Development of Environmental Performance Indicators for ICT Products on the example of Personal Computers

Technical characterisation phase (Work package 2)

Methodology to translate definitions to technical characteristics, application of QFD to technical characterisation, implementation / handling of technology shift

(short version of Deliverable 2) **July 2005**

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1. General description / Introduction

The EPIC-ICT project will develop a method for the definition of environmental performance indicators for ICT products. These indicators will relate to easy to define product properties. In order to integrate the environmental impacts consistently and scientifically well based, the methodology of Life Cycle Assessment (LCA) is applied. The product properties are derived from the technical specifications, the functions and components.

Following this, the goal is to derive environmental indicators, which are on the one hand based on scientific know-how but on the other hand easy to apply and to control in practice. For an application of these indicators for Eco-design purposes, the scientific results of an underlying technical and environmental analysis therefore have to be “translated” into easy measurable and controllable technical specifications for both the respective product designers and policy decision makers. The path from the scientific results to implementable indicators has to be a reliable and comprehensible method.

Such a method is developed in EPIC-ICT. Core of the method is - besides the LCA know-how and data - the adoption of the method of Quality Function Deployment (QFD) for the purpose described above and the use of Generic Modules, parameterized flexible and reliable partial LCA models of electronic parts and sub-assemblies. The EPIC-ICT method will be carried out later in the course of the project at the example of personal computers.

Technical functions, components, EoL issues or use patterns have to be translated into technical characterisations in order to allow the modelling of the product’s life cycle. This phase breaks down functions, components and life cycle properties to single electronic components, such as ICs or printed wiring boards (PWB), single materials, such as housing materials or components’ inherent materials. Other aspects not related to materials or components will be related to technical or physical properties in a quantified manner, such as the power consumption of the use phase in MJ or the grade of recyclability in weight percentages.

The EPIC-ICT method adapts the “House of Quality” known from Quality Function Deployment (QFD) and translates customer demands into technical properties or specifications in a first step. It is adapted to the purpose to translate product components, product parts, functions or customer demands into single technical features or single electronic components, according to the product designer’s language and possibilities. Secondly, results from environmental analyses are linked to these product specifications in order to receive the environmentally and technically most relevant product specifics: Life Cycle Indicators. Therefore the indicators are also applicable for communication with policy makers and proving continuously environmental product improvement.

Deliverable 2 is the report on findings from work carried out within work package 2 “Technical characterisation phase” and contains the results of the respective tasks.

Tasks of work package 2 are

Task 2.1 Adapt a methodology to translate definitions from WP1 to technical characteristics (QFD)

Task 2.2 Define and apply QFD from functions/customer demand to technical characterisation

Task 2.3 Implementation/handling of technology shifts

2. Scope of the QFD methodology

Before the QFD method could be adapted and used in this EPIC-ICT project, some issues have to be discussed and some assumptions to be made.

The developed method within this project for the definition of environmental performance indicators should be applicable for ICT products. ICT products are mostly complex products and have more than one component-level which has to be considered (e.g. main components, subcomponents, materials). Therefore it is difficult to develop a method which includes all dependencies between the considered components. The EPIC-ICT method is developed for general product design and exemplarily carried out at the example of PCs. For this example it has to be considered that there exist different PC types and many application possibilities of the PC types (e.g. gamble or office PC or desktop or notebook).

The different types and application possibilities are reflected in the customer demands. These customer demands define the setting of the technical characterisation of a PC. The technical feasibilities of the components and the restrictions of the designer limit in return the requests of the customer. Therefore the method of EPIC-ICT should be able to express the dependencies of technical characteristics and customer demands. The demands of the customer should be considered as well as the technical feasibility of the components.

The ICT product PC needs a definition of the correlations of main components and subcomponents. It is necessary for the method to know which subcomponent is part of a main component. Therefore expert knowledge is necessary to choose the most relevant parameters according to the different PC types. Considering such a difficult and complex product it could be possible to extend the list of parameters with some special parameters like precious metals in this case. This extension is only feasible with expert knowledge.

The method demands also to define the interactions of the technical characteristics (what is the influence of changing a subcomponent?). Expert knowledge is necessary to define these dependencies and the interactions of the technical characteristics.

For the environmental analysis of all items of the product’s life cycle (components, materials, processes etc.), information in LCA datasets for all defined technical parameters have to exist. An approach that anticipates that some aspects in LCA may be possibly negligible due to cut off criteria, without having analysed it before, is mostly not acceptable. The application of cut off criteria must be based at least on expert judgements, sensitivity analyses or data assumption, but as best on base of full LCA data. It may be that not for all chosen items LCA datasets exist. Therefore it is necessary to apply an appropriate approach, which solves the trade-off between efforts, cost, expert judgements, cut off criteria and data acquisition (see chapter Generic Modules) and it is necessary to create new datasets in an LCA software

based on information of stakeholders, industry and available technical information relating to the life cycle of the product.

Another problematic point considering the method to be developed are the different units of the chosen physical metrics. Some parameters are given in mass, some parameters in area or some parameters in amount. For a final ranking it is necessary to set the units of these physical metrics in relation.

Crucial for the user of the method is that the expert knowledge necessary for a sound information basis, is combined consistently and results in meaningful and applicable indicators, reflecting the highest improvement potentials.

3. Introduction to QFD Methodology

“QFD provides specific methods for ensuring quality throughout each stage of the product development process, starting with design. In other words, this is a method for developing a design quality *aimed at satisfying the consumer and then translating the consumers’ demands into design targets* and major quality assurance points to be used throughout the production stage.” (“QFD: Integrating customer requirements into product design” by Yoji Akao)

Quality Function Deployment (QFD) is a method to define customer needs or requirements and translate them into technical characteristics in order to produce products that fulfil those needs. The "voice of the customer" is the term used to describe these customer needs or requirements, which are gathered in a variety of ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports etc. Once customer needs are collected, they have to be evaluated concerning the customer priorities.

In the next step, with the help of engineers/designers, also known as “Voice of the engineer”, the "whats" (needs) will be translated into "hows" – the product requirements or technical characteristics to satisfy these needs. The technical characteristics have to fulfil the following criteria:

- Global – must not constrain design alternative to one technical approach
- Meaningful – shouldn’t be abstract
- Measurable – must define a target value

The Quality Function Deployment methodology involves four basic stages.
It begins with product planning, where the “whats” will be translated into “hows”; it continues with design planning, where the critical product requirements have to be implemented into construction characteristics. Next, construction characteristics have to be transferred into process and parameter characteristics in a quality plan process. Finally, on the basis of these characteristics a job and testing instruction will de determined.
This is a useful methodology used by product development teams to support a concurrent engineering or integrated product development approach.

The QFD methodology allows that either all four stages are used or only a few. It is also possible to extend the amount of stages and more than four stages are used.

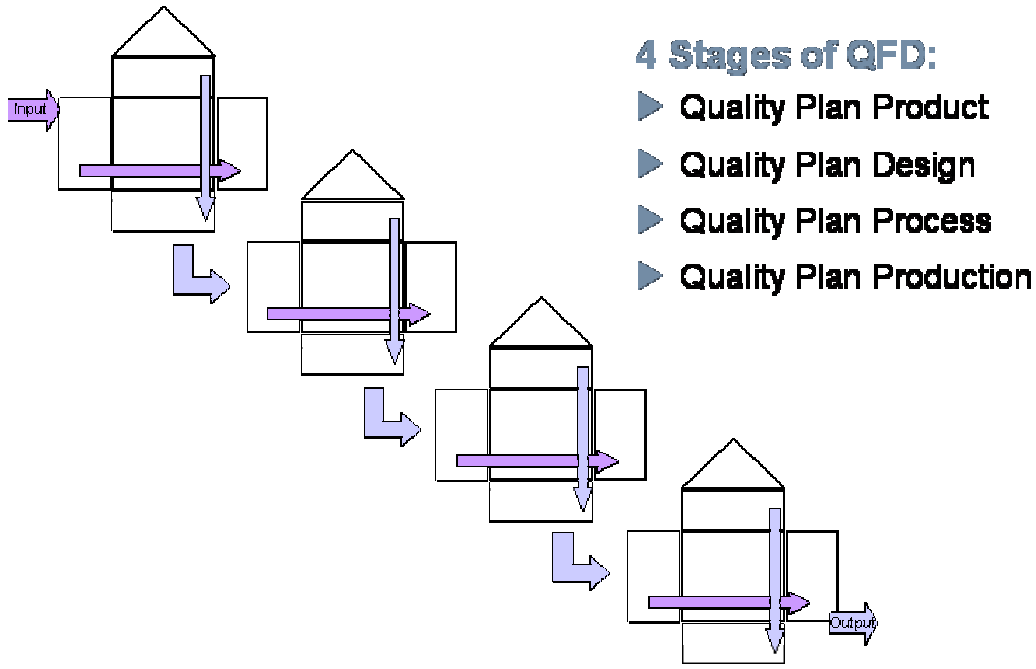

Figure 1: The stages of QFD

Each stage of QFD consists of one or more matrices (HoQ – House of Quality) that are prepared to overcome issues during communication between the product and process planning and design information [1]. An example of such a matrix is represented below:

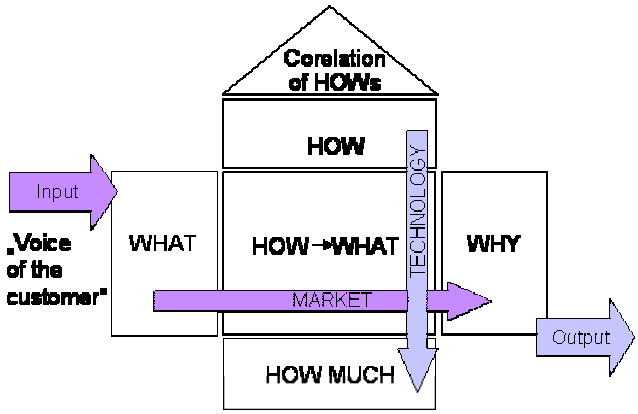

Figure 2: House of Quality (HoQ)

[1] Used literature and internet sites:

1. „QFD: Integrating customer requirements into product design" by Yoji Akao
2. International Council for Quality Function Deployment http://icqfd.org/
3. QFD Institute http://qfdi.org/
4. QFD Institut Deutschland e.V. http://www.qfd-id.de/
5. Das 4managers.de http://www.4managers.de/01-Themen/..%5C10-Inhalte%5Casp%5CQualityFunctionDeployment.asp?hm=1&um=Q
6. „Absolute Kundenorientierung durch QFD - Quality Function Deployment" von Dipl.-Ing. Jutta Saatweber
7. QM-Infocenter http://www.qm-infocenter.de/qm/default.asp
8. Product Development Forum http://www.npd-solutions.com/qfd.html

4. Adaptation of Methodology for EPIC-ICT

Typically Life Cycle Assessment (LCA) is used to determine the environmental impact of a product. LCAs are however specific, and particularly for complex products, such as many ICT products, LCAs are time consuming and thus costly to be applicable for any specific product type and, thus, finally not applicable to define easy to calculate indicators. Oppositely, it is known that sometimes only a few key product properties determine the main life cycle impacts of a product.

Goal of EPIC-ICT is to develop a method to determine life cycle impact indicators for ICT products. The EPIC-ICT method developed makes use of:

- QFD (Quality Function Deployment)
- Full LCA
- Generic Modules

4.1. Customer demands and Technical Functions

In Deliverable 1 the customer demands for personal computers were researched. It was decided to only focus on the customer demand towards the functionality of a personal computer. General and overarching demands to the personal computer by the customer such as adequate price, good quality and good durability, good design (nice looking, but also space saving and easy to clean), low noise, easy to upgrade, inexpensive to repair, etc. have been deliberately left out. It was therefore agreed to adhere to the following customer demands:

- Internet access
- E-mail
- Office tasks / productivity applications
- Multimedia
- Gaming
- VoIP

In Deliverable 1 also the technical functions have been researched. The technical functions of a personal computer are defined by its hardware. Therefore the term “technical functions” has been translated as “main computer assemblies” for this project. It was therefore agreed to adhere to the following main computer assemblies / technical functions:

- Motherboard:
- Central processing unit (CPU)
- Hard Disk Drive (HDD)
- Random access memory (RAM)
- Graphics card
- Sound card
- Drives: CD, DVD or Floppy
- Ports
- Chassis
- Power Supply Unit (PSU)
- Cooling system

Other main computer assemblies used for input/output are defined as:

- Monitor
- Printer
- Speakers
- Keyboard
- Mouse

4.2. QFD House Demands & Assemblies

Goal of this QFD house is to determine type of computer to be assessed (e.g. Office, gamer, multimedia). Thus apples can be compared with apples. In this QFD house assemblies can be further be broken down into possible versions like onboard graphic card vs. two graphic cards or CRT vs. LCD.

An example of such a QFD is pictured below (figure 3).

Office PC			Motherboard		Central processing unit (CPU)		Hard Disk Drive (HDD)		Random Access Memory (RAM)		Graphics card			Sound card		Drives: CD, DVD or Floppy			Communication Ports		Chassis			Power Supply Unit (PSU)		Cooling System	
		Customer Importance	**SFF; highly integrated**	Perf. MB; numerous ports	**Low voltage CPU**	**High performance CPU**	**Small HDD**	**Large HDD/HDD array**	**1 module**	**4 modules**	**onboard Graphics**	**Graphics Card**	**SLI Graphics cards**	**onboard Sound**	**Sound card**	**Optical Drives**	**Rec./-writable Opt. Drive**	Floppy	**USB**	**Ethernet**	**SFF chassis**	**Large space tower**	**Stylish case**	**Silent PSU**	**High Wattage PSU**	**Efficient Cooling System**	**Silent Cooling System**
Customer Demands / Requirements	**Internet access**	9	9	0	9	1	9	0	9	0	9	1	0	3	0	0	0	0	1	9	9	0	1	9	0	1	9
	E-mail	9	9	0	9	0	9	0	9	0	9	1	0	0	0	1	1	0	1	9	9	0	1	9	0	0	9
	Office tasks / productivity applications	9	9	0	9	1	9	1	9	1	9	1	0	3	0	9	9	0	1	1	9	0	1	9	0	1	9
	Multimedia	1	3	3	3	3	0	9	0	9	1	9	0	0	9	9	9	0	9	9	3	1	9	9	1	3	9
	Gaming	0	0	9	0	9	0	3	0	9	0	3	9	1	9	9	9	0	9	3	0	9	3	0	9	9	1
	VoIP	3	1	3	3	3	3	1	3	1	9	1	0	9	1	0	0	0	9	9	9	0	1	9	0	3	9
	Importance (absolute)		*249*	*12*	*255*	*30*	*252*	*21*	*252*	*21*	*271*	*39*	*0*	*81*	*12*	*99*	*99*	*0*	*63*	*207*	*273*	*1*	*39*	*279*	*1*	*30*	*279*

Bold Product (category) specific fields
Italic Methodologically fixed / automatically calculated
fixed!
to be filled in by marketing (manufacturer)

Figure 3: QFD House Demands & Assemblies

4.3. Assembly Impacts and Ranking

Once the type of computer to be assessed has been determine in the first QFD house other actions are carried out. These next steps are not QFD houses. In the next step the main computer assemblies have to be ranked in terms of their environmental impact over the life cycle. Use phase and EoL are included on the same level as main assemblies in this analysis. This needs to be done with an LCA. However, this LCA needs to be done ONLY once for each (sub-) category of products (not for every product)[2]. The LCA of a PC from Task 1.1 can be such an example.

This LCA, which is focused on a product (sub-) category, will demonstrate which *assemblies* have the highest impact and the highest potential for improvement (80/20 rule). Dependencies within assemblies need to be regarded to determine how these assemblies are depended on each other or influence other assemblies.

4.4. Components Impact and Ranking

After determining the main computer assemblies, they can be further broken down into their main components. An example could be the motherboard, which has the PWB, actives, passives, connectors etc. as main components. In this step, design considerations on a component specific level are considered. Therefore not only the qualitative information on the types of the main components of a main assembly but also the quantitative information of the amount / mass is required.

Environmental assessments of components can be done using Generic Modules. Thus, Generic Modules have to be made only for a limited amount of components. These Generic modules are based on a limited set of physical metrics (e.g. number of layers, size of PWB). Generic Modules are flexible since parametric models – changing the parameter(s) adapts the Generic Module to the specific case.

This step will demonstrate which components have the highest impact and the highest potential for improvement (80/20 rule). The physical metrics of the high impact components (of the high impact assemblies) can be taken as environmental indicators for the product.

Interdependencies between sub-components or between main components will be as well considered (see below: 4.5 Life Cycle Indicators).

4.5. Life Cycle Indicators

The physical metrics of the high impact components (of the high impact assemblies) are taken as indicators. Before using these indicators the possibilities for changing issues need to be taken into account. Issues to be regarded are e.g. can issue be changed technically and practically? By how much?. These restrictions may be caused sheer technically (e.g. the only material fulfilling the purpose). They also may be caused by legal restrictions, cost restrictions, contracts etc. To address and implement these restrictions, the EPIC-ICT method takes a so-called “likelihood to change” into account.

[2] Product category is determined here by the different customer demands, e.g. office PC, multimedia PC etc. The product is here the specific regarded PC, e.g. Dell Optiplex 280.

Also dependencies within indicators need to be taken into account. E.g. If indicator A (size PWB) changes, how does indicator B (number of ICs) change? If these dependencies are known and also are known to being of relevant high magnitude, they will be as well considered. In the EPIC-ICT method these relations are named “Major known dependencies”.

The number of indicators, which reflect the “opportunity for change” for a certain product category is expected to be maximum 12.

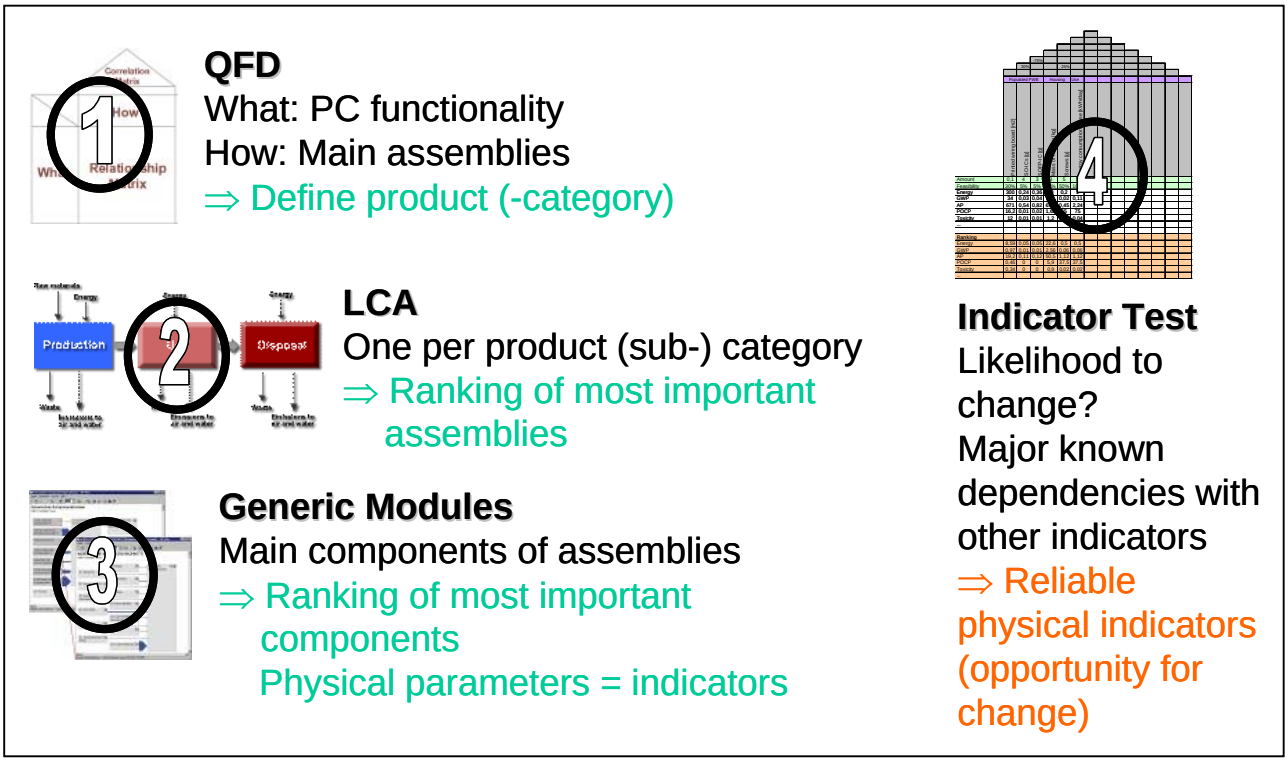

Figure 4: Overview of the elements of the EPIC-ICT Method

4.6. Conclusion

- The using of the QFD method with customer demands and assemblies enable to determine the type of computer.
- By using one LCA per product category a ranking of the most important assemblies can be made.
- A ranking of the most important components of the most important assemblies is possible by using Generic Modules.
- The physical metrics of the high impact components (of the high impact assemblies) can be taken as performance indicators.
- The ranking and the performance indicators will also demonstrate the improvement potential for the designer.

5. Technology Shift

A further requirement of the method is the ability of involvement of technology shifts corresponding with environmental results as effects from technology shifts. Technology shifts by definition are changes of parts, components or technologies, which go beyond a mere progress or trend in developments. Often it is set by a cut in kind of descending of an established technology and rise of an exchanging entirely new technology. Examples are records, CDs and dematerialised mp3 storage media or the shift from CRT to plasma and TFT monitors.

With view on the description of the method in chapter 4 it becomes obvious that almost all components, parts and (sub-) assemblies can be implemented. Pre-requisite is the respective knowledge of the technology in order to be able to implement technological interdependencies, definition of materials, manufacturing processes and other relevant information, which define the part or technology sufficiently. Also a respective LCA model in kind of the Generic Modules is required in order to implement environmental effects of the technology shift within the existing HoQ (House of Quality). Simply those lines and/or columns of the HoQ have to be changed, which are replaced by the new technology. The QFD method has to be re-calculated with the new values reflecting the technology shift. A possible change in the indicator ranking shows the effects caused from the technology shifts.

Also predictions of possible effects from coming technology shifts (or further developments) can be carried out. But fundamentally for the feasibility of those calculations is the existing knowledge of technological details, such as material decisions, manufacturing processes and technological aspects, in order to be able to define Generic Modules sufficiently. The presented method is not able to be applied as an invention tool, which might develop technology shifts or calculate effects of not yet existing parts, products or technologies.

6. Application for ICT products in general

Similar to chapter 5 the HoQ allows the exchange and application of Generic Modules reflecting almost all thinkable parts, components or technologies. Thus the method is not specified on Personal Computers (PC) or electronics in general. As the method is adapted specifically to the needs of complex products such as typically electronic products consist of, one preferred application field is electronic products. Certainly this counts for almost all electronic products beyond PCs. All the more the application is predestined to be applied on ICT in general, as the Generic Modules reflect parts and components of electronics in general and have to be adapted to specifics of PCs and not vice versa (adaptation to more general components coming from PC specifics).

Basis for this is the availability of suitable Generic Modules of general electronic components. A combination of those allows the modelling – and thus the assessment and indication – of almost all electronic products also with specific view on ICT products.