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CONCEPTUAL DESIGN GUIDE FOR ENERGY AND WATER CONSUMPTIONS

Joaquim LLOVERAS
TU Catalonia (UPC), Spain

ABSTRACT

The present paper proposes to analyze the consumption of Energy or/and Water (E/W) in the conceptual design (CD) stage of a product, in order to optimize this consumption. The product normally spends more resources in the use stage.

The paper also discusses issues in the worldwide and in Europe, and particularly in Catalonia, a Mediterranean country which has small fossil fuel deposits and has recently had periods of drought, making it necessary to watch over water consumption.

This article proposes a brief methodological guide including five questions for the designer, or design team, to consider more environmental-friendly consumption alternatives. Ideally, these should be applied in the early conceptual design stage of any product for the entire world.

A case study shows the work by a group of students of Creativity, Ecodesign and Patents subject (academic year 2012-13) entitled "Rainwater storage system for blocks of flats". While thinking about the questions in the methodological guide for the use of E/W, appeared a solution that eliminates the energy consumption in the operation of the installation.

Keywords: conceptual design, early design phases, methodological guide, sustainability, friendly products

Contact:
Prof. Dr. Ing. Joaquim Lloveras
TU Catalonia (UPC)
Projects of Engineering
Barcelona
08028
Spain
j.lloveras@upc.edu

1 INTRODUCTION

Technologies that perform a specific function always move towards improvement until a new technology renders them obsolete. The dynamics of product design makes products increasingly better in performance because most consumers choose the best quality/price products. In this chain of product improvement, designers and design teams have the responsibility and also the challenge and hope to improve products in order to meet consumer needs. This is what motivates their work. Products evolve with society and at the same time transform it.

Today's society has unaddressed challenges related to environmental impacts of fossil fuels and their future depletion and increasingly difficult access. The past abundance of fossil fuels must give way to a change in energy paradigm.

Another growing concern associated with social development is emerging in some parts of the world, like the Mediterranean countries, i.e. water scarcity, a problem which could worsen due to the climate change.

In view of the above, energy and water consumption of products during their useful life must be considered from the conception stage of new designs for products to be rated as world class.

The following section discusses several causes of the above problem and presents the specific case of Europe.

1.1 Use of conventional energy

Material development in advanced countries has been favored by the consumption of large amounts of energy from easy to extract resources. It began two hundred years ago and has since led to many social changes. In coming years peak oil extraction will, if not already, be reached. Then, fossil fuel depletion will make extraction more difficult.

Countries like China, India or Brazil are becoming the world’s factories because of their efficient, hard-working, cheap labour force. There, energy consumption levels are increasing dramatically. Furthermore, despite improvements in energy saving and product energy efficiency, most product purchases are leading to increased global energy consumption.

Apart from shortage and uneven distribution of coal, natural gas and oil deposits, another major disadvantage of fossil fuels is their emissions of CO_2 and other gases into the atmosphere. These accumulate in the atmosphere because of the inability of nature to deal with the environmental effects of current fossil energy consumption. CO_2 grew from 280 parts per million (ppm) during the preindustrial era to approximately 350 ppm in 1987, which is considered a safe upper limit. However, in December 2012 CO_2 was about 393 ppm (CO2Now, 2012), (IPCC, 2013) with the trend going up. CO_2 emissions act as a thermal blanket for the Earth, resulting in an increase in global temperatures, and therefore in climate changes.

The following section is a brief analysis of energy and future trends in Europe.

1.2 The European energy case

Europe has very limited fossil fuel reserves compared to other blocks or world’s regions. That is why Europe needs to import energy from other countries, which affects the economy, particularly in the current crisis. And the situation is expected to get worse.

Europe’s current oil dependence is 32% of its energy consumption (Petroleum Industry, 2012) and total dependence on fossil fuels is 55% (EEA, 2007). Carefree consumption of gas and oil in developed societies is being challenged and will gradually end, giving way to the public’s awareness of the rate of energy expenditure, probably due to rising energy prices.

Energy saving is one of the first actions taken in Europe. It will also become necessary to increase the use of energy efficient electrical appliances, i.e. same performance with lower power consumption; for example, cars that use less fuel per km, or lights that provide the same level of illumination at a lower wattage.

1.2.1 The future of European energy

Probably one of the root causes of Europe’s economic crisis is its dependence on foreign energy. Ending this dependence would prepare Europe for a future of reduced fossil fuel use, leading to an improvement in its economy. The coming years will be difficult ones for Europe, but the long-term future can be bright if the foundations are laid properly. The European Union (EU)’s roadmap is firmly committed to energy saving and fossil fuel consumption reduction, as well as promotion of renewable energies in the production mix.

The EU has three major energy targets (EU targets, 2012):

- "20-20-20" EU targets for 2020:
    - A 20% reduction in EU's greenhouse gas emissions from 1990 levels;
    - A 20% increase in the share of EU's energy produced from renewable resources;
    - A 20% improvement in EU's energy efficiency.
- From 2020, new homes must be nearly zero energy buildings (nZEBs).
- Energy Roadmap 2050 (Roadmap, 2050). Reduction of greenhouse gas emissions to 80-95% below 1990 levels by 2050.

Some reasons for the worldwide use of renewable energies are that:

- They are sufficiently abundant despite their low energy density.
- They are widely distributed.
- Everyone has access to some of them.
- Some do not require large facilities or high-tech for their use, so they are technologically and economically viable to all economies.
- Sources are free.
- Their implementation and maintenance create jobs.

Below is a brief description of another global problem, i.e. freshwater availability.

1.3 Water consumption

Global water consumption is growing due to the increasing global population and development of societies. However, large sections of the world's population still have no access to clean water.

Water conflicts have always existed in the history of mankind because of the vital importance of water, and are expected to grow in the near future due to increased water consumption and climate changes. For example, some warm areas will become arid because of a change in the distribution of rainfall and droughts will therefore become increasingly common.

The water use system is an open cycle in most of the world. Water is obtained, made drinkable, distributed, used and finally disposed of. For some time now used water has been debugged before being discharged into the sea or rivers, thus reducing the environmental impact and improving the quality of ecosystems. Moreover, less water is currently being used than before as a result of the implementation of new agricultural techniques such as sprinkler or dropwise irrigation.

In certain areas, the water use cycle is becoming a closed one because of water reuse technologies, which turn sewage into drinking water. This, in turn, leads to an increase in water availability. For example, water reuse is the common practice the International Space Station (Flynn et al. 2012). Unfortunately, this technology is still rather expensive.

1.3.1 Water in Barcelona (Catalonia), a Mediterranean city

Until the 1950s, Barcelona, the Catalan capital, was self-sufficient in water supplies thanks to its water sources and wells. Since then, the population has grown and its standard of living has improved, resulting in a larger water demand and the need to use water first from nearby rivers like the Llobregat and Besòs, then the Ter in Girona. Moreover, only a few years ago a water transfer from the Ebro river in Spain was attempted but finally the project was not carried out due to political problems. Barcelona had extreme situations where water restrictions were about to be implemented in the years 1990, 2005, 2007 and 2008 (Aigües de Barcelona, 2012). Its current supply depends on the above sources and occasionally on two large seawater desalination plants just recently built but water production is expensive there. Relatively advanced projects to bring excess water from the Rhone River in France, which is about 330 km away by road and 190 km by sea, are on the table but many technical, economic and political issues need to be addressed. A EU water plan to manage and redistribute the available water to drier areas such as the Mediterranean regions is required. In this sense, it is worth noting that climate change projections for the Mediterranean area point to increased drought risk.

In the last 30 years, the average annual rainfall in Barcelona has been 592 l/m2 (DatosClima, 2012). Unfortunately, the rainfall is torrential, with two yearly periods of heavy rains, making it difficult to collect this rainwater. However, a better water management including recycling measures and increased use of rainwater would improve the situation.

In the future, virtual water (Virtual Water, 2013) may be considered for trade between different parts of the world (Hoekstra, 2012) where some natural or artificial dryland products are exchanged for natural or artificial wetland products that require large quantities of water.

1.4 Summary of the introduction

Although fossil fuel reserves, and water to a lesser extent, are not evenly distributed across the globe, the design of a world class product should consider right from its conceptual design phase its energy and water consumption during its useful life in view of their shortage in some parts of the world.
The importance of considering energy and water consumption in the conceptual design stage is discussed below.

2 CONCEPTUAL DESIGN STAGE

The basic process steps of product development and conceptual design stage have been described by several authors, e.g. (Pahl & Beitz, 1996), (Pugh, 1994), (VDI, 1987), (Hurst, 1999) or (Aleixos et al., 2004). Figure 1 shows these stages from conception to market. It is in the conceptual design stage when the product's future is decided.

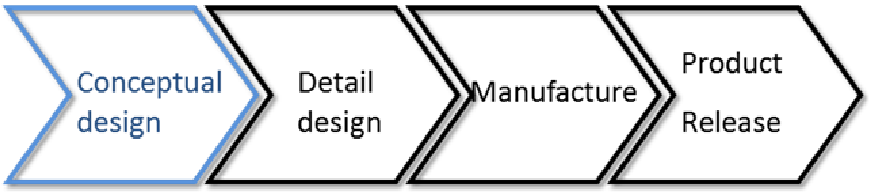

Figure 1. Basic process steps of product development.

The first stage is the Conceptual Design (CD). The structuration of the CD used in this work comprises three phases (Lloveras, 2011), as shown in Figure 2. During the conceptual design phase a design direction must be taken to decide on the best option of design. When this option is found, it is said that the conceptual design is directed (Directed CD). Design tasks are now needed to define the product at a basic level (Defined CD). Finally, when the proposed design is technically, economically and socially viable, it is said that the conceptual design is viable (Viable CD).

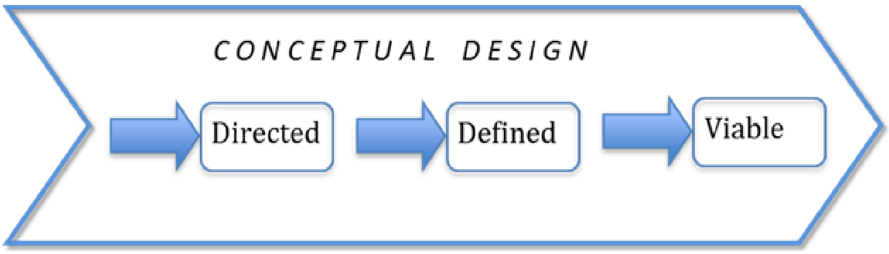

Figure 2. Three sub-stages in the conceptual design.

This process is repeated as many times as needed until a solution is feasible. Then, the process proceeds to the next step, i.e. the detailed design.
It is in the CD stage that energy and water consumption of the new product is roughly determined. To this end, the following methodological guide is proposed.

3 METHODOLOGICAL GUIDE FOR ESTIMATION OF ENERGY / WATER CONSUMPTION BEFORE THE DEFINED CONCEPTUAL DESIGN

Given the prospects of depletion and increased difficulty in obtaining fossil fuels and/or freshwater, especially in some parts of the world, energy and water consumption must be considered in the conceptual design stage of a new product for it to be valid for most consumers. The following methodology does not apply if energy or water can be used freely, for example in the case of renewable energies or reused water with no environmental impact or other side effects.
It is proposed to follow a five-question process about the energy and water consumption expected for the product in use. Figure 3 is the flowchart of the ordered sequence of questions.

These questions are asked before the conceptual design becomes directed or defined depending on the potential importance of energy or water consumption for the product in use; that is, when most consumption commonly occurs.
The flowchart is divided into three major blocks (A, B, C) including the five questions and actions to perform. It starts with the initial ideas of solution of the parts comprising the product and their consumptions.
Block A considers whether the product has Energy or Water (E/W) consumptions, and whether these are essential. The product might have no E/W consumption whatsoever, only energy or water consumption, or both simultaneously. In the last case, it is advisable to use a separate flowchart for each consumption.

A) Analysis of Energy/Water (E/W) consumption during product use

1. Does the product consume energy/water when in use?
   If the answer is yes, two separate flowcharts for energy and water consumption follow. If there is no energy or water consumption, the conceptual design becomes defined in this aspect, and this methodology ends.
2. Is this energy/water consumption essential?
   This question seems obvious if the answer to the first question is yes. However, in some cases either one or both consumptions are actually unnecessary in normal operation of the product. Then, the sequence goes backward.
   Otherwise, we can move on to the second block:

Block B examines the possibility of using alternatives that are more ecological than traditional solutions.

B) Study of alternatives for greener consumption

3. Are there alternatives to the traditional energy/water sources?
   If non-polluting alternative energies, or alternative water sources, are used, question 4 is skipped and the process goes on.
   If energy and water are respectively obtained from conventional polluting sources (fossil fuels) and potable water networks, alternatives with less impact on the environment, and therefore less burdensome on the economy, can be considered (Analysis of Alternatives).
   If there is no possibility of using alternatives, the reduction of consumption, i.e. improvement of product efficiency, is contemplated.
   The next question involves a deeper analysis of the alternatives.
4. Is this the best alternative?
   This question is asked in order to reconsider other possible alternatives of use and find the best one.
   Now follows the last block.

Block C concerns the reduction of E/W consumption.

C) Reduction of consumption by increasing product efficiency

Reduction in the consumption of energy and water obtained both from traditional and alternative sources through improved, more efficient designs is investigated (Reduce consumption E/W).

5. Is this the maximum possible level of efficiency?
   Finally, it is asked whether energy/water consumption has been reduced from the point of view of product efficiency. If so, this series of questions ends.

The design process continues until the defined CD is obtained by considering other design aspects of the product.
The next section presents an academic case study.

4 CASE STUDY

In the Creativity, Ecodesign and Patents (CEP) course offered in the fall semester 2012, seven 3-5 student work groups were formed. The groups were required to choose a topic from a selection given by the lecturer and make an oral presentation which was to be followed by a class discussion.

Groups were also asked to carry out a practical assignment consisting of the conceptual design of a new product presented in the form of a patent. The lecturer gave freedom of choice, but the products had to be a solution to save water, energy or both.

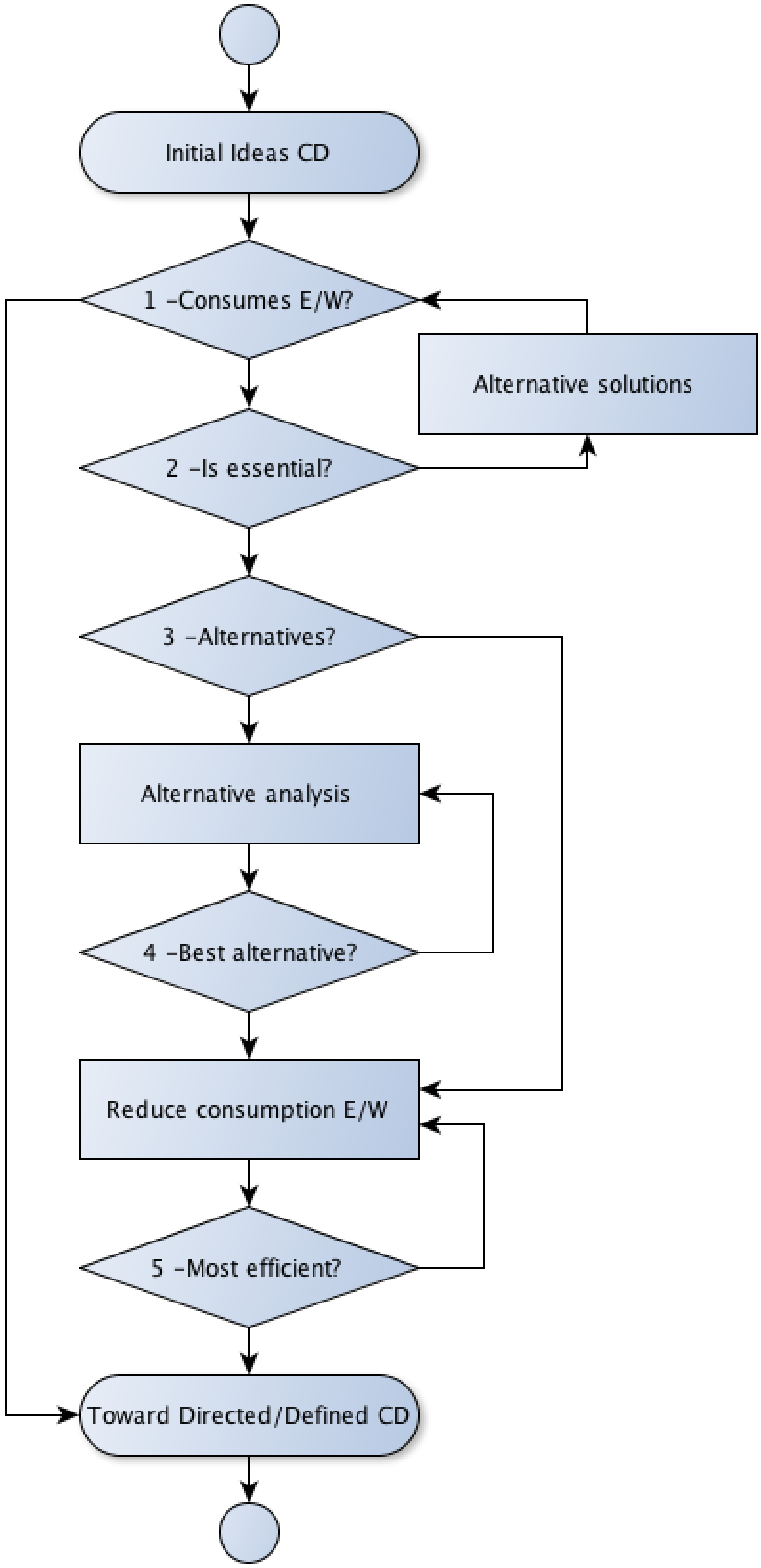

Figure 3. Five general questions about Energy/Water (E/W) consumption in the conceptual design (CD) stage. (Own source. Flowchart yEd Graph Editor).

After a discussion with the lecturer to obtain a conceptual design direction, it was proposed to Group 7 (G7, 2012) to work on a rainwater harvesting system for toilet flushing in a block of flats, as this action accounts for a third of total domestic water consumption (Aigües de Barcelona, 2013). The study involved seven flats inhabited by three people each in a 300m^2 block with two flats per floor located in an area with an average annual rainfall of 592 l/m^2. Savings were estimated to be about 30%.

An initial design of the installation that could be described as conventional is given in Figure 4.

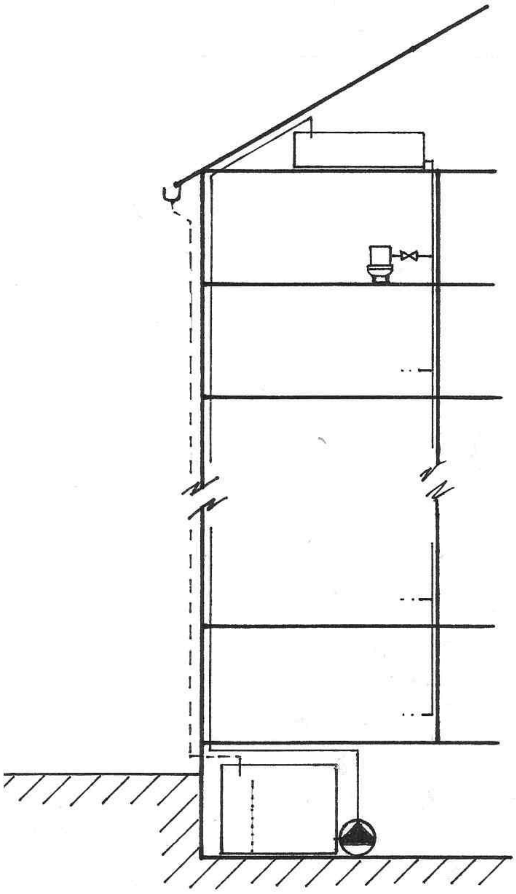

Figure 4. First solution: rainwater collected in the lower reservoir and pumped into the upper reservoir for gravity distribution.

The rainwater is filtered and collected in an underground tank or in the basement of the building where it is treated. The water is pumped from there into an upper reservoir where it is distributed by gravity to the floors when needed. This solution has already been patented (e. g. Torres et al., 2007).

Another conventional solution is to use a pump with a pressure tank that can provide water by a special network to tanks of toilet bowls for discharge when required.

According to the methodological guide in Figure 3, it is asked whether this solution consumes energy or water. Since in this case the product is an installation for rainwater collection, the next step is to reduce rainwater consumption and increase the system's efficiency. Improvements in toilet water saving are not within the scope of this project.

The flowchart is then applied to the energy consumption. The answer to the first question *Does it consume energy?* is affirmative because in these initial solutions energy is used to pump the water for its distribution.

The second question is *Is this energy consumption essential?* At this stage, the answer is yes, and then follows the third question: *Are there alternatives to the traditional source of energy?* Here, a possible answer is to use solar energy panels to supply power for the water pump, thus avoiding the environmental impact. This solution leads to a sustainable but complex system.

Nonetheless, there is another possible answer to the second question, which is a solution that eliminates the energy consumption by using individual tanks located outside the apartment building

where rainwater is stored and supplied by gravity to the points of consumption. Some patents show similar solutions without energy consumption (Gittoes, 2006), (Nagel, 2009), (Ulrich, 2011).
Figure 5 shows the solution given by G7 with deposits outside the building that distribute the collected water. The tanks (one per flat) have a rectangular prism shape (2) resting on crosspieces (8) between two vertical columns. A filter distributor (10) has output pipes to distribute the rainwater that reaches the tanks. For clarity, the figure illustrates three reservoirs and one downpipe (9) to a reservoir (2) only.

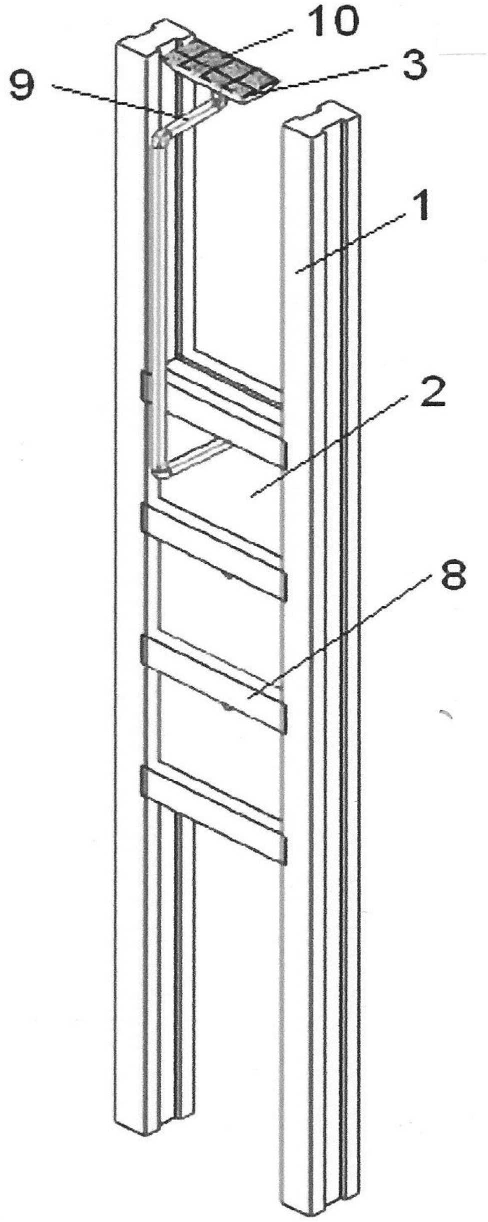

Figure 5. Arrangement of the deposits (2) between two columns and filter distributor (G7 source).

With this arrangement, energy consumption in use is eliminated. A similar solution is found in Masi and Liggia's patents (2011). At this point, a viability study is required.

5 DISCUSSION AND CONCLUSIONS

The analysis of two current problems, i.e. energy and water consumption in some parts of the world, reveals that the massive use of fossil fuels has environmental impacts and leads to future shortages. Savings and increased efficiency, as well as, if possible, the use of alternative energies such as renewable energies, are necessary. As for the water problem, part of the solution could lie in the implementation of recycling and saving policies.

This paper proposes the design of world class products bearing in mind the energy and water consumption of the product in use during the stage of conceptual design in order to improve its environmental impact.
The three blocks with five questions described in section 3 are a guide for designers and design teams in the early stages of the design process to reduce energy and water consumption and increase the efficiency of products in use. This methodological guide is summarized in Figure 6.

A) ANALYSIS OF ENERGY/WATER CONSUMPTION IN PRODUCT USE
1. Does the product consume E/W while in use?
2. Is this E/W consumption essential?

B) STUDY OF ALTERNATIVES FOR GREENER CONSUMPTION
3. Alternatives to the traditional E/W sources.
4. Is this the best alternative?

C) MINIMIZE CONSUMPTION AND MAKE THE PRODUCT EFFICIENT
5. Is this the maximum possible level of efficiency?

Figure 6. Summary of the methodological guide for E/W consumption in the conceptual design phase.

In the case study "Rainwater storage system for blocks of flats", a solution that eliminates the energy consumption in the distribution of rainwater is provided after answering the first questions of this process, namely use of the energy potential of the rainwater collected on top part of the block for water distribution by gravity. This solution requires a built-in construction outside the building equipped with individual tanks, which could have adverse aesthetic effects and a long-term amortization period. However, in some Catalan municipalities new detached constructions are forced by law to collect and use rainwater.
The proposed methodological guide is intended for the use phase of products, when consumption is at its highest, but can be extended to consumption throughout its life cycle.
Finally, this guide helps to design products in harmony with the environment and indirectly beneficial to society.

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