# Development and Application of a Methodology for Selection of Technological products suppliers


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**ABSTRACT**

In market globalization, it becomes important to dispose of a suitable tool that can allow finding the best supplier. It is especially important when it is about technological products. These kinds of products deserve a special treatment due to their own complexity and even complexity of the process that they are involved in. In this paper we present a new methodology for supplier selection that takes account the special characteristics of technological products. It is defined the structure of the methodology and all the parameters used to implement it. As confirmation of validity of the methodology, we show an example of application.

***Keywords:*** Supplier selection, Technological products selection, AHP, methodology

## INTRODUCTION

Given that the market globalization is a very relevant fact in the actual century, the trend is seen as one of acquiring products from other countries, generally due to economic or technological factors. According to product type, there are several possibilities. On the one hand, there are products manufactured in countries where costs of work force, raw material or energy are cheaper than these in the final consumer countries. On the contrary, these products may come from countries with an important knowledge of manufacturing technology and high level of maturity in manufacturing process, which might be higher than the final consumer country.

In scientific literature it is stated an increasing interest on purchasing decision and contracting, especially by means of systematic methods. Weber (1991) [1] and De Boer (2001) [2] presented a wide range of methods and tools for analysis oriented to a supplier selection. Ghodsypour & O'Brien (1998) [3] stated that in the supplier selection process, it is necessary to decide between two problems: which supplier is better and what is the quantity that is better to buy from each one. They gave a special importance to qualitative factors in the supplier selection process. So that, they suggested the integration of the Analytical Hierarchy Process (AHP) and linear planning in order to consider tangible and intangible factors when selecting the best suppliers. Moreover, this method ensures the optimum quantity that must be bought from each one in order to obtain the maximum Total Purchase Value (TPV).

Another application is shown in the same way in Sawalhi, Eaton & Rustom (2007) [4]. They found that the previous classification of contractor is a multi-criteria problem that includes qualitative and quantitative information. In their work, they suggest the use of a hybrid model, combining the best results of AHP and Neural Network (NN) and Genetics Algorithms (GA). In this way, disadvantages of other models, like the model outputs precision or contractor behavior forecast, are overcome. Bertolini et al (2006) [5] proposed the use of AHP as a tool to select the best discount whenever it was necessary to select a public work contract. It was defined as a hierarchical structure containing thirty one criteria in order to show the technique behavior and characteristics.

Other researchers (Bhutta & Huq, 2002 [6]; Liu & Hai, 2005 [7]; Hou & Su, 2006 [8]; Saen, 2007 [9]) used AHP method to indicate the priority in a supplier selection.
AHP provides a structure to formulate compensation evaluation between selection conflicts of criterion associated with different suppliers (Render & Stair, 2000) [10]. Analysing the evidence of several non structured decision rules and with no availability of precise data, some authors (Wray, 1994 [11]; Albino, 1998 [12]; Choy, 2002 [13]; Chen, 2006 [14]; Amid, 2006 [15]; Florez-Lopez, 2007 [16]; Chan & Kumar, 2007 [17]) took some techniques based on artificial intelligence (AI), for example fuzzy logic and NN. These methods were shown as applicable to situations like supplier selection, where it is people who make the decision by expressing heterogeneous opinions. Min (1994) [18] and Petroni & Braglia (2000) [19] used techniques that do not require an assignment of specific weight, as joint analysis. Main component for deriving the weight of selection criteria was analyzed (in different compensation method).

Ghodsypour y & O'Brien (2001) [20] formulated a program that includes a collection of whole and non linear models to solve the problem of multiple supplying materials sources. In their model they took into consideration, on the one hand the logistics total costs, (considered to be the sum of the net price in buying, storage costs and transport) and on the other hand purchasing limitations, quality and required services.

It is paying enough attention to development of effective models for supplier selection, trying to agree with the relevant structured and non structured information, as well as qualitative and quantitative criterion and their weights. De Boer. (2001) [2] wrote that a typical selection problem has four phases:

1. Problem definition.
2. Criteria formulation.
3. Previous qualification of suppliers.
4. Final selection of suppliers.

Other authors (Bhutta & Huq, 2002 [6]; Cebi & Bayraktar, 2003 [21]; Liu & Hai, 2005 [7]) applied a mixing of integer method, AHP, proportion systems and meta- and multi-objectives oriented programming, in order to solve the problem with qualitative and quantitative evaluation, objectives and restrictions.

AHP method was used in other similar applications, as evaluation and selection of industrial projects. Prasanta (2006) [22] used a multiple-attribute decision-making technique in order to analyze projects in front of market, considering technical characteristics and social and environmental impact in an integrated framework. It was demonstrated that not only was time of evaluation reduced and selection of projects but also that the method helps to find optimum projects in the frame of a sustainable development. In this case, methodology was applied to the Indian Tansnational Pipeline, and its effectiveness was demonstrated. AHP was considerably used in technological themes. Malladi, & Min, (2004) [23] proposed decision support models for the Internet access technologies in rural communities. For the first time they constructed an analytical hierarchy process model, which provided the overall priority weights for each access technology under the multiple criteria. Next, they examined the cases of communities pooling their budget resources for additional mutual benefit.

In suppliers selecting field, Tsahat et al. (2004) [24] proposed an integration of Quality Function Deployment (QFD), Analytical Hierarchy Process (AHP) and Preemptive Goal Programming (PGP) techniques. AHP is used first to measure the relative importance weighting for each of the requirements in the QFD process. Then, it is used again to evaluate the supplier´s notation for each evaluation criterion.

In all scientific literature that was analyzed, the closest methodology to the one presented in this paper was that presented by Tin & Cho (2008) [25]. They applied AHP technique to select suppliers and to decide how much should be bought. Then, a model formulation was applied to assign quantity of orders to each one of the selected supplier. Afterwards, twenty eight criteria were considered in the first stage, which was obtained from a study revision and by means brainstorming between members of buyer team from a high-technology company in Taiwan. After that, the same team extracted sixteen criteria. The study was aimed at general supplying. This kind of products differs highly from technological products. They deserve a special treatment due to complexities in which they are involved. In general, they participate as critical elements and they are the ones where a high behavior in terms of efficiency and durability are demanded. As each product corresponds to a different technology, this fact determines parameters to be evaluated. In this way, criteria defined in this paper are not the same as the ones previously cited by other authors. Another aspect that shows a special characteristic over that presented by other authors is that this methodology moreover shows key factors in order to identify possible suppliers for technological desired product.

In previous analysis of scientific papers it is indicated that a high number of authors use AHP method in order to select suppliers. All they agree with is the fact that AHP is the most suitable multi-criteria technique to be used in these cases. Therefore, this paper shows in (section 2) a general explanation of multi-criteria environment and details of AHP method selected. Section 3 presents and develops in detail the obtained methodology in order to select technological products suppliers. Finally, this methodology is applied to a real case study for the sponsor of the project. This application develops details and characteristics of methodology, and it can serve as reference to be applied in thermal solar collector supplier selection or another technological product.

## 1. ABOUT THE MULTI-CRITERIA ENVIRONMENT

"Taking a decision is a process of selecting between alternative courses of action based on a set of criteria in order to achieve one or more objectives"(H. Simon, 1960) [26]. A necessary condition for knowing if one is confronting a multi-criteria decision problem is the presence of more than one criterion; a sufficient condition is that where, the criteria are in conflict. Therefore, a problem can be considered as a multi-criteria, if and only if there are at least two conflicting criteria and there are at least two solution alternatives.

Criteria that can be said to be strictly in conflict means that increasing the satisfaction of one of them implies decreasing the satisfaction of the other; so the sufficient condition of a multi-criteria problem does not stipulate that the criteria are strictly in conflict.

Multi-criteria decision taking has developed its own features using specific terminology that includes new concepts. It should be noted that some of the concepts that will be introduced here have the same semantic meaning and either one or the other will be used depending on the theoretical context in which they are placed. These terms are defined below:

- Alternatives: Possible solutions or actions to be taken by the decision takers or deciding unit.
- Attributes: Characteristic that is used to describe each of the available alternatives. They can be quantitative (objective) or qualitative (subjective). Each alternative can be characterized by a number of attributes (chosen by the decision takers).
- Objectives: Aspirations indicating the preferred directions of selected attributes; associated with the desires and preferences of the decision maker.
- Goal: Aspirations specifying the levels desired of the attributes.
- Criterion: General term encompassing the concepts of: attributes, objectives and goals that are considered relevant in a decision problem.

In decision analysis techniques, the terms: multi-criteria, multi-objective and multi-attribute are terms used to describe decision problems with more than one measure of effectiveness and appear without distinction. There appears to be no universal definition of these terms. The definition of Multiple Criteria Decision Making (MCDM) has been accepted by various authors and is the term under which all the methods based on multiple attributes or objectives are grouped. They are divided into two groups:

Multiple Objective Decision Making (MODM) is related to those problems in which the set of alternatives is large and not predetermined. Such methods are used to designate the 'best' alternative, taking into account interactions with limitations. The solution to these problems is through the classical techniques of optimization.

Multiple Attributes Decision Making (MADM) is used to select "the best alternative" of an explicit set of alternatives, the final decision being taken by comparing attributes.

The multi-criteria evaluation and decision method selected was AHP developed by Saaty (1980) [27].

This method constructs a hierarchical model by decomposing a complex situation, then evaluates it and finally delivers list of alternative solutions from the most likely to the least likely. Some of the components can be easily measured because they describe quantitative aspects. The advantage of AHP is that it also enables the incorporation of qualitative aspects that are often omitted from analysis due to the complexity of their measurement but which can be relevant to some actors involved in decision making such as, for example, risk, uncertainty, equality, participation, etc.

The AHP orders these elements in a hierarchical model, performs binary comparisons (in pairs) and assigns numerical values to judgments (preferences) made by people (with respect to the relative importance of each element), synthesizes the results and aggregates the partial solutions in a single final solution.

The schema of a hierarchical tree used by the AHP is presented in Figure 1.

The highest level in the model is the fundamental objective; the intermediate levels are the criteria and sub-criteria that are used to evaluate the alternatives, which are on the bottom level.

## 1.1 Vector of priorities for each level

Once the hierarchy has been structured, the relative importance of the criteria at a given level must be established with respect to the higher level to which they are related. The comparisons between criteria of the same level (or the alternatives in the last level), whose weights are to be determined, are in pairs, wanting to know in each case, "How much more important is criterion i as compared to criterion $j$?" A scale proposed by Saaty (1980) [27] to evaluate the weightings of the criteria is shown in Table 1.

The value in the numerical scale $P_{ij}$ is the value chosen if criterion i is preferred over criterion j, and the value to be assigned is the inverse of the opposite case. As an example, if criterion i should have much greater weight than criterion j in your judgment, the value to give for $P_{ij}$ is 5. Otherwise, if criterion j should have a significantly higher weight than criterion i, the value to give for $P_{ij}$ is 1/5.

| Verbal scale | Numerical values |
|---|---|
| Equally important, likely or preferred | 1 |
| Moderately More Important, likely or preferred | 3 |
| Strongly More important, likely or preferred | 5 |
| Very Strongly More Important, likely or preferred | 7 |
| Extremely more important, likely or preferred | 9 |
| Intermediate Values to reflect Compromise | 2,4,6,8 |

*Table 1. Fundamental scale for pair wise comparisons.*

Each criterion must be compared with each of the others at the same level linked to the same criterion at the higher level until all paired comparisons have been made. The comparisons are started at the level of the alternatives and continue to each higher level successively until the highest level is attained.

auto vector. It can be demonstrated that $\lambda_{max} \geq n$, where the equality signifies perfect consistency.
A consistency index (CI) and the consistency ratio (CR) are defined as:

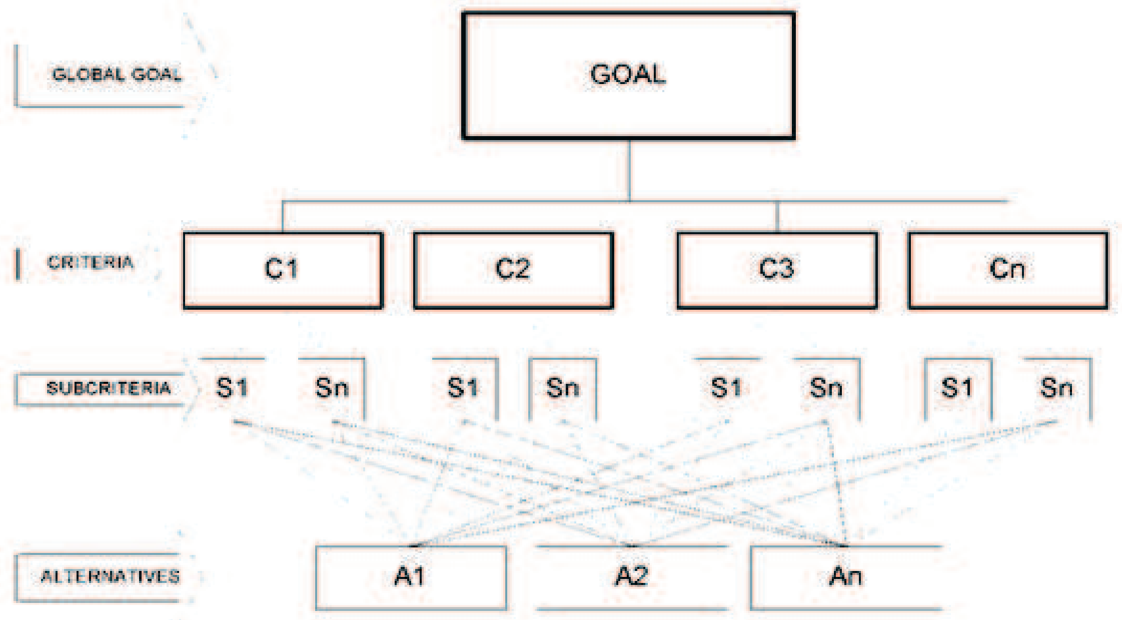


*Figure 1. AHP Hierarchy Scheme*

## 1.2 Consistency

The values $P_{ij}$ are placed in judgement matrices, one for each round of paired comparisons. If the decision taker is consistent, a reciprocal matrix [A] is generated complying with the following equality: [A]·[W] = n[W], where W is the vector of priorities or weights for the criteria $[w_1, w_2, ..w_n]$ and n is the dimension of the matrix.
If the decision taker is not consistent, a matrix [R] is generated that is a perturbation of [A] and complies with the following equality: [R] ·[W] = $\lambda_{max}$ [W], where $\lambda_{max}$ is the dominating auto value of the comparison matrix and [W] is its

$$CI= \frac{\lambda_{max}-n}{n-1} \quad \text{and} \quad CI= \frac{CI}{RI}$$

Where the Random Index (RI) is an average of the inconsistency coefficients of a large sample of matrices whose inputs are chosen at random. Saaty (1980) [27] defines the values shown in Table 2.

| $n$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $RI$ | 0,00 | 0,00 | 0,525 | 0,882 | 1,115 | 1,252 | 1,341 | 1,404 | 1,452 | 1,484 |

*Table 2. The reference values of the $RI$ for different values of $n$*

The method suggests that the consistency ratio must be $\boldsymbol{CR} \leq \mathbf{0.1}$ for the results to be sufficiently consistent.

### 1.3 Global Priorities

Each criterion has an associated global weight, which is calculated as indicated above. The global weight of the criterion is obtained by multiplying its local weight by the global weight of the higher level criterion with which it is associated. The sum of the global weights of each alternative with respect to each criterion provides the evaluation of the alternative.

Additionally, the AHP enables the execution of sensitivity analysis to observe and study other possible solutions on making changes in the importance of the elements making up the model.

## 2. DESCRIPTION OF THE PROPOSED METHODOLOGY

The methodology consists in performing two general stages. The first stage consists in analyzing the type of product to be acquired and the technologies that it might involve. Then industries or companies manufacture or sell this type of product could be identified ,only if they are located in a common geographical region. Next step is the identification of information sources on suppliers and their analysis, which might also provide information about their products. Finally, complementing the information, if possible, with visits to the suppliers' facilities as well as performing an analysis on samples of the products they offer. This first stage will provide a list of possible suppliers with all the characteristics of their companies and their products which are necessary to make a subsequent selection. This stage is called Preliminary Selection of Suppliers. The second stage consists in the application of the AHP technique to obtain a ranking of the most appropriate suppliers with which to establish commercial relationships. The general schema of the proposed methodology is shown in Figure 2.

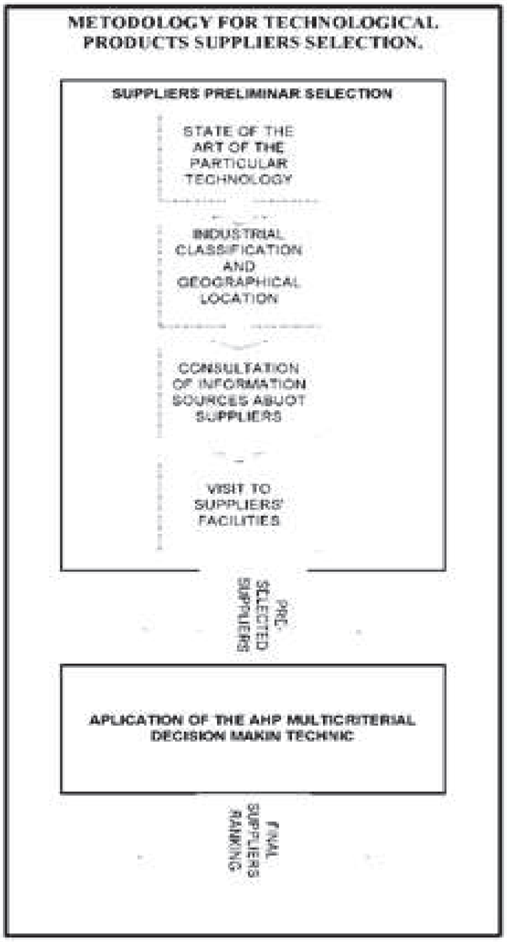


*Figure 2. Methodology general scheme.*

## 2.1 Preliminary selection of suppliers

The steps for making a preliminary selection are described below.

**Study of the state of the art and the technology.** Before undertaking a selection process in the technological environment, it is important to perform a study or analysis of the state of the art and the technology regarding the product. This will give an idea about the technology, the applications for which it may be used, an assessment of how it may change and general information on how to start the selection process. This information will also help to ratify the acquisition decision, whether favorable or not.

**Classification of the industry and geographical location.** Firstly, it is necessary to know which are the industries or companies producing or selling the article or item required. As soon as this is known, the number of suppliers is reduced to a small select group of companies. Also, with reference to commercial records or directories, many of which are classified by industries or organizations, may provide a list of names and locations of possible sources of supply.

In the search of the technology, it is often found that it is more concentrated in specific countries or areas. This will give an idea of the location in which the search should be specifically directed. There are advantages of looking where there is a larger offer of the products in question, but without guaranteeing that the selected supplier will necessarily be located there.

It can also happen that, when making a classification of the industry and business, companies are identified that sell the product and consequently the countries where they are located.

**Consultation of information sources about suppliers.** The most appropriate sources of finding possible suppliers include catalogues, classified telephone directories, buyers' guides, publications and trade magazines, digital information, on the internet, interviews with the suppliers' representatives, trade fairs and commercial exhibitions.

**Visit to suppliers' facilities.** It is useful to visit a potential supplier with the purpose of forming an opinion about them by direct observation of their team, staff and related issues. Such visits should be made "in a team", together with technical and financial experts when it is desired to obtain a more complete evaluation of a company.

In these visits, it is useful to find out from the KBBbout their organization, capabilities, strengths and weaknesses.

The most important aspects that should be kept within view, in a supplier plant visit and which will later help with making a selection are the following:

- General impression of the plant.
- Reliability and quality of the manufacturing process.
- Production in the plant itself.
- Self-sufficiency in the production of critical

elements making up the product.
- Staff and the employee qualifications.
- R&D laboratories.
- Production capacity.
- Prospects for growth.

Analysis of samples. Asking for some samples of the product from the KBBnd subjecting them to examination is very useful for checking whether what is offered is actually being delivered.

For analyzing the samples and evaluating the collected technical information (in catalogues, technical specification sheets, etc.), there must be a listing of parameters or characteristics to be evaluated.

## 2.2 Application of the Analytic Hierarchy Process

It has been determined that a series of parameters must be defined regarding the various aspects of relevance to the selection process. The key steps in determining of these parameters and criteria will be described in their order of importance.

**Determine and analyze the existing technologies.** There can be several alternatives for a technological product to address a specific application. These might arise because of different techniques or manufacturing materials, costs, or even because the product is directed at specific applications where a specific alternative performs better. Therefore it is necessary to initially define and analyze the existing technological options, understanding their function and application, before moving on to detailed analysis. It may turn out that the parameters and comparison scenarios between products of one technology or another are different.

**Study of the Regulations.** In the first place the applicable regulations for product certification and distribution within the target market must be analyzed, taking into account the application standards and certifications for which the product is being considered. Aspects such as environmental regulations or standards should be included in this study, clarifying if there are or are not legally binding.
This study should give sufficient detail of each aspect to enable the evaluator to objectively analyze each product and its supplier. If several applicable technologies are found, the regulations required for each of these must be verified as they generally differ depending on the technology.

It is important to include some information about obtaining certifications, the requirements for obtaining them, times, costs and the entities that can authorize their issuing so that it may be possible to evaluate the viability of performing the process for some supplier who does not currently comply but are capable of doing so if they were being considered by the decision maker.
It is essential to start with this study since, at the time of making a selection, the products that do not comply satisfactorily in this matter are not worth evaluating in a later stage.

**Parameters of the company**. These give a rough idea of the reliability of the company. Here, the applicable quality certifications for manufacturing, financial information, details about the alignment with our company (i.e. if they are a manufacturer, distributor, or if they have distributors in the area where one hopes to market the product) should be listed. Other points to take into account are the age of the company, relationship with research centers, etc.

**Parameters of the product.** The product parameters that must be assessed are the technical characteristics that allow identification of the quality of the product so that it can be evaluated and compared objectively with another. Generally, these are key parameters on the technical specification sheet (efficiency, weight, size, losses, etc.), as well as the characteristics of the components (materials, manufacturing techniques, technology, etc.).

To obtain and evaluate these parameters, expert sources on the product should be consulted.

Generally, the criteria that have been considered important when studying the suitability of a commercial relationship with a company are as follows:

**Criteria that must be fulfilled.**

- Compliance with the Regulations for marketing the product (in the destination country).

- Compliance with the ISO manufacturing standards.

- Alignment with business objectives. (Possibility by the Spanish company of becoming a distributor of the products in Spain/Europe).

**Parameters of the company.**

- Experience (Number of years since they were formed).
- Maintenance of relationships with research and development centers.

- Production capacity.

- Manufacturing technology.

- Self-sufficiency in the critical components for production and product development and/or the need to acquire them from a third party.

**Parameters of the product.**

- Product guarantees (quality and expected life of the product).

- Quality of the construction materials.

- Performance of the product (efficiency).

- Complexity in usage.

A graphical representation of the hierarchy to be considered when applying the AHP technique is shown in Figure 3.

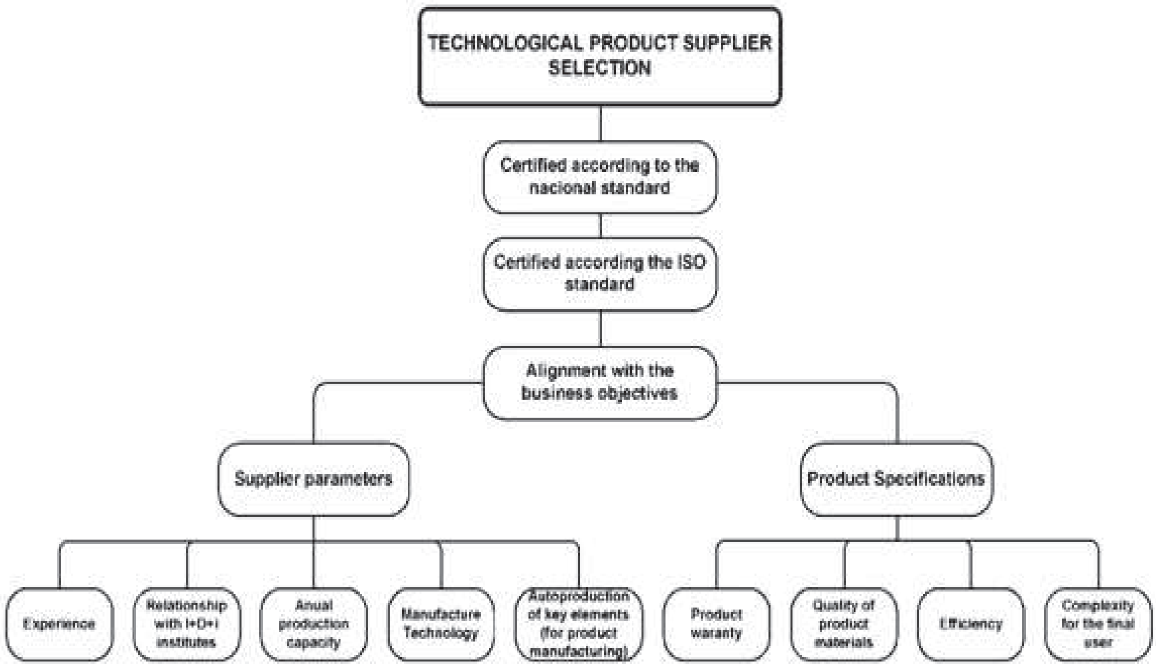


*Figure 3. Hierarchy of the methodology.*





### 2.2.1 Description of each criterion and it´s measurement scale

Criteria that must be fulfilled. As previously mentioned, the result of this selection process is the most appropriate technological supplier for a company to import and distribute these products in the destination country. With this aim, there are three essential aspects that will give the first impression on the viability of being able to market the products from the supplier. These aspects are:

- Compliance with the Regulations for marketing the product (in the destination country). This refers to the regulations and standards demanded in each country for approving and marketing a product. Sometimes these are technical codes. Other times they are standards depending on the country. In the case of Europe, the EN standard is demanded mostly, therefore implying that tests have been performed according to defined procedures and products are also marked with the CE label, and those corresponding to product safety standards.
- Compliance with the ISO manufacturing standards. Of special relevance are the ISO 9000 standards on manufacture of components and systems. Together with compliance with national standards, this gives an idea of the reliability of the product.
- Alignment with business objectives. The possibility of becoming a distributor of the products in the destination country by the Spanish company (Spain/Europe).

These criteria are assessed on a binary scale. There is no other measure than if the supplier complies or does not comply with the criterion.

Parameters of the company. These types of parameters, which have been previously described, are characteristics implicit in the quality and production process of the company.

- Experience. The experience of the company in the production activity of the product required is highly valued. This is because companies with a good career in the field normally have better support for their products, the result of continuous improvement of these processes, techniques and R&D developments. By contrast, there are companies that have often changed their name, reflecting instability and mistrust, as is the case for some companies in China. The unit of evaluation is YEARS since the company was founded.
- Relationship with R&D centers. Whether the company has contacts with university laboratories and other centers enabling them to maintain an appropriate level of technological transfer or lack of such contacts for which evidence can be obtained (quality tests, R&D department, etc.). To score this criterion, the Binary Comparison Scale is used.
- Production capacity. This reveals the capacity of the company when faced with large production demands. Obviously, a higher production capacity is scored positively. The score will be the annual production capacity in units of the product items desired.
- Manufacturing technology. This parameter reveals whether the company is at the technological leading edge with respect to manufacture of the product required. A review will be made to ensure that the manufacturing technique and equipment are those offering the best product quality, that there are processes of controlling the usual manufacturing defects in the products. A company will be positively valued by having product testing laboratory and above all ,develops new technologies. One way of finding more out about this aspect, is by paying a visit to the manufacturer's installations. To score this criterion, the Binary Comparison Scale is used.
- Self-sufficiency in critical component parts. If the company has the ability to manufacture its own components, this fulfils two objectives: it guarantees independence from the market, and consequently the production capacity. On the other hand, the specific component is always available, which guarantees the efficiency of the product in the future. To score this criterion, the Binary Comparison Scale is used.

Characteristics of the product. As it has been previously mentioned, these criteria correspond specifically to the product and generally can be found in the technical specification sheet.

- Product guarantees. This parameter corresponds to the guarantees offered on the quality of the product. These are often guarantees against manufacturing defects, which are generally within a span of 1 or 2 years. Also, there are guarantees on the performance of the product, such as in the case of solar heating collectors where the span usually wider than 5 years, or in the case of photovoltaic panels which offer, for example, 80% performance up to 25 years. Therefore, the applicable measurement scale is in YEARS.

- Quality of the construction materials. The quality of each product depends largely on the materials from which it is constructed. This is observed on analyzing the current technologies; each of them will have some components where the manufacturing material will determine the performance of the product and also its active period. To score this criterion, a qualitative scale is applied.
- Performance of the product. (Efficiency, Effectiveness). This parameter reveals how appropriate and effective the product will be for the application in question. The values to measure for this aspect will depend on the product. A qualitative evaluation scale is recommended for this case.
- Complexity in use. This refers to the ease with which the required product can be installed, applied and maintained. It is possible that a better performance can be achieved with a given technology but this technology may not always be the easiest to apply or use. This aspect plays an important role in the selection. To score this criterion, a qualitative scale is applied.

Measurement scale. As not all criteria have an objective unit of measurement, a qualitative scale is used to make comparison among different alternative (suppliers). One option may be to define a scale such as the following:

| Numeric Scale | Verbal Scale |
|---|---|
| 1 | Very Bad |
| 2 | Bad |
| 3 | Regular |
| 4 | Good |
| 5 | Very Good |

*Table 3. Qualitative scale.*

### 2.2.2 Evaluation and Analysis of each parameter

The next step is to obtain and evaluate the parameters or criteria available for each of the pre-selected supplier companies.

Once all the evaluations have been performed, each company must be analyzed objectively in order to obtain a graduated scale where each of the suppliers can be situated. The importance of each parameter will depend on the aspect that the group of specialists (decision makers) of the company wish to priorities.
It is suggested that this valuation be performed in a comparative table so that it is more visual and practical. Taking the results into account, the analyzed companies can be ordered from the most suitable to the least suitable for becoming a supplier.

Observing the hierarchy of criteria (Figure 3), there are two lower lines where there is s more than one sub-criterion to be compared with, especially in the last, where five sub-criteria appear on the same level for the parameters of the company and in the case of technical specifications of the product, there are four sub-criteria to be used in comparison. In the same way, these criteria must be applied to comparisons of multiple alternatives, as these are the supplier companies with their respective products. This is an example of a multi-criteria decision problem. The general objective of selection of a technological product supplier will depend on the evaluation of all the criteria and sub-criteria applied to each of the supplying companies.

### 2.2.3 Selection of the group of experts

When analyzing complex systems, a single person's opinion in taking a decision may be insufficient, especially where the solution could affect many other people. Therefore, discussion and exchange of opinions should take place among the actors so that their experience and knowledge can help to structure the problem and evaluate possible solutions [28]. It is clear why it is important to use of a selection group of experts.

### 2.2.4 Final selection of the supplier

Once each of the alternatives (supplier + product) have been objectively compared, obtaining the order of suitability in accordance with the criteria established by the multi-criteria decision technique, the respective suggestions and conditions should be made, indicating the most appropriate KBBnd product, and making reference by way of conclusion to the whole selection process, presenting the application of the methodology of this document.

## 3. APPLICATION OF THE SUPPLIER SELECTION METHODOLOGY IN THE SUPPLIERS SELECTION OF SOLAR THERMAL COLLECTORS

In a practical demonstration of the methodology that will reveal some of the details of the process, the methodology has been applied to the selection of suppliers of the Solar Thermal Collector product, as this is the request of the sponsoring company of this development. This section presents this practical application, showing all the steps executed and the results obtained, in order to sell the product in Spain.

### 3.1 Preliminary search and selection of suppliers

Starting the process, a preliminary identification of possible suppliers was undertaken. For this, the sources of information that were described were used. As part of this process, representatives of the company interested in making an acquisition travelled to China, where according to the sources, a large number of manufacturers of Solar Thermal Collectors at highly competitive prices could be found. During this visit, the representatives visited the factories, learned the details of manufacture and interviewed supplier delegates who informed on details such as the relationship they had with research institutes, in-house manufacture of essential components, such as vacuum tubes and glass covers. They also learnt about details such as the soldering process, raw materials, etc. They also requested equipment catalogues and obtained contact information enabling them to request more information for the selection process at a later time.

Also, a visit was made to the energy fair "Genera" in Madrid, where manufacturers of products in the field of energy, with special emphasis on renewable energy, meet every year. Information was obtained about manufacturers from other geographical areas, especially from Germany and Austria. The whole team of decision makers participated in this work. They also visited the Inter-solar fair in Munich where the list of possible suppliers was extended, finding new and interesting offers.

Once all the information obtained had been organized, some data was found to be missing. These were obtained by consulting the web pages, mail, phone contact and by visits of some representatives to suppliers.

## 3.2 Definition and analysis of existing technologies of solar thermal collectors

As was previously indicated, a study should be undertaken to identify the details of the technology to be acquired, with an aim of determining the evaluation criteria. The result of this study, directed at solar thermal collector products is shown below.

The function of the collector is to heat the circulating working fluid, or heat carrying fluid (water with glycol or another anti-freezer), transferring the heat through a primary circuit, storing it in an accumulator. As it is required, the heat is passed from the accumulator to the consumption circuit. It is key to remember that the Edification Technical Code CTE in Spain demands sufficiency of two circuits; one primary with the heat carrying fluid and secondary where mains water circulates.

All the designs must be conceived with the common objective of converting solar radiation into heat with the highest performance possible, and later to supply it efficiently to the consumers. The designs of the collectors varied in quality, performance, construction and cost.

### 3.2.1 Existing technologies

There are many variants in the construction of solar collectors but in general they fall into two groups: the flat-plate collectors and those with vacuum tubes.

Flat-plate collectors: These basically consist of a copper circuit where the heat carrying fluid circulates. The circuit can be in the form of a serpentine or grill, depending on the properties required at the level of load and temperature losses. A plate, which behaves as an absorber, is soldered on to this circuit, to capture the heat and transfer it to the circuit. Both are incorporated into an aluminum shell. Between the circuit and the shell there is a thermal insulator and on the top part, a transparent cover, protecting and insulating the internal components, which allows the passage of incident radiation creating a greenhouse effect. Flat-plate solar collectors are often constructed with areas of the order of 2 square meters, as is seen in Figure 4.

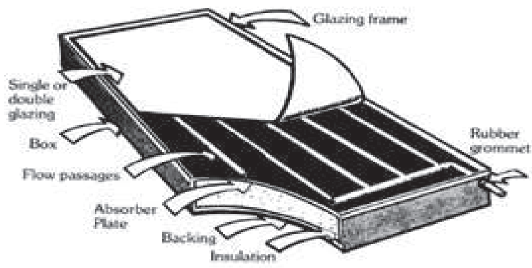


*Figure 4. Heat Pipe Operation. (Courtesy of Missouri Department of Natural Resources*

The efficiency curve of these collectors often has a rising slope, which indicates higher efficiency at high radiation, but this reduces significantly at low radiation.

**Vacuum tube collectors**. These are vacuum glass tubes, which provide better thermal insulation from the exterior, where the radiation collecting components are housed inside.

There are two types of vacuum tube collectors, depending on the method used for the exchange of heat between the panel and the heat carrying fluid:

- *Heat pipe.* This is a closed evaporation-condensation system with no moving parts. In the interior tube, much longer than wide and provided with a certain vacuum, there is a liquid that vaporizes in the range of the temperatures desired. After vaporizing, it rises through the interior of the tube towards the upper part (condenser) where there is a cold area. Here it releases its heat and returns to liquid state. In this process it releases the so-called "latent heat of vaporization", which is necessary for its change of state from liquid to gas and vice versa. This is much greater than the amount of heat necessary to easily increase its temperature. After converting into liquid, the fluid descends again through the tube towards the heat source, where the process starts again. In this way, a large amount of heat is moved without a great increase in temperature. It is as natural as rain water. This metal tube is provided with aluminum vanes with a special covering that optimizes heat capture. The system is enclosed in a borosilicate capsule in a vacuum to minimize losses. In this way, higher efficiencies are achieved than in conventional solar devices. A heat pipe is showed in Figure 5.

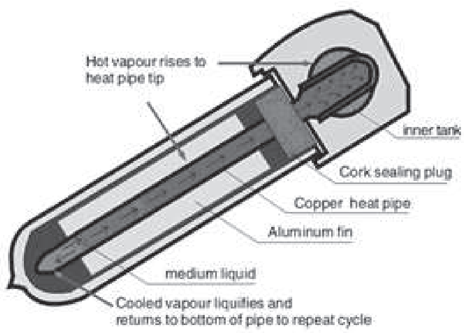


*Figure 5. Heat Pipe Operation. (Courtesy Shentai Solar)*

- *Direct flow*. In this design, the fluid of the primary circuit circulates through the ducts located inside the tube, receiving the heat coming from the absorbing panels directly, returning again towards the heat exchanger to give up its heat. This kind of solar collector is showed in Figure 6.

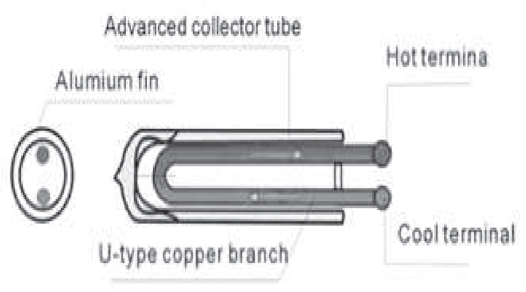


*Figure 6. Operation of the vacuum tube to direct flow (Courtesy Shentai Solar)*

### 3.2.2 Construction components

The most important parameters and characteristics that must be taken into account for each of the collector parts when selecting a collector are presented below:

**Transparent cover.** Its purpose is to protect and thermally insulate the absorber, allowing the passage of radiation to the absorber. The characteristics of the cover are:

- **Transparency or transmittance.** Transmittance is the most important factor on the cover of a collector. It depends on the properties of glass. The parameter is the percentage transmitted by the cover of an incident solar ray of light when shone vertically over it. This value should be as high as possible.

- **Reflectance or emission.** Gives a percentage value of the reflection of solar light on a transparent cover. This value should be as small as possible.

- **Weather resistance.** The cover must be robust and resistant to the effects of the environment (rain, hail, wind, ultraviolet radiation, etc.) and to large temperature fluctuations.

- **Material.** Both the transmittance and the useful life of the cover depend on the manufacturing material. Currently, in high quality collectors, the transparent cover is made of so-called "solar glass", of low iron content, hardened and of high transparency. In the case of tube collectors, the cover is the glass tube. Currently these are manufactured in borosilicate and the interior is often covered with a highly reflective material to direct the radiation towards the absorber.

A double transparent cover (two glass plates) is not advisable because, despite creating a good thermal insulation, it increases reflection, results in higher manufacturing costs and greater weight. Neither is the use of plastic covers, or covers containing some component of this type such as methacrylate, glass fiber, polyvinyl chloride PVC, polyvinyl fluoride PVF, etc. These have been studied and have been found to end up being opaque, yellowing or developing small cracks, breaks or tears over time, due to the high coefficient of thermal expansion of the plastic.

**Absorber.** Its purpose is to convert solar radiation into heat, and the working fluid circulates through fine tubes inside, to be later directed to the accumulator.

- **Absorption $\alpha$.** It is the fraction or percentage of incident radiation absorbed. Given as a percentage, the values are often between 0.9 and 0.96, with the higher the value, the better. This variable gives an idea of the performance of the absorber.

**- Emissivity ε.** This corresponds to the percentage of energy emitted by the absorber for a particular wavelength of light. Given that an absorber should absorb radiation energy, the value of the emissivity should be as low as possible.

**- Materials and coverings.** The performance of an absorber depends essentially on the material from which it is made and the covering that is applied to it to make it more selective; this is the property that enables it to absorb more energy, controlling the amount emitted.

The absorber must be manufactured from a material with good thermal conductivity. Currently copper is used in a majority of collectors for distributor tubes and the fine tubes of the absorber. Also, the absorber plates are made of copper or aluminum. The use of iron is not very common as the material has major drawbacks, such as corrosion.

As the surfaces of metals reflect light to a high degree, it is necessary to cover them with a material of high absorbance for the short wavelengths of solar radiation. The materials and suitable process as currently used for this purpose are:

**- Black nickel/Black chrome.** The copper plate is passed through various baths with solvent and cleaning agents. Then nickel or chromium is applied electrolytically. The effectiveness and stability of these coverings have been demonstrated over a long time.

**- Black crystal. H**aving cleaned the copper plate, a layer of nickel is deposited over it and this in turn is covered by special crystals (of a composition that has not been revealed). Finally this is covered with melted glass (using a galvanic process).

**- Physical Vapour Deposition PVD.** A beam of electrons is directed towards a crucible containing the covering material. This is performed in a vacuum chamber where the surface to be covered is contained. The material vaporizes and is deposited on the component to be covered. The absorbers manufactured in this way are presented to the market under the trade labels "Tinox" and "Ecoselect". A variant of this process is PECVD, where at the end of the process described, an additional layer is applied through the CVD (chemical vapour deposition) process.

**- Cathodic bombardment ("Sputtering").** This is performed in an argon-filled chamber. Electronic bombardment under continuous current, maintaining a high voltage difference between the anode and the material to be covered, which is connected as the cathode. The material is powdered over the copper plate. The material used is often nickel or other mixtures of selective materials.

Coverings that are considered to be obsolete and not recommended are:
- Non-selective solar paints.
- Pigmented aluminum oxide with nickel over aluminum.
- Cobalt oxide / cobalt sulphide (selective) over steel plate.
- Enamel with selective properties over steel.

- Vitrified selective steel absorber.

**Casing.** In the case of flat-plate collectors, the casing encloses the absorber and the thermal insulation, protecting them from humidity and mechanical damage.

**Currently,** it is recommended that the casing be made of aluminum as in the past galvanized steel was used, which gave rise to oxidation and corrosion.

**Joints**. In the case of flat-plate collectors, they are used to protect the union between the frame and the transparent cover. These joints must guarantee good water-tightness against rain water and humidity in general, and for the case of the connection joints, they must withstand the temperatures to which they will be exposed.

Materials based on ethylene propylene diene monomer (EPDM) have been proven to be adequate. These profiles should be vulcanized. In other cases, the unions can be protected with silicone and EPDM placed on the exterior as materials based on silicone are adequate for unions.
For the case of vacuum tubes, the joints must close the tubes, insulating their components from the outside and enabling the passage of heat conductors towards the outside. Therefore they must be impermeable and resistant to temperature.
**Insulators**. Thermal insulation for flat-plate collectors is essential because in this way, thermal losses are reduced. Generally, the back wall and the sides of the casing are thermally isolated.

**Therefore,** materials of low thermal conductivity are used for this purpose. Mineral wool has been the material with the best performance based on experiences from models tested over many years. Secondly, they are rigidly expanded polyurethane foams, but recommended for collectors without selective absorbers in which the working temperatures are not too high.

For collectors with aluminum frames, insulation on the lateral wall is required as it prevents a thermal bridge between the absorber and the frame that causes thermal losses.

In the case of tubular collectors, this insulation is achieved by means of the vacuum contained in the glass.

### 3.2.3 Installation options

This factor is oriented to the needs of the customer. Here, the difficulty for the collector to adapt to different surfaces or mounting options, be it on an inclined roof, a flat roof, facade, with architectonic integration or as a closure or roof, should all be taken into account.

The orientation and inclination (azimuth and inclination angles) and the architectonic and visual aspects, both play an important role here.
- **Mounting on a flat roof.** In this case, the optimum inclination angle for solar collectors can be obtained by the use of an appropriate supporting structure. Inclinations of around 45º are more or less suitable for collectors located in average latitudes for the domestic hot

water system. The inclination will depend on the specific application. For example, for a system supporting heating, a higher inclination angle, favoring its performance in cold seasons, is required. Another factor affecting the determination of the angle is the climatic condition of the area. So a heavy mist in the morning or the evening may influence the choice of angle. For the case of direct flow vacuum tubes, they can be placed directly on the roof in a horizontal position. However, this solution is not recommended in regions where it snows. On melting and freezing again between the tubes, the snow may give rise to forces that can bend or cause breakage of the tubes. In some designs, the tubes or the absorbers can revolve, and made to face the sun at the desired angle. In the case of "Heat Pipe" type vacuum tubes of the, horizontal placement is not possible as they require a minimum inclination of 20º to 30º.

- **Mounting on an inclined roof.** In this case, the angle of the collector often has to be the same as that of the roof. While this is between 20º and 50º, the reduction of annual solar contribution will almost always be less than 5%, when compared to the optimum. If the inclination of the roof departs from these values, the inclination of the collectors needs to be adjusted alongside accessories. Both flat-plate modules and vacuum tubes can be placed with hooks supporting them on the roof, making the mounting even less complicated, more economical and with ease of substitution of the collector.

- **Mounting on the facade.** Radiation on a vertical surface in countries of average latitudes is between 60% and 65% of that on an optimally inclined surface. However, this mounting is used for aesthetic reasons or due to lack of other suitable surfaces. In this mounting, there will be a corresponding reduction of annual solar contribution. Flat-plate collectors can be installed at a different angle from that of the facade, for example to contribute to the provision of a shade. They can also be completely integrated into the facade, which in turn contributes to the improvement of their thermal insulation. Vacuum tubes can be installed on vertical surfaces. Some have absorbers that can be rotated on mounting, to give better alignment with the sun, thereby achieving better performance than flat-plate collectors mounted on the facade. For the case of vacuum tubes of the "Heat Pipe" type, they can only be placed on the facade in a vertical manner.

- **Direct integration in the roof.** This is an option available only for flat-plate collectors. These can be mounted directly on the formwork or the beams. Visually the collector seems to be an integral part of the roof. Both installation and substitution may be somewhat complicated. The minimum inclination for roofs is recommended to be 20º as this is generally the minimum recommended by the collector manufacturers in order to guarantee impermeability. For different values to these, mounting on the roof is more appropriate.

**Ease of installation.** There are two key factors framing this aspect. One of them is the weight of the module, where vacuum tube collectors have the advantage in being on average the lightest. The other factor affecting installers is lack of knowledge of the product and the installation technique required for tubular collectors and the apparent vulnerability to breakage. Because of this, installers often opt for flat-plate collectors.

**Ease of substitution.** In case of damage, vacuum tube collectors have the advantage of allowing partial replacement, that is, one or several tubes making up the collector can be replaced. This is easier and sometimes cheaper than for the flat-plate collector, where generally the whole unit has to be replaced.

### 3.2.4 Conclusions about existing technologies

- The presence of galvanized steel is not suitable in the components of a solar collector, neither in its casing nor in the tubing.
- The quality of the collector is reflected in its characteristic efficiency curve, which is the fundamental parameter. From the formula for the curve, it is deduced that the efficiency is higher when the optical efficiency is higher and the linear losses constant is lower. However, it is useful to analyze the geographic zone and the application with which the collector is to be used to determine the most suitable curve.
- For applications where the collector must form part of the roof, the flat-plate collectors are the most appropriate.
- The vacuum tube collector is ideal for heating and industrial processes; dryers, desalination, heating processes, heating for hotels, spas, buildings, sports complexes, etc., as its performance is much better than the conventional flat-plate collector and the fluid reaches higher temperatures.

## 3.3 Analysis of the applicable regulations for marketing thermal collectors in Spain

Taking into account that the country defined for marketing the product in this case is Spain, the Spanish regulations applied to the marketing of solar thermal collectors have been analyzed.

**UNE-EN Regulations.** it is determined that the trials covering the complete tests as indicated in the regulation UNE-EN12975-2 [29] and verification in accordance with regulation UNE-EN 12975-1 [30] are the minimum requirements of a collector for its certification in Spain. Similarly, for pre-manufactured collector systems, the regulations are UNE-EN 12976-2 [31] and UNE-EN 12976-1 [32] for trials and verification respectively.

The regulation UNE-EN 12975-1 describes the criteria that must be fulfilled by collectors in order to have their conformance with the regulations verified. It is concerned with the evaluation of the results of the tests and of security aspects, as well as of the identification and documentation of the product. It also provides information about conformity of materials with the regulations and their durability, their ecological balance and on repeat tests in case of modifications in the manufacturing process.

Regulation UNE-EN 12975-2 describes the testing process to be applied both to collectors without a cover (for example for heating swimming pools) and to flat-plate or tube collectors provided with transparent covers. Section 5 describes the durability and reliability tests and section 6 describes the procedures for measuring the performance curve, loss of load and the determination of the thermal capacity.

**The "Solar Keymark".** There is a European certification programme enabling the national organizations to recognize each other at international level, it is issued together with the national symbol. In this way, a customer in Europe has the security that, regardless of the place of manufacture and the place of testing, the same minimum defined quality is demanded for each type of test. For solar thermal collectors, its award especially depends on compliance with the regulation EN12975.

**Ecological labels (Blauer Engel).** This voluntary labeling is given to products with lower negative effect on the environment and satisfying high demands of health and work protection and suitability for use. Such products also have to guarantee the economical use of raw materials and natural resources during the whole of the life cycle. The fact that a product has got this labeling shows concordance with Appendix B of the regulation UNE EN-12975-1:2006, on environmental protection.

**ISO 9001 Standard.** If the company claims ISO 9001 certification, it absolutely guarantees that the production process respects minimum quality standards and assures that the collectors produced have very similar characteristics to those of the ones already tested.

**Technical Building Code (Código técnico de la edificación CTE) in Spain.** It is the key to the approval of solar thermal energy projects. Its basic document, HE4 [33] minimum solar contribution for domestic hot water, defines the minimum requirements that buildings must comply with.

## 3.4 Selection of the group of experts

For evaluation and taking decisions, a reduced group of professionals is formed, which is directly involved in the process:
- Advisory Project Manager: evaluates the model, gave guidelines for the determination of criteria weights and the alternatives to be selected.
- Head of the Purchasing and Contracting Department: receives offers in accordance with the company's criteria, received the alternatives coming from the approved companies.
- Specialist Technical Engineer: specialist in the product to be selected who make suggestions for weighting and qualification of technical criteria.

## 3.5 Evaluation and Analysis of each parameter

The criteria to be evaluated were those defined in section 3.2.1 and the hierarchy to be used is presented in Figure 3 of section 3.2.
Before starting to evaluate the criteria, the list of possible suppliers was reviewed, because on first contact ,it had been observed that some did not match the

objectives of the purchasing company or in other cases there were irregularities in their manufacturing process or product sale, which made them unsuitable for inclusion in the selection process. Having a pre-cleaned list is useful as it makes the process more efficient.

The process of evaluation started evaluating those criteria that must be fulfilled or "Filters" that are exclusive. The supplier company that does not meet all these is not evaluated for other criteria in the AHP process. The comparison of the information obtained by applying the filters to the suppliers can be seen in Table 4. Here, there is an additional column labeled "Certificate", where the certifications possessed by the supplier in relation to the product are listed.

**Evaluation of the criteria that must be fulfilled "Filters"**

| SUPPLIER | CERTIFICATE | Compliance with the Regulations | ISO 9001 Standard | Alignment with business objectives |
|---|---|---|---|---|
| KBB | ISO 9001, BLUE ANGEL, KEYMARK, TUV | YES | YES | NO |
| Ritter Solar GMbH &Co. KG | EN 12975, Blue Angel, Solar Keymark · ISO 9001 | YES | YES | NO |
| Donauer | TÜV, DIN y EN (12975 - 2), Solarkeymark.ISO 9001, Blue Angel | YES | YES | NO |
| CONSOLAR | Solar Keymark, EN 12975, ISO 900 | YES | YES | NO |
| SCHOTT | ISO9001, TUV, EN 12975 | YES | YES | NO |
| WESTFA | ISO9001, EN12975, Solar Keymark | YES | YES | YES |
| SONNENKRAFT | ISO9001, EN12975, Solar Keymark | YES | YES | YES |
| TH SOLAR | ISO9001, EN12975 | YES | YES | NO |
| FIVE STAR | ISO 9001, EN12975, | YES | YES | YES |
| YOUYIJIA | ISO 9001-14001, | NO | YES | YES |
| SHENTAI | ISO9001, CE, EN12975 en trámite | NO | YES | YES |
| CIB | (ISO9001, CE en trámite) | NO | YES | YES |
| SUN-MASTER | ISO 9001, UNE 12975 | YES | YES | YES |
| SCHUCO | EN 12975-2, TUV, CE, Angel Azul, ISO9001 | YES | YES | NO |
| ERGOM | ISO 9001, UNE 12975 | YES | YES | YES |

*Table 4. Evaluation of the "Filters" to the suppliers found.*

After applying the three initial filters, the pre-selected companies were the following:

WESTFA, SONNENKRAFT, FIVE STAR, SUN-MASTER and ERGOM

Then, the multiple selection criteria corresponding to the parameters of the company and product specifications were applied to the companies on the list. See Table 5 in the Appendix.

Before assessing the criteria for the alternatives (companies) chosen, a study of the preferences of the decision takers about each criteria was made. This was done by the use of questionnaire, obtaining a consensus view of the four decision makers. The survey form applied, including the results of the consensus evaluation, are both shown in Table 6 in the Appendix too.

### 3.6 Weighting of criteria and sub-criteria, AHP method.

The approximate method was used to obtain the vector of weights W by calculation of [A] and $\lambda_{max}$, later verifying the consistency index.

Once the weights had been obtained for each of the criteria and sub-criteria, they were consolidated in a single hierarchy of weights diagram, similar to that presented by Ting & Cho [25], as shown in Table 7.

| | | Local Weight | Global Weight |
|---|---|---|---|
| SELECTION OF TECHNOLOGY SUPPLIER | | 1 | 1 |
| C1. | PARAMETERS OF THE COMPANY | 0,67 | 0,67 |
| SC1 | Experience | 0,14 | 0,10 |
| SC2 | Participation in R&D | 0,10 | 0,06 |
| SC3 | Production Capacity | 0,23 | 0,15 |
| SC4 | Manufacturing technology | 0,39 | 0,26 |
| SC5 | Self-Sufficiency in critical components | 0,14 | 0,10 |
| C2. | PARAMETERS OF THE PRODUCT | 0,33 | 0,33 |
| SC6 | Product Guarantees | 0,1 | 0,0429 |
| SC7 | Quality of the construction materials | 0,2 | 0,0528 |
| SC8 | Efficiency η | 0,4 | 0,1452 |
| SC9 | Complexity in use | 0,3 | 0,0858 |

*Table 7. Weights diagram for each criterion and sub-criterion.*

## 3.7 Evaluation of alternatives

The alternatives that did not have defined units were evaluated according to a scale of 1 to 5 (Table 3). Applying the global weights within the whole of the hierarchy (multiplying by the weight of each sub-criterion) gave the values shown in Table 8.

SELECTION OF ERGOMF THERMAL COLLECTORS

| COMPANY | WESTFA | SONNENKRAFT | FIVE STAR | SUN-MASTER | ERGOM |
|---|---|---|---|---|---|
| PARAMETERS OF THE COMPANY | | | | | |
| Experience | 0,12 | 0,29 | 0,33 | 0,12 | 0,14 |
| Participation in R&D | 0,29 | 0,29 | 0,12 | 0,12 | 0,18 |
| Production Capacity | 0,20 | 0,24 | 0,20 | 0,28 | 0,08 |
| Self-Sufficiency in critical components | 0,22 | 0,22 | 0,22 | 0,22 | 0,13 |
| Manufactu-ring technology | 0,24 | 0,24 | 0,10 | 0,19 | 0,24 |
| PARAMETERS OF THE PRODUCT | | | | | |
| Guarantee | 0,29 | 0,29 | 0,14 | 0,14 | 0,14 |
| Quality of the construction materials | 0,23 | 0,23 | 0,14 | 0,18 | 0,23 |
| Efficiency | 0,19 | 0,20 | 0,20 | 0,20 | 0,20 |
| Complexity in use | 0,24 | 0,24 | 0,14 | 0,24 | 0,14 |

*Table 8. Application of the global weights*

Finally, summing the preferences of the alternatives for each of the sub-criteria according to the global weight (sum of the rows for each supplier), the ranking shown in Table 9 was obtained. The sensitivity of the model was verified by checking that the order of preference was not affected by small changes in scoring the alternatives for each sub-criterion.

| COMPANY | SCORE | PREFERENCE ORDER |
|---|---|---|
| WESTFA | 0,88 | 2 |
| SONNENKRAFT | 0,96 | 1 |
| FIVE STAR | 0,68 | 5 |
| SUN-MASTER | 0,81 | 3 |
| ERGOM | 0,71 | 4 |

*Table 9. Final Ranking.*

From these results, it was concluded that the preferred supplier is SONNENKRAFT. Therefore this supplier was most suitable to be the supplier of the solar thermal collectors for the purchasing company.

## 4. CONCLUSION

A new methodology for supplier selection that takes account of the special characteristics of technological products was presented. The structure of the methodology and all the parameters used to implement it, were all defined .As confirmation of validity of the methodology, an example of application was shown the selection of a solar thermal collector supplier for the Spanish market, this objective was achieved successfully.

This work is especially interesting for companies that needed to import technological products. Problems arise when they try to select technical suppliers from several countries. It is necessary that the product comply with the quality, technical and legal standards an laws from the final consumer country.

In order to determine suitable parameters and criteria to be applied in the methodology, it was necessary to use multi-criteria decision techniques. Due to this reason, Analytical Hierarchy Process (AHP) was included in the methodology.

The practical viability of the proposed methodology was demonstrated in selecting a supplier from two more different technological products: solar photovoltaic modules and distribution transformers. It is even possible to think that there are few differences between solar thermal collectors and solar photovoltaic modules, the only thing in common being the sun. Each technology varies, so technological parameters were different too; as in the case of transformers, there was not any relationship with the others products. And the proposed methodology was successfully applied in all the cases. All this information is collected in a book published by the Institute for Energy Engineering of Universidad Politécnica de Valencia.

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## APPENDIX: TABLES 5 and 6

| | WESTFA | SONNENK-RAFT | FIVE STAR | SUN-MATER | ERGOM |
|---|---|---|---|---|---|
| **Location** | Germany | Austria | China | Austria | Poland |
| **Model** | ADK | SK200 | F3.0A | A2S | A2S |
| **Type of collector** | Flat | Flat | Flat | Flat | Flat |
| **PARAMETERS OF THE COMPANY** | | | | | |
| **Experience (years since created)** | 6 | 15 | 17 | 6 | 7 |
| **Relationship with R&D centers** | Own laboratory –Agreements | Own laboratory – Agreements | Own laboratory | Own laboratory | University Agreements |
| **Yearly Production Capacity (Units)** | 250,000 | 300,000 | 250,000 | 350,000 | 100,000 |
| **Manufacturing Technology** | Laser welding | Laser welding | Conventional welding | Ultrasonic welding | Laser welding |
| **Self sufficiency in critical component parts** | YES | YES | YES | YES | NO |
| **PARAMETERS OF THE PRODUCT** | | | | | |
| **Waranty (Years)** | 10 | 10 | 5 | 5 | 5 |
| **Quality of the construction materials** | Low Iron Glass – Copper Absorber | Low Iron Glass – Copper Absorber | Low Iron Glass | Low Iron Glass – Copper and Aluminium Absorber | Low Iron Glass – Copper Absorber |
| **Eficience η** | 0,762 | 0,791 | 0,789 | 0.793 | 0,777 |
| **Complexity in use** | Easy installation options | Easy installation options | No Easy installation options | Easy installation options | No Easy installation options |

*Table 5. Information selection parameters for each supplier.*

| *Criterial* | *Indifferent* | *Moderate* | *Strong* | *Very strong* | *Extreme* |
|---|---|---|---|---|---|
| ☒ ***Parameters of the company***<br>☐ ***Parameters of the product*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ***Subcriterials. Company*** | | | | | |
| ☒ ***Experience***<br>☐ ***Participation in R&D*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☐ ***Experience***<br>☒ ***Production Capacity*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☐ ***Experience***<br>☒ ***Manufacturing technology*** | ☐ | ☐ | ☒ | ☐ | ☐ |
| ☐ ***Experience***<br>☐ ***Self-Sufficiency in critical components*** | ☒ | ☐ | ☐ | ☐ | ☐ |
| ☐ ***Participation in R&D***<br>☒ ***Production Capacity*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☐ ***Participation in R&D***<br>☒ ***Manufacturing technology*** | ☐ | ☐ | ☒ | ☐ | ☐ |
| ☐ ***Participation in R&D***<br>☒ ***Self-Sufficiency in critical components*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☐ ***Production Capacity***<br>☒ ***Manufacturing technology*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☒ ***Production Capacity***<br>☐ ***Self-Sufficiency in critical components*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☒ ***Manufacturing technology***<br>☐ ***Self-Sufficiency in critical components*** | ☐ | ☐ | ☒ | ☐ | ☐ |
| ***Subcrterials Product*** | | | | | |
| ☐ ***Product Guarantees***<br>☐ ***Quality of the construction materials*** | ☒ | ☐ | ☐ | ☐ | ☐ |
| ☐ ***Product Guarantees***<br>☒ ***Efficiency*** | ☐ | ☐ | ☐ | ☒ | ☐ |
| ☐ ***Product Guarantees***<br>☒ ***Complexity in use*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☐ ***Quality of the construction materials***<br>☒ ***Efficiency*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☐ ***Quality of the construction materials***<br>☒ ***Complexity in use*** | ☐ | ☒ | ☐ | ☐ | ☐ |
| ☒ ***Efficiency***<br>☐ ***Complexity in use*** | ☐ | ☒ | ☐ | ☐ | ☐ |

*Table 6. Evaluation questionnaire paired preference of criteria, which show the results.*