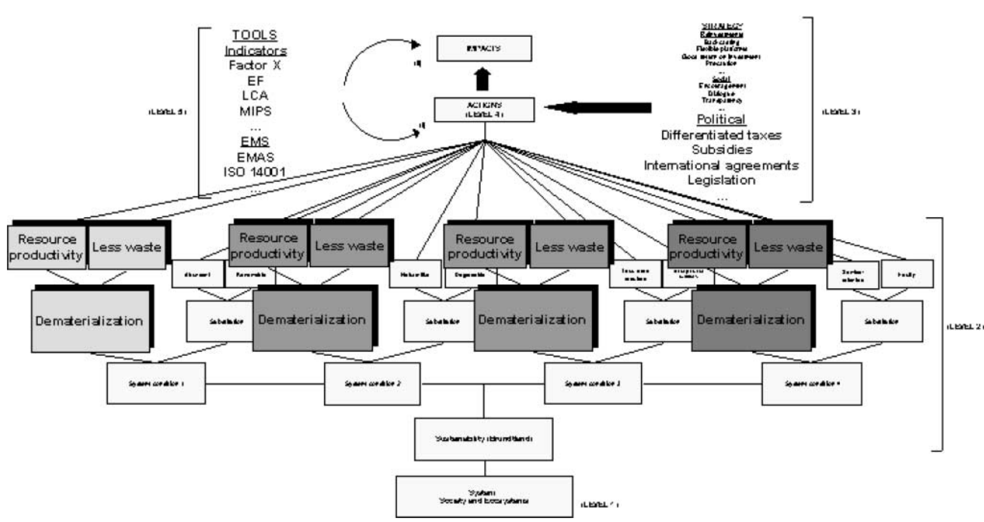
3.6. Cleaner Production

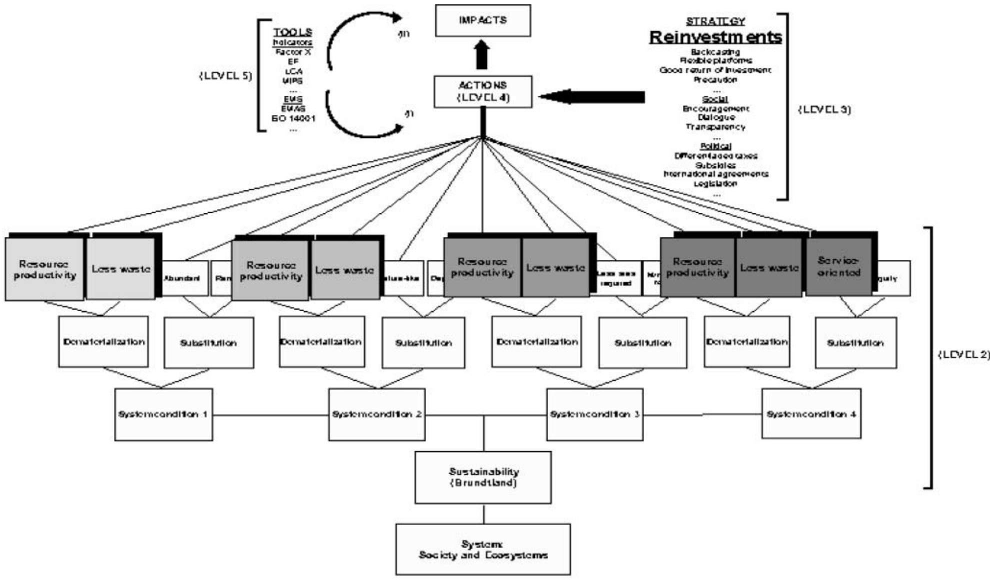
UNEP has promoted, through the Division of Technology, Industry and Economics, a “Cleaner Production” programme. For UNEP, Cleaner Production, is the continuous application of an integrated preventive strategy to process products and services and or to make efficient use of raw materials, including energy and water, to reduce emissions and wastes, and to reduce risks for humans and the environment [43]. “Cleaner Production” leads to the same entry point into the model, and the subsequent intellectual consequences from this, as Zero Emissions Forum. Besides the qualitative focus on dematerialization as such, and substitutions of materials that should be phased out, Cleaner Production has endorsed Factor 10 as a quantitative benchmark for sustainability within the industrialized world.

Because of UNEP’s central position in Society’s international policy making, there are some major differences between Cleaner Production, and the other institutions presented in this survey. As demonstrated by the launch of the International Cleaner Production Declaration [44], the Cleaner Production Programme objective is to catalyse, in all parts of the world, Cleaner Production activities, and to promote the use of similar concepts such as eco efficiency, waste minimization, and pollution prevention. It also aims at facilitating exchanges between cleaner production activities undertaken in the world, and reporting about progress. Every two years an international high level seminar brings together about 150 experts from industry, government, academia from all parts of the world to exchange best practices, and discuss tools and programmes: Those global events are building on the “Regional Cleaner Production Roundtables”. Cleaner Production is more closely tied to policy making at the governmental level than any of the other institutions presented in this survey.

3.7. Natural Capitalism

Natural Capitalism [9] attempts to define and describe means to connect human institutions including business within the flow of natural cycles including ecosystem services. To do so it is necessary to integrate all relevant aspects of society into an economic framework used for decision-making, particularly those aspects that are becoming increasingly scarce, or are at increasing risk. Hence, our “global commons” — the well-being of global ecosystems and the long term quality of life of all people — must be integrated into any comprehensive economic model. Such an economic model recognizes the critical relationship between the pursuit of human productivity, and thus higher income, and the greater use of natural capital. Natural capital includes not only the resources demanded by business and society, but also includes the flow of services that flow from ecosystems that are not monetized or valued. Natural Capitalism describes a set of fundamental assumptions necessary for this integration of economy, ecology and societal demands. These include viewing the economy as a subset of the global environment; future economic growth will be limited by natural capital rather than human-made capital; radical increases in resource productivity





will be necessary to eliminate pressure on natural capital, requiring a full valuation of all forms of capital in market systems, and a shift in focus on services that meet human needs rather than goods per se as a means to address inequalities in income and well-being and reinforce resource productivity. The base assumptions are then applied directly to both short and long term business and governmental decisions as part of an overall societal strategy.

Hawken et al. have introduced four central strategies of natural capitalism for businesses that are located under level two and level three of the model for sustainable development presented in section one (see Fig 1). They aim to move commercial and governmental institutions towards a more integrated and environmentally inclusive approach to economic decision-making. Increased resource productivity extends across the system conditions as a method for dematerialization (level 2). This also fits with today's business needs to eliminate waste and improve efficiency. Similarly, moving to strategies of a "service and flow" economy where the function of business is defined by the delivery of services rather than goods further eliminates the concept of waste on a system wide scale. Focusing on economic services, as opposed to the production of goods, as an end goal will lead directly to substitutions that better and more directly meet human need and in more resource efficient manners. As a subset of system condition four, this change in focus will catalyze resource productivity in line with the other system conditions. Changing the very nature of the materials that flow through the economic system reduces toxicity and ecological damage while increasing the possibility of materials for re-use. Finally, reinvestment in natural capital is pointed out as a key strategic principle (level 3) that businesses must follow as a means to increase the pool of capital that will either enhance or limit future economic growth.

4. Discussion

To have a clear view of the goal is a prerequisite for applying the term "strategy". In very complex systems, like the ecosphere with its societies, this can be a difficult task. For complex objectives, like achieving sustainability, it is even more difficult. However, if the goal is not described on the detailed level, but more generally, albeit completely, by a framework of principles, it is possible and highly advisable to achieve overall comprehension of the objectives, and to generate a strategically defined *direction* to the planning process. Given that there is often a lack of clarification regarding the ultimate objectives of "green work", the indicators of the work are often selected and designed in an equally unclear way [45,46]. A recent study has shown that the indicators decided on in creating an EMS, such as LCA, rarely influence final business decisions [47]. This is in spite of the growing intellectual awareness that proactivity is likely to improve bottom line. It is our belief that one reason for this discrepancy is that the systems perspective proposed in this study, and the integrated and comprehensive strategic planning it allows, is often lacking.

As one step in creating a rigorous and structured overview of the pursuit of sustainability, we have presented a general model of interrelated and essential elements for sustainable development. It has been demonstrated to be helpful in:

- Creating a comprehensive view of sustainable development, so that the neglect of essential elements and underlying principles can be avoided (global perspective on sustainability, ecological *and* social aspects, dematerialization as well as substitutions — including the cultural level),
- Designing action programs that are strategic from a

sustainability perspective and allow a conscious and strategic management of trade offs (based on backcasting from a successful outcome based on underlying principles),

- Selecting and designing tools that are relevant for the strategic approach (not only monitoring activities that are relevant from the current status of the market, but to avoid "dead ends" in the future),
- Shaping tax structures, charges, certificates, labeling, subsidies, custom duties and R&D priorities that can support approaches toward sustainability,
- Planning future export and economic aid policies designed to help avoid the ecological collapse.

Applying the model to a variety of organizations and initiatives has shown that, regardless of the primary focus of the respective organizations studied, other essential aspects of sustainability are generally addressed as a consequence of exploring the primary focus and by integrating a systems perspective of the type presented in the model. While each organization studied may not explicitly address or describe all aspects of sustainability, the convergent evolution observed indicates the need to directly and explicitly integrate principles for sustainability and for sustainable development into ongoing and future sustainability initiatives. Two additional conclusions can be drawn from this:

> Firstly, that there are no major obstacles stemming from the philosophical standpoint or strategic origins of the different various initiatives studied. This creates opportunity for presumptive cooperation. Secondly, since the primary foci are different, perspectives and experiences should be different enough to allow synergies if greater cooperation was established and emphasized.

An experiment of thought: Synergies from cooperation can be exemplified by an imagined enterprise, with the primary objective of approaching a sustainable business model in a strategic way. This entails designing how the enterprise will meet human needs — "service orientation" — within the market and in compliance with the system conditions, i.e. not to contribute to the violation of any of those, and in a way that allows money to flow in even during the early stages of the transition. An example of how these perspectives can be combined in a deliberate backcasting strategy comes from Electrolux's high priority on phasing out CFCs — based on their deleterious impacts on the ozone layer. In doing so, they simultaneously abandoned plans to change to *other* relatively persistent compounds foreign to nature, like HCFCs. These compounds did not fit Electrolux's backcasting perspective with regard to system condition II [10,21], and, thereby, Electrolux avoided a simplistic trade of known problems for unknown ones. Furthermore, these reflections were essential to develop business models that can help the developing world to avoid previous mistakes by the industrialized world in this business sector.

Through a lens of the system conditions the critical flows of today's activities were listed by the imagined firm, as well as the alternative ways of meeting the needs on the market without those critical flows. Quantitative benchmarking follows from this qualitative analysis. The firm then decides to be bold and to apply Factor 10 as the overall guiding principle for dematerialization under each system condition, and as a means to be able to afford some of the essential substitutions with respect to materials and management routines. This, in turn, requires the selection and design of tools to monitor the process.

It follows, that the tools must not only measure the society's or firm's responses to questions like "do we emit compounds that have a very high index regarding destruction of this and that?" but also to questions on the principle level like "do we contribute to decreased concentrations of compounds in nature, decreased degradation of nature by physical means, and do we always contribute as much as we can to the meeting of human needs in our society and worldwide, and with a responsible attitude to all people on whom we have an impact?"

The qualitative analysis of the current critical flows of the firm speaks in favor of applying some form of LCA to get a concise and quantitative estimate of the flows. Depending on the result of the qualitative assessment, the conclusion may be to allow the LCA to keep its qualitative perspective remaining in line with the TNSF model, or to aggregate the dematerialization aspects and relate the result to utility in line with the MIPS perspective, or to develop this tool in line with the Zero Emission concept. To make this choice, all alternatives are first considered.

To stimulate the creative process to come up with attractive business options, triggered by the sustainability analysis, it is decided to make an inventory of successful case studies collected by the various institutions presented in this survey.

Finally, the overall business plan is integrated into a management tool (EMS) like ISO 14001 or EMAS. In this, the backcasting perspective is brought in by making explicit the ultimate sustainability objectives of the firm. These objectives provide the context for the subsequent detailed plan. This implies that the EMS should be made an integral and strategic part of all business decisions, partly by focusing restrictions to avoid future dead ends, partly by focusing business on opportunities future markets will offer. Finally, by integrating a systems perspective with clear objectives based on sound principles, specific decisions, actions and outcomes have been linked to the overall goal of sustainability.

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