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SUSTAINABLE INDUSTRIAL DESIGN METHODOLOGY FOR CHANGE IN A FACTOR 10 DIRECTION

Kristin Støren Wigum and Ole Jørgen Hanssen

Abstract

A future estimation concerning the world population, energy and material consumption and global ecological sustainability, indicates the need for radical changes in products and system development. The background theory is operating with numbers which call for 25-95% (factor 4-20) reduction in material consumption per capita, and 50% reduction in total global extraction of material resources. These numbers are evaluated by researchers and eco-designers in research projects, to explore and construct new procedures for future development. This paper is presenting a suggestion for a new general design methodology divided in six phases, based on the results from a pilot project focusing on the drinking systems in the Norwegian market. The methodology is including three major principles which seem to reveal promising results. These principles appear in the methodology through phase A; including broad and transdisciplinary analyses, phase B; execution of long term (30-40 years) diverse scenario building, and phase C; parallel design of products and systems towards total concept solutions. The paper is closing by proposing further research which explores this thinking as eco-innovation expressed in three categories; the human process and organisation, the methodology with its three principles and finally, the end results as new designs of product and system concepts.

Keywords: Factor 10, Eco-innovation, System and product design methodology

1. Background

The environmental issues are in many occasions hard to grasp, and especially hard to understand concerning the dimensions of the damages, which humans cause nature in an ecologically unsustainable way. We are extracting too large amounts of resources such as materials, fossil based energy, water and soil which are vital also to coming generations. Factor 10 is an expression which reflects the estimation of how the consumption of materials and energy should decrease per unit of prosperity and per capita, in order to create sustainable conditions for future generations. The global total consumption should in the future decrease to the half of the total consumption in 1998 [1]. If we assume stability of the world population counting about 10 billion people in 2040, sustainable solutions for the future must integrate the calculation of the needs for this amount of people. The estimations and definitions of needs and units of prosperity are based on uncertainties, but in spite of these, there is no doubt that we are facing enormous ecological and human challenges for the next two generations, which demand for new thinking and innovation on many levels, in a serious matter.

2. Research for factor 10- system and product design methodology

During the last five years there have been carried out different research projects based on the factor 10-thinking [1],[2]. These projects all have some common procedures and methodological elements. To achieve the changes in society, which this type of research seeks, demand for participation of different drivers for development, although universities or political authorities have been main drivers for these projects to be initiated and developed so far. The theme of the mentioned projects vary, but the use of future scenario building techniques is a methodological element that is presented in all the projects as a method for analysing the long term possibilities or threats, and in some projects for presenting conceptual future solutions. The weak aspects to many of these projects, is the lack of continuity down to the concrete system and product solutions which can be concrete organised and produced in short time perspective. Key factors such as human behaviour, needs concerning social, cultural and spiritual dimensions are also lacking in most of the projects. These are crucial elements in designing for ecological and human sustainability [3]. The factor 4 theory by Weiszäcker and Louvins [2] are exemplifying through different existing products that already through only small changes, there is a large potential in decreasing the material consumption in the life cycle of many product by 90%. If the product is connected to its context and users there are additional possibilities in reduction of material and energy consumption.

2.1 Development of operational methodology towards total factor 10- solutions

A difference between eco-design approach and the traditional industrial design is the constant attention to the interaction between humans, the product and system being designed, and nature. The consequences from the use of the solutions and the total lifecycle of the material products are also of major importance. There is further a longer time perspective included in the more radical eco- design, or factor 10 design which we are discussing here. These aspects are forcing the designer and the companies to bring more than short term economic thinking into the projects. The goal of a new research project should be to develop methodology of a more general character through the case study of a chosen existing system of functions, products and systems. The methodology should be transferable and adaptable to other initiatives in industry, organisations and public authorities.

To secure results with holistic character, the methodology is developed on the basis of transdisciplinarity; meaning interactivity between different disciplines, long term thinking to evaluate short term decisions, and finally interactivity between products and systems fulfilling human defined needs.

2.2. Factor 10 –sustainable drinking systems for the Norwegian market

Norwegian businesses, Oestfold Research Foundation and Norwegian University of Science and Technology have through a continuing research project, deeply studied the factor 10 theory, discussed methodology, eco-philosophy and eco-design as such. The results can be divided into different categories, which are of both general and specific character connected to the case study focusing on drinking systems in Norway. Two phases of the study are completed [4][5] and the third phase is under preparation. The three different phases include: 1) the systemising of factor 10 information, LCA-data from the lifecycles of drinking systems in Norway, cultural data, mapping of scenario techniques, and discussion of the new factor 10 visions for drinking systems, based on the ecological problems found in the analyses. 2)

Trend- and marketing analyses, future scenario building with companies, and discussions of conceptual strategies for the new concrete solutions, short and long term. 3) This phase will be concrete projects based on the two first phases, mainly in close relation to the different companies and network co-operations. The next sections of this paper will reveal and discuss the results and experiences from the two first phases of the two first phases of the project.

3. The results presented as general methodology, explained through the specific results in the case study

The factor X design process differs from traditional eco-design, by looking at a situation in society or a concrete ecological problem, instead of an existing product as the starting point. There is in the beginning no single reference product, but there may be ”reference functions” or “reference activities” in a broad sense. As an example, future office solutions would be focusing on the working activity. A sustainable bath would not be rooted in the use of water and energy, but in the context of basic needs and functions which the bathroom is serving. In connection to the discussed research project, NTNU diploma students have worked intensely on this methodology [6][7][8].

The working process in the research project can be explained as a very open process, where all possibilities where included, whereas the companies and the researchers in co-operation extracted the interesting areas for problem definitions and system borders (Model 1, phase A). The analyses of functions, systems and products where founding a base for further conclusions which sharpened the problem definitions even more. The use of LCA in this introduction phase of the project is mapping the problem areas connected to the different types of drinks and user consumption. The outstanding problems can therefore be connected to the different stages in the lifecycle of the drinks in general, and some problems to the different types of drinks offered in specific. The user needs and consumption patterns where also evaluated. This information gave guidelines to the project of what to give priority and focus, down to the level of concrete solutions.

The long time perspective is expected to be taken care of in the extensive work with future scenarios (phase B). At this stage of the process the participants have the possibility to dive deeper into reflective thoughts, disconnected from daily short term actions. The results of scenarios are supposed to represent different future climates in political, economic and social perspectives, and not whished directions. Further the scenarios in the pilot project, where used by the researchers to evaluate their possible threat and promising value for the companies attending the project, and new ideas for sustainable concepts.

Development strategies where extracted from the life cycle analyses in Phase A, which gave direction of the idea generation for problem solving areas, placed in the framework of the different scenarios. Research project part 1[4] and 2[5] represent in the following methodological model, phase A, B, C . Phases D, E, and F shall be continued in a part three in close connection to specific companies, with common goals towards total system solutions.

A
Analyses

- Choice of need and system, users, market, reference functions/activities/prod.
- Company analyses: future perspectives, historic development
- Problems, needs, goals, factor 10 possibilities/ changes towards sustainability, global connection

B
Background scenarios

- Future settings, development of background scenarios for the society, companies and people.
- Introduction of sustainable "major" principles, development strategies, visions for new systems

C
Design oriented scenario

- Redefining the problem. Exploring the problem: System concept development, principles for solutions, introduction of more specific sustainable principles.
- Design criteria . Systems: functional totality, products involved, served satisfaction compared to needs and expectations…change of needs??
- Market and user evaluation.

D
Concept development and evaluation

- Generating ideas, development of products in the system , Products: functional, aesthetical, ergonomically, materials,….. system and service organization/administration
- Concept evaluation in connection to guidelines and sustainable principles. Collection of more specific LCA-data.
- Selection of concept for further concept development and testing.

E
Detailing

- Improvement, detailing in connection to sustainable criteria: products, service, system
- Preparation for production, communication and operationalisation

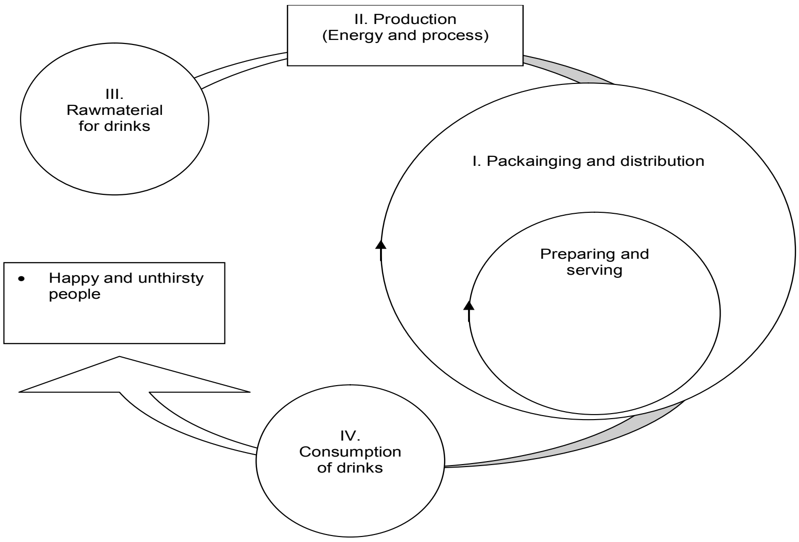
F
Preparation for operation-alising

- Realisation, launching (further development)
- Management of system
- Maintenance, responsibility through life cycle

Model 1. The main activities of the suggested methodology is generalised and divided into 6 phases

3.1 Phase A Analysis

The needs, desires or functions are placed in a global perspective, looking at the environmental impact connected to existing solutions, the history of the different product solutions and the future drivers for new solutions, with the focus on human ”real” needs. This part of the introduction phase in the design process is filled with input from many different fields of research and practical experiences. Different types of scenario building (phase B and C) have been good methods in the projects, to puzzle this wide type of information together in interaction with the problem definition, to explore the most interesting possibilities and directions for future solutions.



Model 2. Abstraction of the lifecycles interacting in the drinking systems

As example from the pilot case; the ecological impact from the drinking systems of today was screened by gathering data of the different partial systems connected in a reasonable holistic picture. It included drinking products, such as spring water, coffee/tea, milk, mineral water, fruit juice, beer, wine and spirits. Many of the data are still under review and are not sufficient, but at this point there could be extracted some important sources to great ecological impact from these systems:

- The traditional agricultural systems which are delivering many of the basic ingredients to the different types of drinking products are causing many different types of ecological disturbance (such as eutrophication and toxicological impact).
- Health risks connected to not sufficiently cleaned drinking water.
- Large leaks in the drinking water distribution net, and unnecessary high degree cleansing of water (e.g. used in manufacturing processes)
- Transportation(fossil fuels) and use of packaging for the end products (material waste)
- Use of energy for cooling of drinking products during the product life cycle

These problem areas where connected to the functions and activities in the reference system. Actual methods for problem solving, where introduced superficial at this stage, placed in a table (table 1) in connection to the functions and problem areas. At this early stage of the project the methodology is revealing several possible sub-projects for new system and product developments.

Table 1. The analyses in phase A is mapping the major connections between the existing system functions and related problem areas. The table is also systemising possible methods for problem solving

Functions and activities	**Problem area**	**Actual method for problem solving**
Main function: Relief thirst	Unhealthy pattern of drinking consumption Keep the quality of drinking water	Offer more precise volumes of drinks Promote water as the best alternative Reduce the misuse of water, reduce the need for maintenance of water pipes and resources, look for local drinking water solution
Consume drinks	Waste, packaging and remainders	Simplified recycling system, holistic design Tailor made packaging
Prepare drinks,	…………………	…………………..

Through literature study such as “The Natural Step”[9], workshop and cultural studies, the project group sketched visions for the new Factor10-drinking systems. They are following as a consequence of the environmental analyses, and should lead in the direction of

- A system for drinks which cover physiological basic needs in the population, fulfill social and cultural functions, and is at least ten times more resource and environmental efficient than solutions of today.

  This can be realized through such as

  - higher consumption of spring water as substitution for other less environment friendly and nutritious drinks
  - customer selection of products with the lowest resource and environmental impact in production and distribution
  - use of packaging and distribution with the lowest wastage of main product (drinks) in distribution, reuse for suitable packaging, and as high degree of recycling as possible for disposed packaging

The vision should be supported by more detailed strategies for system and product development.

3.2 Phase B Background Scenarios

The future scenarios used in this research, are based on both forecasting and back casting methodology. This includes both statistical continuity (forecasting) and radical systems changes (back casting). Four scenarios have been built, concerning economy, technology, health, demographic development, political climate and educational level in the population. These scenarios are not presenting the whished future, but different possible futures. The scenarios are then used as framework to generate new system and product concepts which point in different directions of solutions. The project of drinking systems produces this way a number of differentiated sub-projects. The further development operates still including the wider perspective, in order to discover possible synergies between the subsystems.

The four scenarios (table 2) built in the pilot study, represent different values and priorities in the use of technology vs. human responsibility and activity. This implies for example the use of high-tech vs.-low-tech solutions. As a sustainable principle, the diversity of solutions points to the importance that each of the scenarios represents the differences of human personalities and needs in the future. The manifold of solutions can therefore be thought of as the variety of existing concepts within a society at the same present.

Table 2. The four main scenarios from the pilot project are characterised by extreme variations of political, economical and social drivers. Each scenario therefore contains a different atmosphere which in this table is illustrated through typical human characteristics, products and systems that are representative.

Scenario	**Characteristic user situations and human personalities; life phases, life situation and lifestyle**	**Typical product/systems which might be representative in the scenario**
1. Technological optimism (Turbo-techno society) High technology in focus and great fascination of the digital and synthetic.	• Dominating age 20-35 • Desirable with many and more superficial social relationships • No Children, travelling and outdoor life • Self realisation through work and technological networks • Dining out with or without friends	• ”Smart-house”, • Small electronic and mobile units for communication, work , security etc. • Data-chip pin on the body to measure the ozone layer, sun and emissions
2. Cultural and political diversity (Society of manifold) Great variation between high- and low-tech solutions. Individual contribution is characteristic for the products and systems	• 50-70 years of age is dominating the society from ca 2015-230, multicultural backgrounds • High interest for other cultures both in work and private • Winter-tourists in warmer countries • Much work in NGO’s • Focus on sharing facilities • Good economy	• Service products is commonly used • Public transportation has high priority • Focus on justice, ecology and high quality
3. Economic breakdown (The Buble broke) Simplified solutions, preferable are low tech and minimised product life cycles, such as personal owned packaging brought to the stores.	• Lower education • Less travelling, high involvement in local conditions • Focus on own loved ones (family and friends) Closed outwards, but more open inwards (socially and political?) • Low budget with focus on basic needs. Traditions and roots have	• Basic resources such as seafood and fresh water have high value • Total productivity (including unofficial) is the base for BNP • Less technology focus • Local solutions have high priority in substitution for centralised systems • “nature-products”

	re-entered peoples life	
4. Increased insecurity and vulnerability (The isolation society) Advanced control and use of high-technology to secure the quality of all systems, e.g. organic recycling. Security has a higher priority than economy and ecology.	• Protectionist attitudes • Personal development is reduced due to insecurity and fear for the future • Meals are enjoyed at home, only lunch at work	• All products are "security-declared". This includes food and other types of products. • Close and loyal relationships between producer and consumer • High-tech mobile control-equipment is just as common in 2003 as the cell phones in 2003. • Synthetic secured production processes are preferred rather than products from natural processes.

3.3 Phase C Design oriented scenarios

At the phases C and D, concept development and evaluation is performed. The designer and the project team must develop systems which involve several products designed in parallel to fulfil functions in new systems. A schematic evaluation can be used in the idea generation to keep an overview and maintain the connection between the products in the system (table 3).

Exemplified in the pilot study we look at the subsystem of the lifecycle of packaging, focusing on the kitchen and how the packaging solutions will effect the possibilities of closing the material loops through a good solution for waste and material treatment in the kitchen. We assume that the kitchen (private and public) in the future will become even more important in the chain of material loop closing. The participation of the public and households in loop closing, is today seen as one of the weakest links in the material chain. The legislation and demands for recycling is expected to increase in the future, this has therefore to be of concern in both the solutions for distribution and packaging, and the systems designed to treat the material through the loops.

Table 3. Parallel design of products and systems. The table is to be read by rows. Each row is presenting harmonised solutions of the connected products and systems. The technology and user interface is characterised by each actual future scenario.

Scenario/ product and system area	Design of packaging	Chosen principles for the recycling system	Kitchen solutions for loop closing
1.Optimistic and technological atmosphere **(Turbo-tech society)**	High-tech focus is dominating and the fascination of digital and synthetic solutions is large	Different stakeholders gather the sorted material(waste) available	Use of data chips, biotech and decentralised processors, favourable placed in the private homes
2.Cultural and political rebirth **(Society of manifold)**	Large differences between high- and low-tech solutions. The packaging is characterised by the content.	A manifold of solutions is possible through individual concepts and deals with stakeholders and responsible authorities	Combination between digital, biological and manual solutions for high flexibility. Service solutions frequently used
3. Economic brake down **(End of the Bubble)**	Simplified low-tech solutions and minimalistic lifecycles, such as private owned	Private delivery to local connection points, developed with high functional and esthetical value	Manual systems based on clear visual labelling for local sorting and gathering/delivery. Reduction of waste as main focus
4. Great unsecurity and vulnerability **(Society of isolation)**	Use of high-tech solutions to secure the quality and avoid sabotage of the system. Security has highest priority.	Automatic gathering of all material and waste, sorted by professionals for further sale and use.	Computer technology, centralised and automatic, system, minimal responsibility placed by the private household.

In the light of the different scenarios, the fulfilment of functions and activities, can be explored parallel in simple overviews as shown in table 3 for closing loops by certain kitchen solutions, packaging and recycling systems.

3.4 Phase D Evaluation of the factor 10 solutions

The further and more specific work concerning the drinking systems will include work which may lead the companies to ”think out of the box” and see new possibilities through new perspectives in their market.

The solutions can be designed in a promising way, through the use of sustainable principles and eco-design strategies, but in a factor 10 perspective they are also evaluated in connection with the surrounding systems. In the case of the kitchen systems and packaging, it would be the total amount and reduction of consumption and waste, and % of recycled material per capita. This will also depend on design qualities such as usability, and expectations in the market.

A calculation may be made of the clear material aspects to the solution strategies, but concerning the behavioural changes, experiments and surveys must be considered for clearer implications for evaluation. The global perspective in the theoretical background material of this type of projects, must be transferred to the local and practical situations. This contributes to complicated judgements, for instance, how simple can a function or activity be, and still be developed through the factor 10 design methodology? Do more businesses have to be involved or can it be only one business with a single product type?

The water distribution, including drinking water in Norway is based on underground pipes leading from natural resources to the single households. The total amount of water is cleaned or kept to the standard of drinking water, even if the water will be used for flushing the toilets, or it just leaves the pipes through leaks in the system (ca. 30 %). The amount which is actually used for drinking is 0,7 % of the total use of water entering a household, per person, and 28 % is used for activities in the kitchen. In a future scenario the water system must probably be redesigned in order to sustain the level of water quality which is needed. This affects the products concerning water distribution to the households, and may demand for new products, such as packaging and system services, for drinking water delivery. Many of these cases are complex and demand for co-operation between different companies and authorities. Still single companies likely can contribute within the larger picture through more informal connections with other participants.

4. Discussion and proposals for further research

This pilot study has carried out the phases A, B, C and partly D, in the new design methodology. Partly D, E and F are remaining. These phases will probably reveal the consequences of this broad approach of system and product design. In addition to the concrete design methodology, there seem to be two other important parameters for successful results. These are the human processes and the project organising. Further research may include interviews with participants in the discussed projects to map the individual experiences and professional development. The hypothesis for further research may be in the direction of the following descriptions.

4.1 The synergy between the human process, project organisation and the design methodology

The transdisciplinary approach in a teamwork demands for good and clear communication. The definitions of sustainability and understanding of the ecological and human problems was growing during the work process in the pilot study. This means that the steps in the process will become clearer along with the effort, and it is therefore hard to define the total project on forehand. The participants may also have different motivations and ambitions which affect their contribution to the project. It is therefore very important, to be aware of the individual diversity both in the project planning and the execution of the project.

There seem to be barriers in the culture and traditional corporation thinking, integrating a factor 10-project in the agenda of a company. Short time perspective in planning and lack of proactive ambitions connected to sustainable development are parameters which often follow each other. Further, an internal competition within the company and lack of internal communication, are barriers to co-ordinate more total system thinking. Finally a closed image towards other businesses, is not inviting for synergy-effects between companies.

It is a great challenge to combine a scientific approach to a more practical development process. There are different rules and systems of working within the different fields which shall be combined. It is important to stress the effort in connecting the results from deeper fragments of study to the more all round idea generation and concept development. This is to maintain the holistic focus in the development of new sustainable solutions.

4.4 Eco-innovation in three categories

The term eco-innovation, seem to appear in both non-material and material character. The process of a factor 10 project is depending on an open climate where companies and the people representing these, are generous in their information flow, but also in the interest of learning, discussing and exchanging views. The methodology which has slowly been developed through the pilot project, is a result of the transdisciplinary approach which seems to be demanded for these complex questions about sustainability, global consumption and future solutions. Through the process of reading relevant literature, gathering LCA data for drinking products and systems, mapping trends concerning consumption, marketing, packaging and production, the team members found new perspectives. This has further been explored through scenario techniques with future- and long term thinking, which gave guidelines for development strategies. This revealed the need for cooperation between companies and organisations, in order to move in a factor 10 direction. In light of these experiences, the *eco-innovation* can be put in the categories of 1) human process and project organisation, 2) methodology of transdisciplinary character, and finally 3) results and designs of new products and systems.

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Kristin Støren Wigum, Industrial Designer/PhD-candidate, Department of Product Design Engineering, Norwegian University of Science and Technology, Kolbjørn Hejesvei 2b, 7491 Trondheim, Norway, phone: ++47 73 59 01 00/82 80, fax: ++47 73 59 01 10, kriswig@design.ntnu.no, www.design.ntnu.no, www.indecol.ntnu.no