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A PROCESS OF CONCEPTUAL ENGINEERING DESIGN FOR NEW PATENTABLE PRODUCTS

Joaquim Lloveras
Technical University of Catalonia (UPC)

ABSTRACT

The conceptual design phase is usually a poorly-structured process, and this is especially true when developing new patentable products. This paper proposes a procedure to address the conceptual design phase of a new product. A well-structured top-down successive search of solutions by creativity techniques and Ecodesign and patent drafting strategies helps come up with new concrete ideas of solution and prepare this conceptual design for the detailed design phase. Three stages of conceptual design are identified: directed conceptual design, defined conceptual design, and viable conceptual design.

This procedure is followed in a free elective course offered by the Technical University of Catalonia (UPC) titled *Creativity, Ecodesign and Patents*. This course mainly focuses on initial product design phases or first stages of conceptual design. Drafting patents in the conceptual design phase helps clarify and easily refine solutions, as well as coming up with alternatives of solution. Moreover, it serves as a stepping stone towards for the final patent draft of the product.

The paper also presents the work performed by a group of students on the recovery of energy from falling wastewater in a high building to exemplify the above procedure.

Keywords: Conceptual design stages, patent drafting, ecodesign, creativity.

1 INTRODUCTION

There exists an ambiguous space or fuzzy area between product design initiation and detailed product design phase, which is commonly known as Conceptual Design (CD) phase. Several authors [1] - [7] have discussed or proposed different guides to conduct this phase. However, no consensus has been reached in this regard because of the inherent difficulty of this phase.

The starting point of an engineering design is a technical problem to solve. Technical problems can be classified according to their level of detail. In this paper three levels of technical problems are defined:

- General problems: They affect many people and since the level of detail is very low, many solutions are possible, for example water shortage affecting large areas of the world.
- Specific problems: They are more specifically defined than general problems and have fewer solutions than general problems, for example limited water resources in a housing development located in a dry area in a given country.
- Detailed problems: The level of problem definition is high and the number of solutions is very small, for example the design of a domestic water-saving tap which has other defined requirements.

The above examples of technical problems can be inventive problems, i.e., those whose solutions require new ideas and are patentable. Naturally, not all engineering designs are patentable nor is there always an interest in patenting them. In the *Creativity, Ecodesign and Patents* course (see section 3), the focus is on those solutions that can be patented.

2 METHODOLOGY

In this paper, the design starting point is a general problem from which a process to find an inventive solution is described.

Three ends of stages of Conceptual Design (CD) are proposed:

1. Directed conceptual design
2. Defined conceptual design
3. Viable conceptual design

Each end of stage has an objective defined by the above three adjectives, namely directed, defined and viable (see figure 1). Therefore, the stages are: stage to directed conceptual design, stage to defined conceptual design and stage to viable conceptual design. This nomenclature indicates finality and is more dynamic than Analysis, Definition and Validation, which may suggest an indefinite continuous state of activity in each stage.

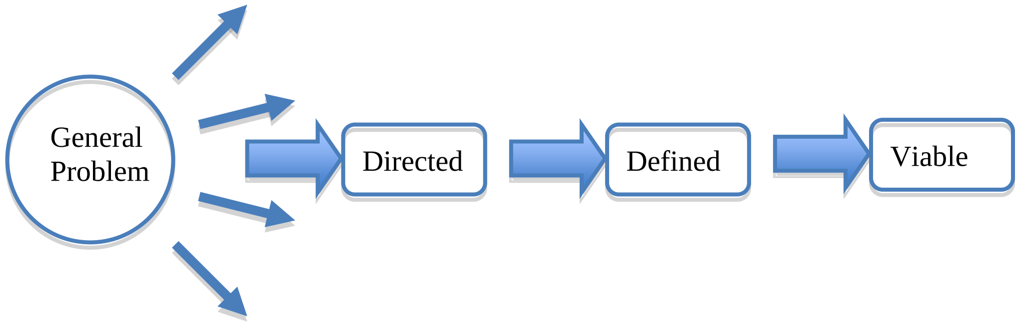


Figure 1. Conceptual Design (CD) process from general problem before Detailed Design process with three proposed ends of stages: Directed, Defined and Viable.

An academic exercise to find a particular solution for a general problem, i.e., water shortage, illustrates the above stages. The first tasks are to search possible solutions to water shortage and select a general one, for instance to capture and store rainwater. At this point, we have a particular direction of search from among many possible directions of solutions, and this marks the end of the first stage of the conceptual design process, i.e., directed conceptual design. The main details of the capture and storage of rainwater are discussed in the next stage and when these details are well defined, the defined conceptual design is reached. Finally, in the next stage of conceptual design, an analysis of technical and economic viability is performed and then the viable (or not) conceptual design is achieved. The following stage focuses on the detailed design.

The process of search for a particular solution of a general technical problem is described below (only the two first stages, to directed and to defined CD, are considered).

2.1 General process

The main objective of this procedure is to come up with a patentable product that is a solution of a general (or specific) problem. Three phases are involved in the process. The first concerns the directed conceptual design, with a well-structured top-down development of solutions [8], [9], and the use of creativity techniques. In the following stage, namely defined conceptual design, creativity techniques, and Ecodesign and patent drafting strategies are applied.

These two phases are described in the following subsections. The last phase, i.e. viable conceptual design, is devoted to technical and economic viability considerations and includes a prototype or simulation test. After completion of the above stages, the detailed design phase starts. The issue of economic viability is not addressed in the *Creativity, Ecodesign and Patents* course or in this paper although it is obvious that the economic aspects must be analyzed in all phases of the actual product development.

Naturally, iteration processes between stages are possible and often necessary. Iterations can also occur within each stage, when both divergent and convergent thinking alternate.

2.2 Directed Conceptual Design

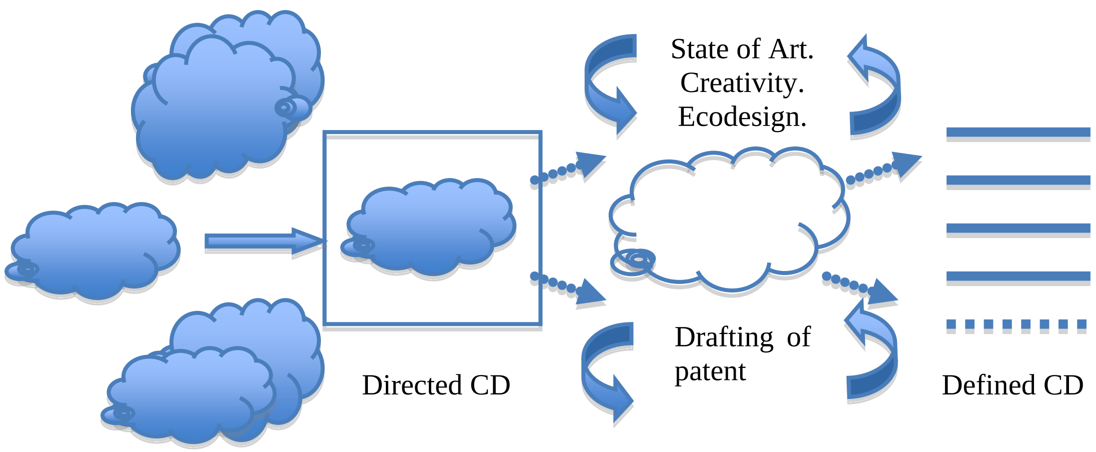
A design process starts with the statement of a problem. In the case of a specific problem, it is abstracted to a general one. From this general problem, several different solutions are obtained at their first level of development.

Figure 2 symbolises the two first stages of CD. The clouds represent different vague solutions that come to the mind in the face of a general problem. When one of these solutions is selected, a direction of solution is achieved (Directed CD). If we are tackling a specific problem, the possibilities to apply the selected solution are analysed against the problem and that closes the loop (specific problem-general problem-directed solution-specific problem).

This procedure is repeated until a directed design is reached by searching technical information and patents and using creative techniques.
The procedure indicates a direction of design, with some ideas of constitutive parts of the new product. Finally, the directed conceptual design for a new product is reached and the process continues towards the defined conceptual design phase. Although this directed CD is a provisional solution, afterwards there are more iterations, which can confirm when the defined and viable CDs are attained.

2.3 Defined conceptual design

After finding a direction of conceptual design, the design is refined and several sub-solutions are found by using creativity techniques and general Ecodesign strategies, consulting patents and especially drafting an initial patent application (see figure 2). The search of patents can contrast the novelty of this conceptual design.



Each cloud represents a diffuse area of a solution.

Steps to reach defined CD

Figure 2. After finding a directed conceptual design, creativity techniques, Ecodesign strategies and drafting of initial patent application help define CD.

The design then reaches the defined conceptual design phase, after which the final viability of the defined design is analysed.
General Ecodesign and patent drafting strategies are explained in the following subsections.

2.3.1 General Ecodesign strategies

In this process, general ecodesign strategies are applied to obtain a first rough analysis of ecodesign [10], e.g., considerations of environmental impacts through life cycle analysis [11], of materials, of recyclability, etc. are made, which can lead to changes, even drastic ones, in the general structure of the new product. However, at this level of design development, modifications are easy and cheap.
After the conceptual design phase, more detailed Ecodesign strategies can be applied during the detailed design phase.

2.3.2 Drafting of an initial patent application as a tool to improve conceptual design

If the search of patents indicates that the new design is a new patentable product, the next stage is to draft an initial patent application. This serves to clarify the product definition and also find alternative solutions at a stage where changes can be easily made.
Although producing a first draft at the conceptual design stage might seem unnecessary, it serves as a stepping stone towards the final draft.
The structure of a patent application [12] is as follows:

- Title of the invention. Brief statement of technical field.
- Background of the invention.
- Summary of the invention.

- Brief description of the drawings.
- Detailed description of one or more embodiments of the invention.
- Drawings.
- Claims.
- Abstract of the invention.

Nevertheless, the order used by the students of the *Creativity, Ecodesign and Patents* course prior to following the classic format (see above) was

- Drawings with numbered parts.
- Table of numbered parts and definitions for own use.
- Title.
- Claims.
- Others.

This first draft gave rise to iterations of design solutions as patent drafting is a reflexion period during which new solutions can be introduced.

Drafting an initial patent application has several advantages:

- The design comes clear for the work group.
- The product, its parts and main claims are clarified.
- Alternative solutions are sometimes found which complete the conceptual design.
- This first version serves as a stepping stone towards a final, complete patent application.

The directed and defined conceptual design stages were explained and practised in the *Creativity, Ecodesign and Patents* course.

3 *CREATIVITY, ECODESIGN AND PATENTS* COURSE DESCRIPTION

In the autumn term of the academic year 2010-11, a new free elective course titled *Creativity, Ecodesign and Patents* (*Creativitat*, *Ecodisseny i Patents*) was first offered in the Technical University of Catalonia (UPC) [13], [14]. The objectives of the course are to provide insights into the conceptual design phase and skills to manage the process towards the completion of the conceptual design, as well as motivating students to come up with a new useful product and draft the corresponding patent.

Material from previous free elective courses [15], i.e., *Innovation and Patents* ("Innovació i Patents") [16], *Ecodesign* ("Ecodisseny") [17], and *Creativity, Development, Innovation* (“Creativitat, Desenvolupament, Innovació") [18] is combined.

The course meets twice a week from September to December in 120-minute classes consisting of lectures lasting 30 to 45 minutes and the remaining time being devoted to student work and discussion of solutions.

At the beginning of the course some general necessities of our time and country, e.g., water and energy scarcity, are presented. Students are asked to find partial solutions to these general problems by coming up with a new product or technological system. Examples of specific products that partially solve these problems are given to the students. The practical part of the first two or three classes involves the selection of group work topics. As the title of the course suggests, the three main themes of conceptual design, i.e., creativity, Ecodesign and patents, are specially dealt with.

First, creativity techniques such as exercises of imagination, brainstorming and Mind Maps [19] are used. Patents are then searched in Internet patent databases to verify the novelty of the proposed designs.

The following sessions focus on the presentation of Ecodesign strategies for students to use in their group work. Simultaneously, solutions of the new products are discussed and refined. These Ecodesign strategies are used for improving constitutive materials by use of clean and recyclable materials and saving energies throughout the life cycle of the products. “Cradle to Cradle” [20] is explained, and the lifespan of products versus rapid obsolescence is discussed.

One class is devoted to aesthetic concepts.

At the end of the course, when the new product is more defined, patents are written. As explained above, first drawings with numbered parts are produced. Next, claims are written. This is a good time to think of alternative sub-solutions and possible changes, which can be incorporated into the product conceptual design. Finally, a basic level of defined conceptual design is reached.

The main objective of the course is to draft the patent of new products. Because of the complexity of the task, several classes are devoted to polishing patent claims.

The topics for the 2010-11 course were energy and water saving. Now follow the specific topics chosen by students:

- Efficient cooking pot for gas stove. (Energy saving). Work group 1.
- Grey water energy recovery system. (Energy saving). Work group 2 (described in next section).
- Digital display for tap water flow counter. (Water saving). Work group 3.

Writing a first patent application led to several alternative sub-solutions in the three work groups.

The course finished with the delivery of a report and an oral presentation of the defined conceptual designs.

All works must include an innovative part. As for final marks, groups presenting a well-written patent can receive a B and an A if the report is also satisfactory. In the 2010-11 course, the three groups worked well and steadily; two groups obtained an A while the other received a B.

4 CASE STUDY

This section presents the academic exercise of the development of the process towards the defined conceptual design conducted by work group 2, which was formed by four students.

From the general problem of saving energy, this group proposed several directions of work at the beginning of course. They focused on energy saving in buildings and eventually chose the topic of energy recovery systems from falling grey water, in particular a system for a multi-storey hotel with high rates of water consumption. Grey water is generated by the use of showers, baths, hand basins and washing machines. (In contrast, black water, not used in this exercise, is generated by toilets, dishwashers and kitchen sinks.)

In order to produce a directed conceptual design, several creativity techniques were used, technical information was searched and patent databases were consulted. For course time reasons, this phase was shortened.

For group 2 exercise, it was considered that if a hotel has 10 floors or more, falling wastewater can be converted into electricity by a turbine and an electric generator (see figure 3).

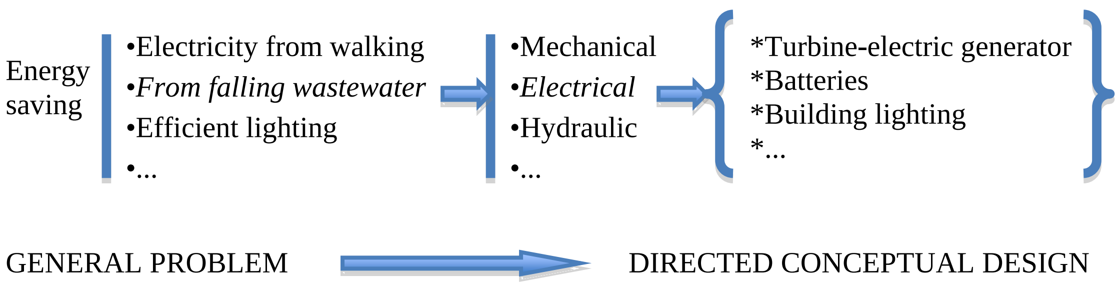


Figure 3. Process from general problem of energy saving in buildings to a directed conceptual design. The recovery of energy from falling wastewater by a turbine-electric generator was selected.

In the search for similar solutions, one system of recovery of energy from falling wastewater was found [21]. However, the system proposed by the group was innovative because it aimed to solve the problem posed by an irregular wastewater flow, especially when it is low, which could result in insufficient energy to move the turbine. The solution was to place a wastewater buffer tank with automatic discharge into the main drain pipe on each floor.

Figure 4 illustrates the process from the directed conceptual design (last part of figure 3) to a defined conceptual design (schematically drawn in figures 5 and 6). In order to complete this second stage, the state of the art, creativity techniques, ecodesign strategies and patent drafting were applied, and an initial version of the patent was written. The result was a technical system where the constitutive parts were defined broadly, rather than narrowly.

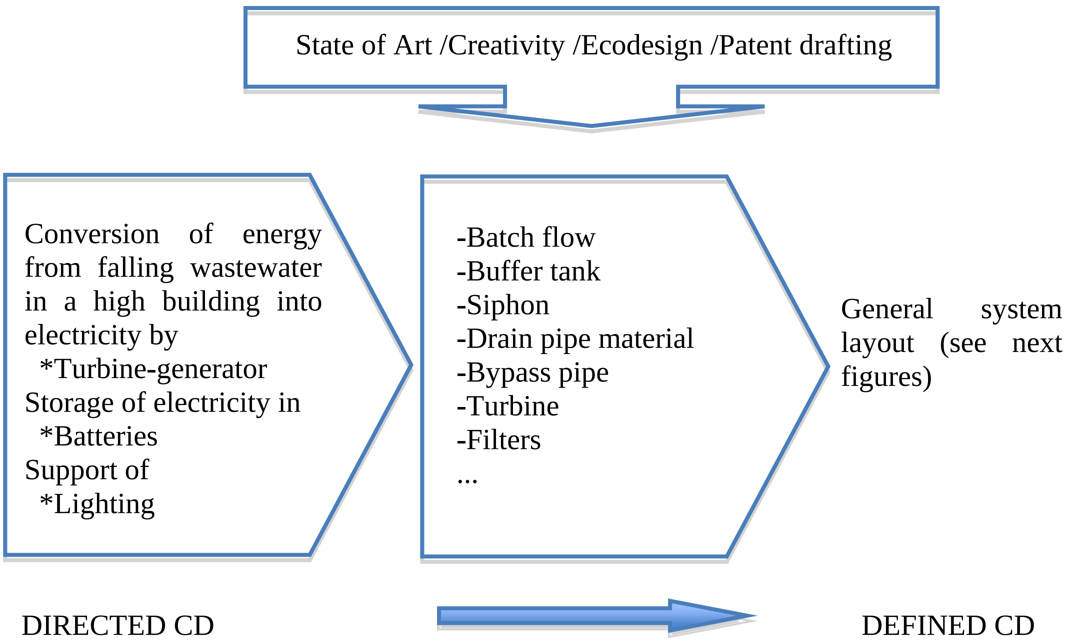


Figure 4. Process from directed conceptual design to defined conceptual design using creativity, Ecodesign and patent drafting tools of the case study.

Figure 5 shows a schematic drawing of the system (1) of this defined conceptual design. The non-scale drawing represents a section of a multi-storey building. The main drain pipe (3) collects grey water from the floors. At the bottom of the drain pipe (3), a Francis turbine [22] transforms the lineal movement of vertically falling wastewater into the rotational movement of a shaft connected to an electric generator. This device transforms mechanical energy into electricity, which is subsequently stored in batteries (5). The electricity generated supports the lighting system of the hotel.

A buffer tank (2) on each floor stores the wastewater falling from the immediate upper floor. When the buffer tank is full, a self-activated siphon allows automatic discharge of wastewater into the main drain pipe.

The buffer tanks can have different capacities because the mass of wastewater required to turn the turbine is smaller when wastewater falls from higher floors than from lower floors.

An enlarged view of the turbine system (4) is shown at the bottom of figure 5. The main drain pipe (3) carries the wastewater to the turbine (19) and from there into the exhaust drain (20). In the case of overflow, a bypass pipe (17) carries excessive wastewater into the exhaust drain (20). The same happens when the turbine is being serviced and a valve (18) stops the flow to the turbine. The upper part of the bypass pipe is slightly inclined to redirect wastewater splashes into the main drain pipe (3) in normal operation, or prevent bypass flow in the case of a small overflow.

A register (22) is needed for special maintenance of the filter placed before the turbine (not shown).

The system generates electricity to light large spaces in the building by highly-efficient, long-lived LED bulbs (the drawing illustrates a traditional incandescent bulb).

Figure 6 shows a schematic of a buffer tank (2) with numbered parts for the patent draft in which liquid is discharged automatically by a self-activated siphon (10) [23] when the liquid level in the buffer tank exceeds the siphon elbow.

The wastewater flows by “batches” upon draining of the buffer tanks to endure the minimum flow required for the proper operation of the turbine-generator system

If the wastewater inlet (6) allows a large flow to pass and the siphon has insufficient capacity to handle it or its filter (11) is dirty, an overflow pipe (9) carries the wastewater to the main drain pipe. A filter at the entrance of the buffer tank is placed.

For best removal of the liquid, the tank base is slightly sloped downward to let the wastewater flow to the siphon filter (11). Moreover, sludge settles at the bottom of the tank, thus allowing its easy removal.

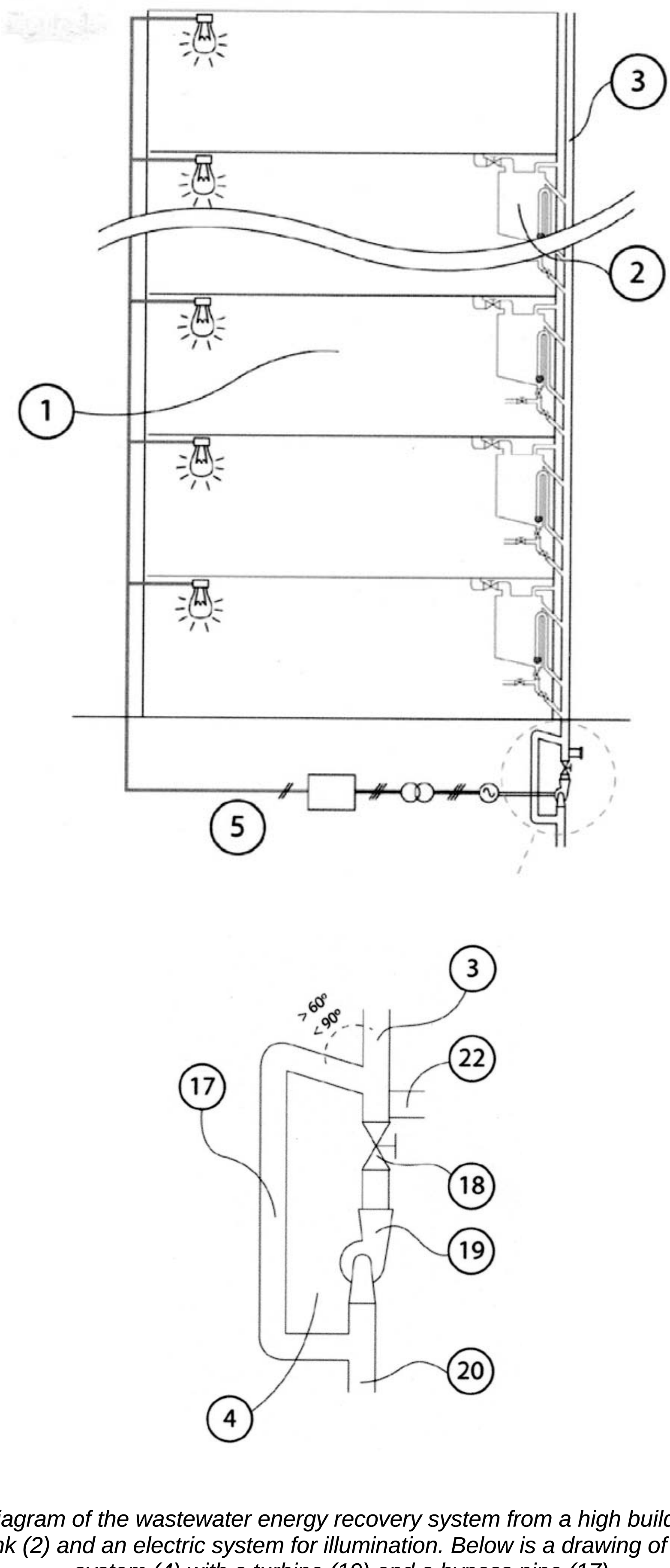


Figure 5. Diagram of the wastewater energy recovery system from a high building (1) with a buffer tank (2) and an electric system for illumination. Below is a drawing of the turbine system (4) with a turbine (19) and a bypass pipe (17).

Some pipes and valves are used to easily isolate, clean and maintain the tank system in good condition. Direct drainage through valves (13) and (15) leads residues sludge through the pipe (16) to the main drain pipe. When valves (14) and (13) are open and valve (15) is closed, a counter current of clean water flowing through an additional inlet (7) cleans part of the filter (11) and tank base. Also, the filter (11) is partially cleaned when the remaining liquid in the upstream siphon arm falls into the tank whenever the siphon stops working.
Sometimes, a bypass pipe of the buffer tank may be necessary to allow wastewater to flow directly to the main drain pipe (not shown), e.g., during tank maintenance.
A pipe (8) ensures the ventilation of the tank (2) to the open air.

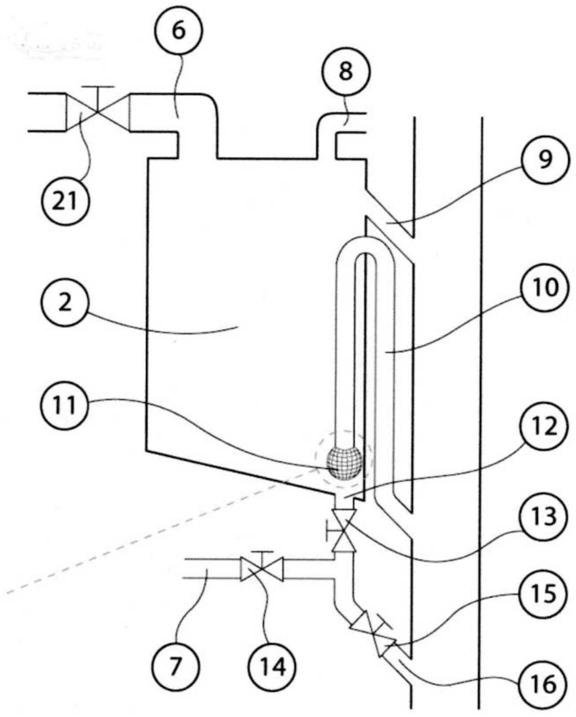


Figure 6. Diagram of buffer tank with automatic discharge by self-siphoning.

In order to complete the defined CD stage, Eco-indicator '99 [3] is employed. According to the eco-indicator calculation for obtaining cubic meters of materials, the manufacture of Polypropylene has a lower environmental impact than that of Polyvinyl Chloride (PVC). For this reason, it is proposed to use the former as pipe material.
This work ended with an economic estimation of the energy recovery. The 11-storey Industrial Engineering School building in Barcelona was used for the calculations. The average quantity of grey water is approximately 3400 litres per day, although the recovery of energy varies from floor to floor because of the difference in height of the buffer tank. A rough 38 KWh can be recovered per day, which represents a saving of about 900 € per year. This estimation gives a long period of economic return considering the current water prices.

5 CONCLUSIONS

There exist several possible processes or ways to obtain a finished conceptual design. The choice probably depends on one’s knowledge and the problem characteristics. The difficulty lies in finding an optimized conceptual design process for each case.
This paper proposes a process for conceptual engineering design that emerges from the academic experience. Such process is used in the *Creativity, Ecodesign and Patents* course offered by the Technical University of Catalonia.
The process starts with the statement of a general problem or a specific problem abstracted into a general one. From this point, an innovative or patentable product that partially solves the initial problem must be designed.

Three stages of conceptual design are identified. The first stage ends when a clear direction of design is taken: directed conceptual design. The second stage finishes when the design is set: defined conceptual design. In the third stage, the technical and economic viability of this conceptual design is analysed: viable conceptual design. Then, the detailed design starts.

These three stages are based on creativity, search of information and patents, general Ecodesign strategies and drafting of an initial patent.

Writing the first version of a patent helps discuss and clarify the product in the designers' minds. The results of this reflection exercise can be easily expressed in the drawings at this stage. Also, this initial version serves as a stepping stone towards the final patent that must be drafted when the whole design process is completed.

The *Creativity, Ecodesign and Patents* course instructs on the above process, providing knowledge and skills for conceptual design development. Patent drafting is probably the most challenging part of this course, but still within students' capability.

An example of student group work for the recovery of mechanical energy from falling wastewater in high buildings by an electric conversion system is explained. This system for recovery of falling wastewater energy could be a technology for future energy savings in high buildings.

However, the main objective of this exercise is to train students in the conceptual design process using an exercise proposed by them to enhance their motivation.

An anonymous student questionnaire conducted at the end of the course showed that the course was generally considered interesting by the students.

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Contact:
Dr. Joaquim Lloveras
School of Industrial Engineering of Barcelona (ETSEIB).
Technical University of Catalonia (UPC)
Dpt. Projects
Av. Diagonal, 647. 08028 Barcelona
Spain
Tel. +34 934016642
Fax +34 934016646
j.lloveras@upc.edu

Joaquim is professor of Engineering Design, at the Departament of Projects of the School of Industrial Engineering of Barcelona. Is interested in: Conceptual design, creativity, ecodesign, innovation, design methods, product appreciation and patents.
Coordinator of the Doctoral Programme: Technological Innovation Design in the Product Engineering and Process. Director of post-graduate course of Fundacio UPC: Creative Management and Product Innovation.