TECHNISCHE UNIVERSITÄT BERLIN: INSTITUT FÜR WERKZEUGMASCHINEN UND FABRIKBETRIEB

Industrial Engineering Master Thesis

Workplace specific set of energy related indicators considering recent challenges in the automotive and semiconductor industry

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Abstract

Energy and resource efficiency are important aspects in sustainability strategies of producing companies. For improving energy consumption awareness, practical usable indicators on workplace level are necessary. In this thesis a method for defining workplace specific energy related indicators should be developed. Therefore indicators for workplaces on different levels and every class of production equipment have to be regarded that address energy consumption, efficiency and improvement potential and provide energy related knowledge, awareness and prediction within the factory. For use cases in automotive industry a workplace specific set of energy related indicators should be defined

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List of abbreviations

EPI: *Energy Performance Indicator*

KPI: *Key Performance Indicator*

MBO: *Management by Objectives*

PI: *Performance Indicator*

PMS: *Performance Measurement System*

TdB: *Tableau de Bord*

1. Introduction

1.1. Motivation

Within de higher awareness of the urgent need to make better use of the world's energy resources, energy efficiency offers a powerful and cost-effective tool for achieving a sustainable energy future. Not only they would reduce the production costs, but environmental benefits can also be achieved by the reduction of greenhouse gases emissions and local air pollution.

Energy strategies in the manufacturing industry must be accompanied of energy aware employees. In other words, workers involvement is essential to guarantee energy efficiency improvements. They are the ones that consume energy and perform the daily activities, so their energy behaviour and use routines influence considerably energy consumption. Their personal objectives must be aligned with the company energy goals.

Without a Performance Measurement System, the energy strategies or policies cannot be evaluated. Indicators are the main tool in order to monitor and control energy practices and determine whether they are effective or not. Furthermore, they provide the appropriate information to facilitate the roles' decision-making.

This thesis tries to propose a useful methodology in order to improve energy efficiency in industry, by developing a set of energy related indicators for specific roles.

Some specifications about the initial master thesis proposal and the final document must be done:

- The current title is "Workplace specific set of energy related indicators considering recent challenges in the automotive and semiconductor industry", although the paper is not focused anymore in workplace, but in roles. The main reason was that after some investigation period, it seemed to be more relevant for the indicators. Different workers use the same workplace for different purposes, so in order to measure the efficiency of the projects actions, it would be more appropriate to have specific roles indicators.
- The initial purpose was to implement two applications, one for the automotive industry and the other one for the semiconductor industry. Regretfully the second application could not be performed due to time problems. However, most of the practical general results obtained are based in use cases of both industries.
- At the beginning it was not considered any type of automatic application. After some work in the methodology, it was considered that creating an automatic solution would provide potential opportunities and possible applications. Hence more time was invested in the methodology structure than in the data requirements, subject that is not analysed in depth.

The thesis is fruit of current energy challenges in the semiconductor and automotive industry. It tries to help by finding a way of describing specific roles energy related indicators in order to measure energy efficiency. The specific use cases' information was provided and two important predefined documents were also given. This documents are the "Energy related objectives' hierarchy and the list of possible "Energy related indicators". The whole methodology is based on the first document and the second one was very helpful in order to define the role specific indicators.

1.2. Aim and structure

In this thesis a methodology to develop role specific set of energy related indicators is presented and applied by the author. The main purpose of the thesis is to achieve that all roles are involved in the energy efficiency strategies by defining some specific indicators according to their specific tasks and responsibilities. Moreover, the methodology should make possible a future automatic application.

The thesis is divided in 6 chapters. The first chapter contains the motivation behind the thesis, which introduces the main subjects related, and describes the aim and the structure.

In the second chapter the state of the art is presented. First, energy awareness and current trends in general and in the manufacturing sector are reviewed. The principles of energy management and practices are presented, as well as the most common energy barriers. Afterwards, the roles environment is analysed including organisational structures, individual's information behaviour and motivations factors. Moreover, some specific methodologies focused in specific roles are introduced. Finally, the energy related indicators' characteristics and attributes, as well as different approaches from literature regarding performance measurement methodologies are described.

In chapter three, a brief summary of the whole state of the art is presented analysing the needs and reasons which justify the development of the methodology.

Chapter four contains the explanation of the developed methodology and a detailed description step by step. The methodology includes some templates and tables that can be found in the appendixes. Afterwards it introduces the automatic application and the basic data requirements for the indicators' set.

In chapter five, the application is documented step by step for an automotive use case, showing some of the results. All the results can be found in the appendixes. Finally, a role specific set of indicators is defined and some conclusions of the specific application are done.

The last chapter presents a critical review about the presented methodology and its application. In the end, an outlook regarding the implementation of future applications is provided.

2. State of the art

2.1. Energy challenges

Governments in many countries are increasingly aware of the urgent need to make better use of the world's energy resources. The benefits of more efficient use of energy are well known and include reduced investments in energy infrastructure, lower fossil fuel dependency, increased competitiveness and improved consumer welfare. Improved energy efficiency is often the most economic and readily available means of improving energy security and reducing greenhouse gas emissions and local air pollution [IEA-08].

Economic growth is generated either by increased inputs of capital and labour, or by the more efficient use of those inputs. This can come about as a result of new technology, or through better management. Energy is one of the critical inputs in the energy intensive industrial sector, and as growth based on increasing inputs of capital begins to reap diminishing returns, the efficiency with which energy is managed becomes increasingly important [Asi-00].

The current rate of energy efficiency improvement is not nearly enough to overcome the other factors driving up energy consumption. As a result we are heading for an unsustainable energy future. There is a clear need to substantially increase it in order to tackle climate change and move towards a more secure and sustainable energy future. New ways to accelerate the decoupling of energy use and CO2 emissions from economic growth must be found. This is indeed possible; there is still significant scope for adopting more cost-effective energy-efficient technologies in buildings, industry and transport [IEA-07].

Energy efficiency is only one of a number of factors that impact energy use, so it is perfectly possible to have improving energy efficiency, while still seeing rises in energy consumption [IEA-08]. In order to change the current patterns of energy use, it is necessary to understand, in detail, the trends in energy efficiency and the other factors that influence energy consumption [IEA-07]. Better understanding of the factors affecting energy use requires indicators based on more detailed data [IEA-08].

2.1.1 Trends

In order to introduce the recent energy trends the term "energy intensity" must be clarified. Energy intensity indicators measure the quantity of energy required to perform an activity, such as the production of output. Energy efficiency is effectively the inverse of this ratio, but aims to measure 'how well' the energy is used to produce output [Asi-00]. Energy intensity is the most commonly used basis for assessing trends in energy efficiency since a truly technical definition of energy efficiency can only be obtained through measurements at the level of a particular process or plant. Energy intensity is thought to be inversely related to efficiency, the less energy required to produce a unit of output or service, the greater the efficiency. A logical conclusion, then, is that declining energy intensities over time may be indicators of improvements in energy efficiencies [Mal-96].

Recent History

Since the oil crisis of the 1970's, quantitatively assessing the factors that contribute to changes in energy consumption has been important for understanding past trends in energy use, measuring the performance of energy-related policies, forecasting future energy demand and improving the overall efficiency of energy use [Mal-96]. Analysis shows that there have been substantial improvements in energy efficiency in all major energy-intensive industries and in all world regions. This is often as a result of the introduction of new, more efficient technology [IEA-08].

Energy use has been increasing more slowly than economic activity in most countries. As a result, global energy intensity, calculated in terms of final energy use per unit of gross domestic product (GDP), fell by 26% between 1990 and 2005. The reductions in energy intensity were largest in non-OECD countries, due to a combination of structural changes and efficiency improvements [IEA-08].

Improved energy efficiency has been the main reason why final energy use has been decoupled from economic growth. Without the energy efficiency improvements that occurred between 1973 and 2005 in 11 of those countries, energy use would have been 58%, or 59 EJ, higher in 2005 than it actually was [IEA-08].

However, energy efficiency gains have been relatively modest since 1990 and significantly lower than in previous decades. Some small encouragement can be found in the fact that the rate of improvement seems to be increasing slightly in the last few years. It must be acknowledged that energy efficiency measures need time to take effect. Anyway, these findings confirm that the changes caused by the oil price shocks in the 1970s and the resulting energy policies did considerably more to control growth in energy demand and reduce CO2 emissions than the energy efficiency and climate policies implemented since the 1990s [IEA-07].

Industry energy consumption

Energy is the lifeblood of manufacturing. Industry converts fuels to thermal, electric or motive energy to manufacture all the products of daily life [NAM-05]. It is a key input in the production of many manufactured goods. All other things being equal, an increase in manufacturing production (output) will generally lead to an increase in energy consumption [IEA-07].

Historically, industry has been the largest final energy user, but its share has fallen since 1990. In 2005 it represented the 33% of the total. Between 1990 and 2004, total final energy use industry increased by only 3%, despite the fact that manufacturing output (as measured by value-added) increased by 31% over the same period. CO2 emissions showed an even greater decoupling from economic growth, with an increase in emissions of just 1% [IEA-07].

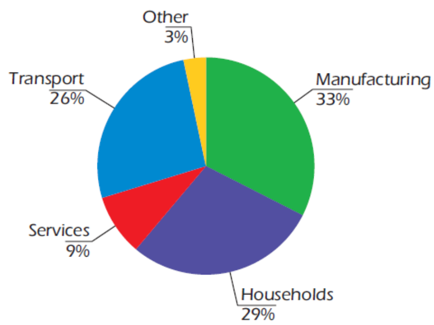


Figure 1: *Shares of global final energy consumption by sector, 2005 [IEA-08]*

Despite the recent improvements in energy efficiency, there still remains a large potential for further energy savings across all sectors. For instance, analysis of industry shows that the application of proven technologies and best practices on a global scale could save between 25 EJ and 37 EJ per year, which represents between 18% and 26% of current primary energy use in industry. The associated CO2 emissions savings are 1.9 Gt CO2 to 3.2 Gt CO2 per year. The largest savings potentials can be found in the iron and steel, cement and chemical and petrochemical sectors [IEA-08].

Manufacturers should recognize that energy is a controllable operating expense and that energy should be managed with the same expertise as other parts of the business. [Ene-07]

2.1.2. Energy Management

In 1970, industrial energy decision-making was simpler than it is today. Production targets and prevailing facility technologies largely dictated energy consumption. Natural gas and power utilities distributed their commodities at regulated prices. For most of industry, energy consumption was perceived as a fixed, uncontrollable cost of doing business. Energy management entailed little more than paying utility bills on time to avoid late charges. A combination of forces emerging since 1970 has complicated industry's energy decision making [NAM-05].

Energy management *is the process of monitoring, controlling, and conserving energy in a building or organization*. Normally it involves the following steps [Biz-11]:

1. Metering energy consumption and collecting the data.
2. Finding opportunities to save energy, and estimating *how much* energy each opportunity could save. Typically meter data to find would be analysed and routine energy waste quantified. The energy savings that one could make by replacing equipment (e.g. lighting) or by upgrading your building's insulation might be also investigated.
3. Taking action to target the opportunities to save energy (i.e. tackling the routine waste and replacing or upgrading the inefficient equipment).
4. Tracking progress by analyzing meter data to see how well the energy-saving efforts have worked.
5. Back to step 2, the cycle continues.

Many people use "energy management" to refer specifically to those energy-saving efforts that focus on making better use of *existing* buildings and equipment. Strictly speaking, this limits things to the behavioural aspects of energy saving (i.e. encouraging people to use less energy by raising energy awareness), although the use of cheap control equipment such as timer switches is often included in the definition as well. Nevertheless, energy-saving measures that involve buying new equipment or upgrading building fabric could be also considered [Bizz-11].

All manufacturers should start with energy audits of their facilities. Industry surveys indicate that the average facility can reduce its energy consumption by 10 to 20 percent. At least 30 percent of industry's overall energy savings potential can be obtained without capital expense, by simply making changes to procedures and behaviour. Obtaining these results by making energy management standard operating procedure, and not just a one-time project, is a process that bears a striking resemblance to financial planning [NAM-05]:

- Establish goals and a strategy for goal attainment;
- Learn about available solutions and select the ones needed to reach the goals;
- Start early, and maintain regular contributions over time;
- Keep track of earnings; and
- Grow wealth and defeat risk through reinvestment and diversification of earnings.

Energy Efficiency Practices

Efficiency is the difference between the actual energy use and "best practice," i.e., the lowest energy use achievable. What is achievable is influenced by operating conditions that vary between plants, so the measure of best practice must take these conditions into account [Gal-11].

Energy efficient practices are aligned with the principles of lean manufacturing and continuous improvement. Industry's near-term energy-saving opportunities come from energy-smart procedures applied to current assets. In addition, there are a range of secondary benefits that come with a comprehensive energy efficiency strategy, including [NAM-05]:

- energy training and skills helps reduce the investment risk associated with new technologies;
- combustion volumes reduce proportionately with fossil fuel consumption, contributing to emissions compliance while also reducing energy costs; and
- emerging business development opportunities related to environmentally superior products and production processes

If industrial facilities do not optimize their energy consumption, opportunities to create value are lost with energy waste. "Energy efficiency" refers to technologies and standard operating procedures that reduce the volume of energy per unit of industrial production [NAM-05].

Facility managers need to understand how energy efficiency supports overall corporate goals. The very activities that provide energy efficiency also provide better control over plant assets and inputs. For example, energy efficient practices ensure that thermal resources are applied at the right temperature, for the right duration and in correct proportion to raw materials. This control reduces a facility's scrap rates as well as energy consumed per unit of production. Control provides reliability. Greater reliability means less down time. Less downtime means orders are filled faster, which allows the facility to complete more orders over the course of a year—thus making more revenue. Energy efficiency is not just about reducing utility bills. It's also about boosting revenue through greater productivity. Companies like Ford Motor Company recognize energy efficiency's potential to provide non-energy benefits such as reduced raw material waste, reduced water consumption, reduced maintenance and repair, improved process cycle times and other equipment performance enhancements [NAM-05].

By strategically building energy efficiency decision-making into production, manufacturers will identify new ways to [NAM-05]:

- cut costs, raise productivity, and improve shareholder value;
- improve managerial performance;
- meet environmental standards;
- create energy efficient products and market opportunities;
- improve their competitive position; and
- ensure better community relations.

In addition to how manufacturers implement energy efficiency in their facilities, other factors affect energy use, such as government policies and programs, environmental regulations and technological and managerial innovations [NAM-05].

Investment in innovative technologies can achieve substantial additional benefits not only to the financial bottom line but also to corporate image and community relations. The cost-and-benefit analysis for investment in technology, however, needs to take into accounts all of the potential benefits for a company and not just the immediate financial results. Advances in information technology, materials sciences, process control technology, alternative energy research, nanotechnology and other fields have created many new opportunities to increase energy efficiency through technical innovation [NAM-05].

Barriers to energy efficiency

Human, technical, financial and organizational capacities all contribute to a manufacturer's ability to build wealth through energy efficiency. Similarly, the barriers to energy efficiency are evident when the manufacturer lacks these capacities. Manufacturers can and do make money despite inefficiencies. However, the burden of energy waste, lost income and increased exposure to operating risk are increasingly hard to bear in a globally competitive economy [NAM-05].

• **Misunderstanding of business value.** The term "energy efficiency" is easily confused with other concepts. Having dual-fuel capabilities in the powerhouse, for example, simply means the operator has a choice of fuels. Enlisting an energy marketer to purchase fuel usually helps to even out energy price fluctuations, but has no impact on efficiency of energy use. Consuming renewable energy sources such as wood by-products is fine as an alternative to fossil fuel, but this consumption is equally susceptible to waste as it is converted to process work. The first hurdle to advancing energy efficiency is to understand that it is a business opportunity to reduce expenses, build revenues and control risk [NAM-05].

• **Lack of staff and management awareness.** Staff doesn't always make the connection between energy choices and money. For example, compressed air leaks are often overlooked because "air is free," although this conclusion ignores that fact that five horsepower of electricity are consumed to generate one horsepower of compressed air. Steam system management is susceptible to similar thinking. Plant operators who assume that scrap rates are of no importance "because scrap can be melted down and used again" are not considering the excess energy consumption that this practice requires [NAM-05].

• **Lack of cross-departmental cooperation.** The manufacturer's first priority is to make product and get it out the door, not save energy. Every position on the company's personnel chart has a job description, accountabilities and incentives, all tied to production. Departments within a company often compete against each other in the budget process. For example, energy efficiency projects might be expensed from the maintenance budget, but the savings accrue to the production budget. When departments do not cooperate, waste is allowed to continue. Unless top management takes action, energy efficiency is a duty that occupies the blank space on the personnel chart, the space where there are no boxes [NAM-05].

• **Outdated accounting techniques.** Many industrial facilities still have only one utility meter to measure consumption for an entire plant. In this situation, traditional accounting practices treat plant-wide energy as an overhead cost, which is then allocated across departments according to their numbers of workers or square feet of space. Moreover, the cost of any one department's energy waste is distributed to all departments. Even worse, this accounting system is a disincentive to any one department taking the initiative to improve energy efficiency, because that department's results will be diluted by the artificial allocation of costs. Improper allocation of energy costs may distort financial decisions such as product pricing, income and tax declarations, production mix, compensation and bonuses, and capital investment allocations. But today's advanced energy metering technologies can monitor actual consumption by substations within a facility, improving department managers' abilities to control their energy costs [NAM-05].

2.2. Specific roles

In today's competitive business environment, employees represent one of the organization's most valuable assets. Which means the company's productivity—and ultimately, its profitability—depend on making sure every person in the organization is working up to his or her full potential [Suc-11].

The current chapter introduces different issues that affect worker's performance and information needs, as well as some methodologies to find specific roles' objectives.

2.2.1. Organisational Structure

Industry consolidation has become increasingly important in the twenty-first century. Among organizations of all sizes, concepts such as agile manufacturing, just-in-time inventory management, and ambidextrous organizations are impacting managers' thinking about their organizational structure. The early twenty-first century has been dominated by the thinking that changing organizational structures, while still a monumental managerial challenge, can be a necessary condition for competitive success [How-11].

Organizational structure is the way responsibility and power are allocated, and work procedures are carried out among organizational members. Among many variables, organizational structure includes the nature of layers of hierarchy, centralization of authority, and horizontal integration [Raf].

The best organizational structure for any organization depends on many factors including the work it does; its size in terms of employees, revenue, and the geographic dispersion of its facilities; and the range of its businesses (the degree to which it is diversified across markets). There are multiple structural variations that organizations can take on, but there are a few basic principles that apply and a small number of common patterns. [How-11]

Vertical Organization

Hierarchically structured organization where all management activities are controlled by a centralized management staff. This traditional type of organization often develops strong bureaucratic control over all organizational activities with graduating levels of responsibility and power in one direction and diminishing levels of autonomy and authority in the other.

In traditional bureaucratic structures, there is a tendency to increase task specialization as the organization grows larger. The traditional model of organizational structure is thus characterized by high job specialization, functional departments, narrow spans of control and centralized authority [How-11].

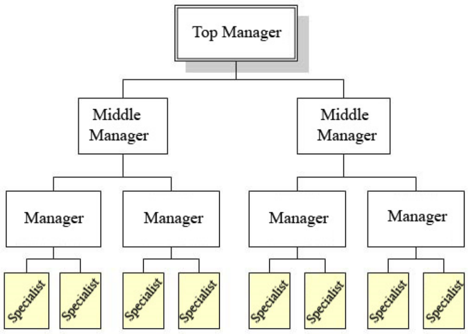


Figure 2: *Vertical Organization [BSC-11]*

Horizontal Organization (also known as flat organization)

It refers to an organizational structure with few or no levels of intervening management between staff and managers. The idea is that well-trained workers will be more productive when they are more directly involved in the decision making process, rather than closely supervised by many layers of management [Wik].

The flat organization model promotes employee involvement through a decentralized decision-making process. By elevating the level of responsibility of baseline employees and eliminating layers of middle management, comments and feedback reach all personnel involved in decisions more quickly. Since the interaction between workers is more frequent, this organizational structure generally depends upon a much more personal relationship between workers and managers. Hence the structure can be more time-consuming to build than a traditional hierarchical model [Wik].

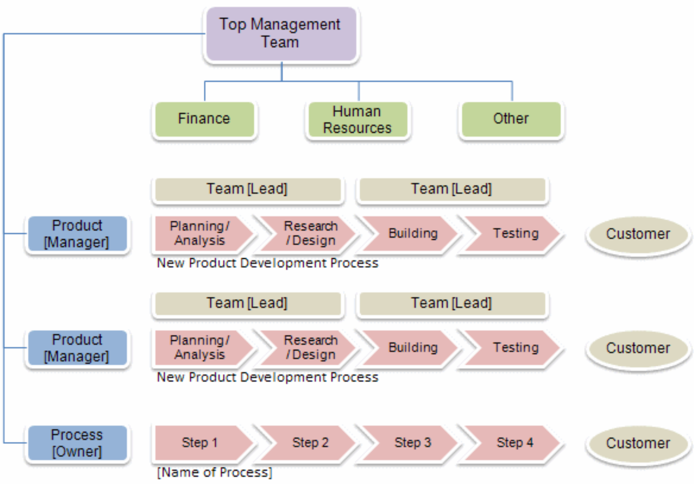


Figure 3: *Horizontal Structure [Ver-11]*

Part of the impetus toward the horizontal model is the belief that this kind of structure is more effective for employee motivation. Various studies have suggested that steps such as expanding the scope of jobs, involving workers in problem solving and planning, and fostering open communications bring greater job satisfaction and better performance [How-11].

Functional Organization Structure

Every organization of a given type must perform certain jobs in order to do its work. For example, key functions of a manufacturing company include production, purchasing, marketing, accounting and personnel. Using such functions as the basis for structuring the organization may, in some instances, have the advantage of efficiency. Grouping jobs that require the same knowledge, skills, and resources allows them to be done efficiently and promotes the development of greater expertise. A disadvantage of functional groupings is that people with the same skills and knowledge may develop a narrow departmental focus and have difficulty appreciating any other view of what is important to the organization; in this case, organizational goals may be sacrificed in favour of departmental goals. In addition, coordination of work across functional boundaries can become a difficult management challenge, especially as the organization grows in size and spreads to multiple geographical locations [How-11].

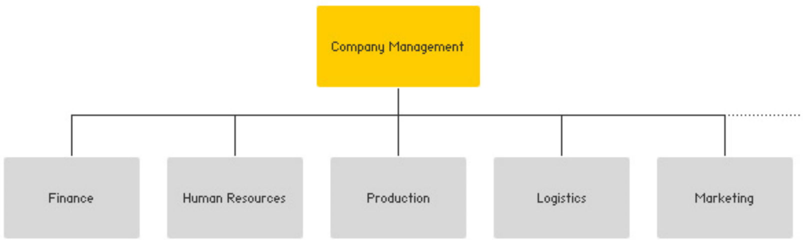


Figure 4*: Functional organization [DHL-08]*

Divisional Organization Structure (also called product structure)

The divisional structure groups each organizational function into a division. Each division within a divisional structure contains all the necessary resources and functions within it. Divisions can be categorized from different points of view. One might make distinctions on a geographical basis (a US division and an EU division, for example) or on product/service basis (different products for different customers: households or companies.)

The advantage of this type of structure is that the personnel in the group can focus on the particular needs of their product line and become experts in its development, production, and distribution. A disadvantage, at least in terms of larger organizations, is the duplication of resources. Each product group requires most of the functional areas such as finance, marketing, production, and other functions [How-11].

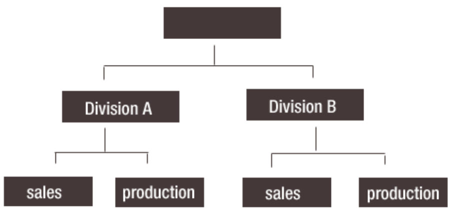


Figure 5*: Divisional structure [Ste-08]*

Dual Authority structure in a Matrix organization

One approach that attempts to overcome the inadequacies is the matrix structure, which is the combination of both structures mentioned before. Functional departmentalization commonly is combined with product groups on a project basis [How-11].

One advantage is that it facilitates the use of highly specialized staff and equipment. Rather than duplicating functions as would be done in a simple product department structure, resources are shared as needed. In some cases, highly specialized staff may divide their time among more than one project. In addition, maintaining functional departments promotes functional expertise, while at the same time working in project groups with experts from other functions fosters cross-fertilization of ideas [How-11].

The disadvantages arise from the dual reporting structure. The organization's top management must take particular care to establish proper procedures for the development of projects and to keep communication channels clear so that potential conflicts do not arise and hinder organizational functioning. In theory at least, top management is responsible for arbitrating such conflicts, but in practice power struggles between the functional and product manager can prevent successful implementation of matrix structural arrangements [How-11].

Besides the product/function matrix, other bases can be related in a matrix. Large multinational corporations that use a matrix structure most commonly combine product groups with geographic units. Product managers have global responsibility for the development, manufacturing, and distribution of their own product or service line, while managers of geographic regions have responsibility for the success of the business in their regions [How-11].

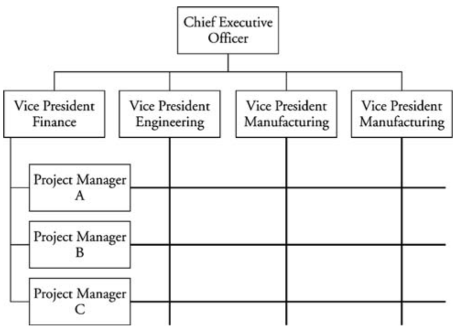


Figure 6: *Matrix Structure*

2.2.2. Information Specifications

Vertical/Horizontal information flow

Except for the matrix organization, all the structures described above focus on the vertical organization; that is, who reports to whom, who has responsibility and authority for what parts of the organization, and so on. Such vertical integration is sometimes necessary, but may be a hindrance in rapidly changing environments. A detailed organizational chart of a large corporation structured on the traditional model would show many layers of managers; decision making flows vertically up and down the layers, but mostly downward. In general terms, this is an issue of interdependence [How-11].

In any organization, the different people and functions do not operate completely independently. To a greater or lesser degree, all parts of the organization need each other. Important developments in organizational design in the last few decades of the twentieth century and the early part of the twenty-first century have been attempts to understand the nature of interdependence and improve the functioning of organizations in respect to this factor. One approach is to flatten the organization, to develop the horizontal connections and de-emphasize vertical reporting relationships. At times, this involves simply eliminating layers of middle management. For example, some Japanese companies (even very large manufacturing firms) have only four levels of management: top management, plant management, department management, and section management [How-11].

Specifically a role communicates in the following three directions of information flow in the organisation [Dev-96]:

1. Communication down the line which is basically of five types :
   - Job instructions specific task directives;
   - Job rationale information designed to produce understanding of the task and its relation to other organisational tasks;
   - Information about organisational procedures and practices;
   - Feedback to the subordinate about his/her performance; and
   - Indoctrination of goals information of an ideological character to inculcate a sense of mission.
2. Communication upward which can be reduced to what people say:
   - about themselves, their performance and their problems;
   - about others and their problems;
   - about organisational policies and practices; and
   - about what needs to be done and how.
3. Horizontal communication between colleagues at the same hierarchical level.

Information need

Identification of information needs is essential to the design of information systems in general and to the provision of effective information services in particular. But it has been found to be a difficult task as it is almost an investigative or detective work [Dev-96].

The turbulent and changing information environment calls for continual research to ensure that the needs of the information users are satisfactorily met. To ensure this, there is an urgent need to understand and grasp the complex process of 'identifying information needs.' Further, one might spend a lot of time, effort and money mining the various information sources and gather a great deal of sound information that does not answer the key questions of the users' decision making/ action taking process. Hence before initiating, building and developing any information center/ system, the relevance of information to be gathered must be checked thoroughly, which in turn depends entirely on the 'identification of information needs' [Dev-96].

Moreover, the effectiveness of an information system depends on the extent to which the system's characteristics are in correspondence with the situation of the user and on how much the potential user of the system is willing and able to make use of the services provided by the information system. A careful identification, analysis and classification of the 'real' information needs of users are an essential basis for the planning, implementation and operation of information systems. In fact, any lapse in proper identification of information needs will affect the efficiency and effectiveness of information systems and services [Dev-96].

In day to day work, lack of self sufficiency constitutes information needs. This information needs represent gaps in the current knowledge of the user. Apart from the expressed or articulated needs, there are unexpressed needs which the user is aware of but does not like to express. The third category of need is the delitescent or dormant need which the user is unaware of. But the information services provider may be able to bring to light these needs [Dev-96].

According to Crawford, information needs depend on [Dev-96]:

- Work activity
- Discipline/ Field / Area of interest
- Availability of facilities
- Hierarchical position of individuals
- Motivation factors for information needs
- Need to take a decision
- Need to seek new ideas
- Need to validate the correct ones
- Need to make professional contributions
- Need to establish priority for discovery etc.

Information needs are affected by a variety of factors such as [Dev-96]:

- The range of information sources available;
- The uses to which the information will be put;
- The background, motivation, professional orientation and other individual characteristics of the user;
- The social, political, economic, legal and regulatory systems surrounding the user; and
- The consequences of information use.

Information needs identification is a complex process. Some of the factors adding to the complexity are: [Dev-96]

- Same information is perceived by different users differently due to their information need;
- Researchers need original documents whereas planners need digests of `point of view ' / opinions;
- Information is put to different uses (R & D personnel, Application developers and Technicians all put information to different uses);
- Need is satisfied by having access to the identified information in a particular package and form, and at a suitable time;
- The flow of information and channels of communication are complex; and
- Individual preferences and behavioural aspects add a further dimension.

Study of the user’s environment

In order to find the specific information needs, the immediate environment of the user must be studied. At this point, it may be necessary to delineate the category of users whose information needs are to be identified. Some of the aspects to be covered in this study are [Dev-96]:

- Background or history of the concerned unit/ department, its objectives and functions;
- Organisational structure;
- Details of products and/ or processes of manufacture and/ or research;
- Details of plant, machinery, equipment, testing and other facilities;
- Scope of each discernible activity/ function of the department/ unit;
- Information flow (vertical and horizontal) in the functioning of the department/ unit;
- Present sources of information (external and internal) and the channels and media used in the units;
- Types of information services being used in the unit;
- Specific subjects on which information is being sought including type of information and kind of presentation (theoretical, experimental, commercial, technical digests, reviews, data compilations, opinions, etc.) required;
- Recent significant events and problems solved and the way they are solved including specific information used in solving the problems and the "sources" of the required information; and
- Any other items of interest such as on-going projects, training programmes etc., in the unit.

It may be necessary to spend sufficient time in the user's department to understand and acquaint with the working of the department, its organisational set up, the various activities etc., and thereby understand the situation in which the user is operating. This understanding will help to easily correlate the user's information needs in relation to his environment/ situation [Dev-96].

Study of the user

Unconscious values, emotions, and “non-rational” perceptions of information seem to affect behaviour in using information, especially information from formal sources. Therefore it is necessary to study the specific user of the information system. Users are individually and they all haven’t got the same information needs [Dev-96].

In order to collect analysis information on roles, there are different methods:

- Observation methods: observe the worker’s activities
- Interview methods: structured interviews, unstructured interviews, open-ended questionnaires (individually or in groups)
- Questionnaires methods
- Examining Manuals or existing report.
- Combination of methods etc

Information Behaviour

By information behaviour is meant those activities a person may engage in when identifying their own needs for information, searching for such information in any way, and using or transferring that information [Wil-99].

Information behaviour may be defined as the more general field of investigation, with information-seeking behaviour being a sub-set of the field, particularly concerned with the variety of methods people employ to discover and gain access to information resources. Information searching behaviour is then defined as a sub-set of information-seeking, particularly concerned with the interactions between information user (with or without an intermediary) and computer-based information systems, of which information retrieval systems for textual data may be seen as one type [Wil-99].

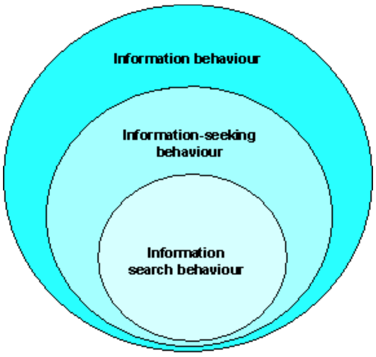


Figure 7: *A nested model - from information behaviour to information searching [Wil-99]*

The nested model might be extended further by showing that information behaviour is a part of human communication behaviour:

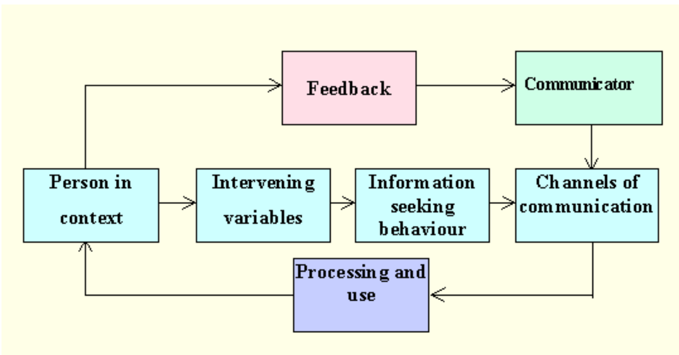


Figure 8: *Relationship between communication and information behaviour [Wil-99]*

The diagram links the basic model of information behaviour to the communicator as the originator of messages over the channels of communication and shows a feedback loop through which the communicator learns of the recipient's response to the communication. Enlarging the original model in this way enables us to link the two fields and may enable us to identify and consider relationships in the information-seeking process that have not had detailed treatment in information science research [Wil-99].

Information behaviour models

Wilson's model

The aim of this model was to outline the various areas covered by what the writer proposed as information-seeking behaviour, as an alternative to the then common information needs, but it is clear that the scope of the diagram is much greater and that it attempts to cover most of what is included here as information behaviour [Will-99].

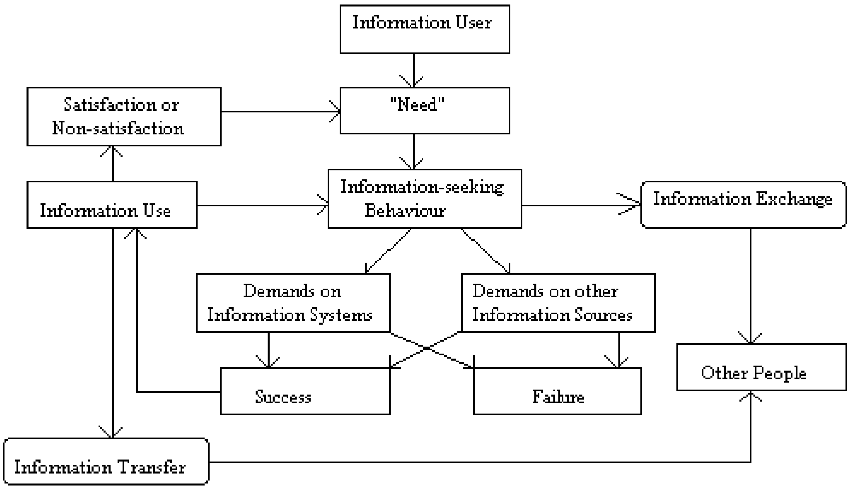


Figure 9: *Wilson's information behaviour model* [Will-99]

The model suggests that information-seeking behaviour arises as a consequence of a need perceived by an information user, who, in order to satisfy that need, makes demands upon formal or informal information sources or services, which result in success or failure to find relevant information. If successful, the individual then makes use of the information found and may either fully or partially satisfy the perceived need - or, indeed, fail to satisfy the need and have to reiterate the search process. The model also shows that part of the information-seeking behaviour may involve other people through information exchange and that information perceived as useful may be passed to other people, as well as being used (or instead of being used) by the person himself or herself [Will-99].

The limitation of this kind of model, however, is that it does little more than provide a map of the area and draw attention to gaps in research: it provides no suggestion of causative factors in information behaviour and, consequently, it does not directly suggest hypotheses to be tested [Will-99].

Information seeking behaviour models

Wilson 1981

Wilson's second model of 1981 is based upon two main propositions: first, that information need is not a primary need, but a secondary need that arises out of needs of a more basic kind; and second, that in the effort to discover information to satisfy a need, the enquirer is likely to meet with barriers of different kinds. Drawing upon definitions in psychology, Wilson proposes that the basic needs can be defined as physiological, cognitive or affective. He goes on to note that the context of any one of these needs may be the person him- or herself, or the role demands of the person's work or life, or the environments (political, economic, technological, etc.) within which that life or work takes place. He then suggests that the barriers that impede the search for information will arise out of the same set of contexts [Will-99].

This model is shown in a simplified version (which also shows the search behaviours defined by Ellis in Figure 2, below. Wilson's model is clearly what may be described as a macro-model or a model of the gross information-seeking behaviour and it suggests how information needs arise and what may prevent (and, by implication, aid) the actual search for information. It also embodies, implicitly, a set of hypotheses about information behaviour that are testable: for example, the proposition that information needs in different work roles will be different, or that personal traits may inhibit or assist information seeking. Thus, the model can be regarded as a source of hypotheses, which is a general function of models of this kind [Will-99].

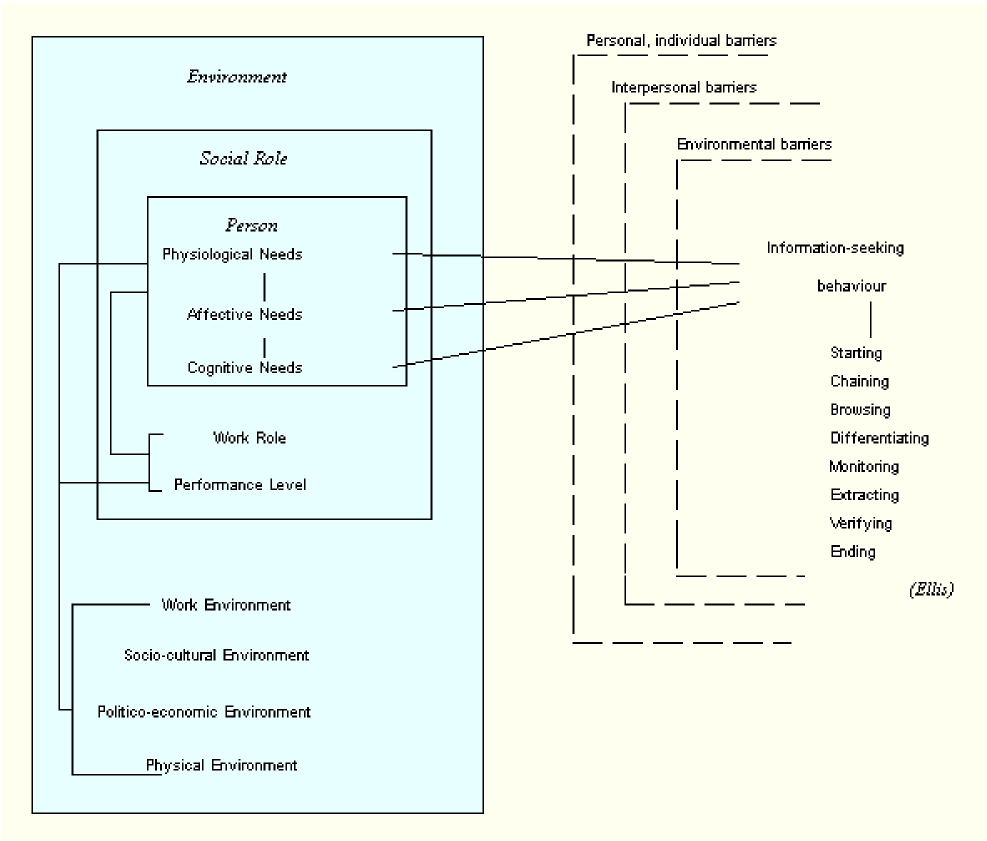


Figure 10*: Wilson's information-seeking behaviour model [Will-99]*

The weakness of the model is that all of the hypotheses are only implicit and are not made explicit. Nor is there any indication of the processes whereby context has its effect upon the person, nor of the factors that result in the perception of barriers, nor of whether the various assumed barriers have similar or different effects upon the motivation of individuals to seek information. However, the very fact that the model is lacking in certain elements stimulates thinking about the kinds of elements that a more complete model ought to include [Will-99].

Ellis 1989

Ellis's elaboration of the different behaviours involved in information seeking is not set out as a diagrammatic model and Ellis makes no claims to the effect that the different behaviours constitute a single set of stages; indeed, he uses the term 'features' rather than 'stages'. These features are named and defined below: [Will-99]

- Starting: the means employed by the user to begin seeking information, for example, asking some knowledgeable colleague;

- Chaining: following footnotes and citations in known material or 'forward' chaining from known items through citation indexes;
- Browsing: 'semi-directed or semi-structured searching' (Ellis, 1989: 187)
- Differentiating: using known differences in information sources as a way of filtering the amount of information obtained;
- Monitoring: keeping up-to-date or current awareness searching;
- Extracting: selectively identifying relevant material in an information source;
- Verifying: checking the accuracy of information;
- Ending: which may be defined as 'tying up loose ends' through a final search.

It is then possible to suggest a diagrammatic presentation of the model, as in Figure 11:

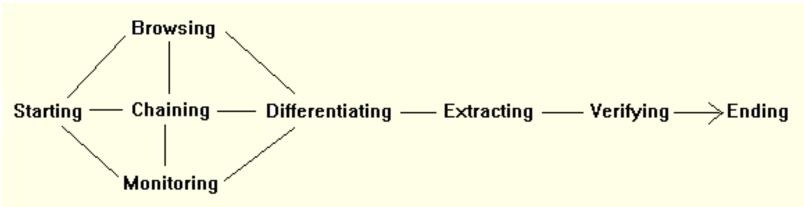


Figure 11: *A process model based on Ellis's 'characteristics'[Will-99]*

Thus, the models of Wilson and of Ellis are intended to function at different levels of the overall process of information seeking and this fact is demonstrated by the ability to nest one within the other [Will-99].

Wilson 1996

Wilson's 1996 model is a major revision of that of 1981, drawing upon research from a variety of fields other than information science, including decision-making, psychology, innovation, health communication, and consumer research [Will-99].

The basic framework of the 1981 model persists, in that the person in context remains the focus of information needs, the barriers are represented by intervening variables and information-seeking behaviour is identified. However, there are also changes: the use of the term intervening variables serves to suggest that their impact may be supportive of information use as well as preventive; information-seeking behaviour is shown to consist of more types than previously, where the active search was the focus of attention; information processing and use is shown to be a necessary part of the feedback loop, if information needs are to be satisfied; and three relevant theoretical ideas are presented: stress/coping theory, which offers possibilities for explaining why some needs do not involve information-seeking behaviour; risk/reward theory, which may help to explain which sources of information may be used more than others by a given individual; and social learning theory, which embodies the concept of self-efficacy, the idea of 'the conviction that one can successfully execute the behaviour required to produce the desired outcomes' [Will-99].

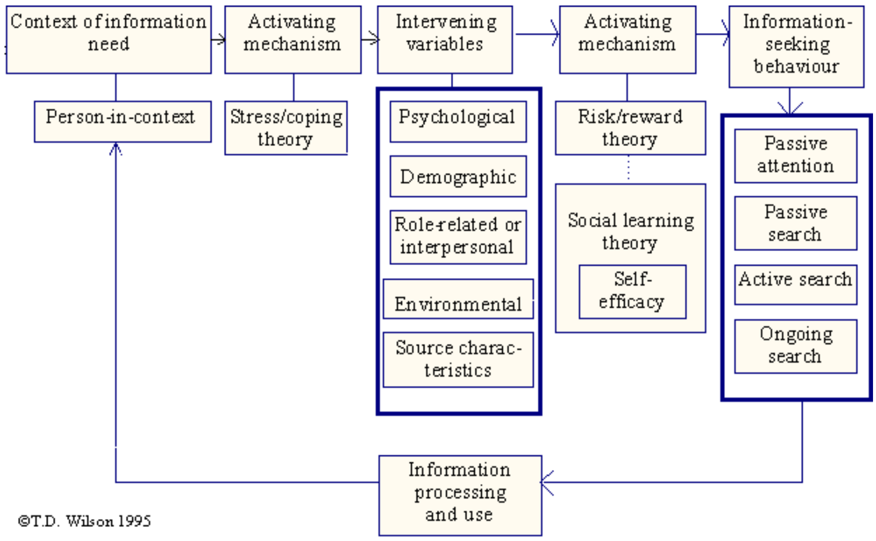


Figure 12: *Wilson's model of 1996 [Will-99]*

Thus, the model remains one of macro-behaviour, but its expansion and the inclusion of other theoretical models of behaviour makes it a richer source of hypotheses and further research than Wilson's earlier model [Will-99].

Leckies

Leckie's model emphasizes that the roles and associated tasks performed by professionals in the course of daily practices provoke particular information needs, which in turn begin an information-seeking process. "Given that the Leckie model is restricted to 'professionals'…, it is not surprising that 'work roles' and 'tasks' are thought to be the prime motivators for seeking" [Lia-11].

As shown in Figure 13, the six components of the model include: [Lia-11]

- Work roles (service provider, administrator/manager, researcher, educator, teacher and student);
- Associated tasks (specific tasks, for example, counseling, report writing, etc.);
- Characteristics of information needs (variables/factors that direct or form the information needs of professionals, such as individual demographics, status in the organization, years of experience, area of specialization, context, complexity, acting as a filter in the process, etc.);
- Sources of information (types of channels or formats: internal/external, oral/written, and personal);
- Awareness of information (direct or indirect knowledge of various information sources, familiarity, trustworthiness, timeliness, quality, accessibility, etc.);
- Outcomes (which include the positive results of the process and a feedback loop which drives the next round of information-seeking). Any of the components of the model can occur concurrently to illustrate the complexity of a professional's work life.

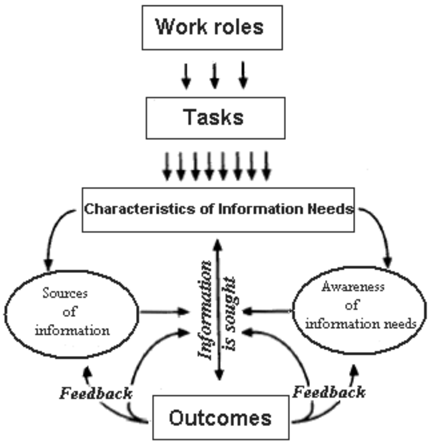


Figure 13: *Leckie's Model of Information-Seeking of Professionals [Lia-11]*

As Leckie's model indicates, once the information-seeking process has originated, two interacting factors – sources of information (all potential sources of information available) and awareness of information (an individual's knowledge about those sources and their likely usefulness) – become critical in the success of the seeking process. The selection of an information source can combine several sources (either concurrently or in sequence) to satisfy an information need. Both factors develop the dynamic nature of information-seeking activities and outcomes. At the finishing point, outcomes are the result of the information-seeking process. A "feedback" loop indicates that information-seeking may resume until the need has been filled. Leckie, Pettigrew, and Sylvain (1996) implied that the feedback loop only looped back as far as the characteristics of the information need. However, some researchers pointed out that the looping could go back further to the task and work roles to redefine the information need, task, or role, and a new information-seeking process may be stimulated with different combinations of sources and awareness factors. [Lia-11]

Information searching models

Ingwersen

Ingwersen's model is slightly simplified in Figure 14. When one examines this model, one can see its close family resemblance to other models of information seeking behaviour. In particular, the elements user's cognitive space and social/organizational environment, resemble the person in context and environmental factors specified in Wilson's models and the general orientation towards queries posed to an IR system point to a concern with the active search, which is the concern of most information-seeking models. Ingwersen, however, makes explicit a number of other elements: first, he demonstrates that within each area of his model, the functions of the information user, the document author, the intermediary, the interface and the IR system are the result of explicit or implicit cognitive models of the domain of interest at that particular point. Thus, users have models of their work-task or their information need, or their problem or goal, which are usually implicit, but often capable of explication. Again, the IR system is an explication of the system designer's cognitive model of what the system should do and how it should function. Secondly, Ingwersen brings the IR system into the picture, suggesting that a comprehensive model of information-seeking behaviour must include the system that points to the information objects that may be of interest to the enquirer. Thirdly, he shows that various cognitive transformations take place in moving from the life-world in which the user experiences a problem or identifies a goal to a situation in which a store of pointers to information objects can be satisfactorily searched and useful objects identified. Finally he points to the need for these models or cognitive structures and their transformations to be effectively communicated throughout the 'system', which will include the user, the author and the IR system designer [Will-99].

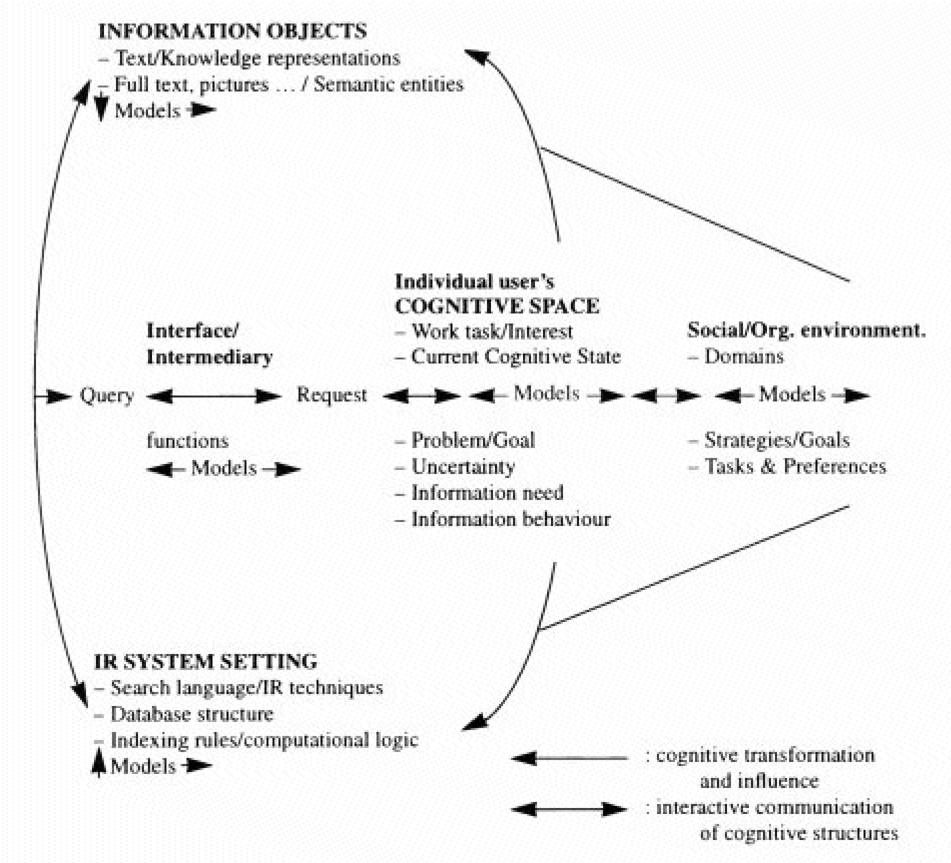


Figure 14: *Ingwersen's cognitive model [Will-99]*

Thus, Ingwersen's model, to a degree, integrates ideas relating to information behaviour and information needs with issues of IR system design, and this, together with the focus on cognitive structures and the idea of poly-representation, is an important strength of the model. A potential weakness is that the whole of information behaviour as defined in other models examined in this paper is subsumed under the heading of the user's cognitive space. Issues of how users arrive at the point of making a search, and how their cognitive structures are affected by the processes of deciding how and when to move towards information searching, may be lost. From the point of view of Wilson's 1996 model the significant part of Ingwersen's model (apart from its explicit cognitive theory orientation) is in the description of the active search process and the elements of that process [Will-99].

Saracevic

Saracevic's own model is described as a stratified interaction model and posits a simplified three level structure: surface, cognitive, and situational. Again, this model shows a strong resemblance to that of Ingwersen. At the surface level, a user interacts with a system through an interface by issuing commands or queries that represent, in some way, a problem statement. At the same level, the system responds either with meta-information, or texts (including images, etc.) or with queries of its own designed to elicit from the user further information on the nature of the problem. At the cognitive level, the user interacts with the output of the system, or with texts obtained subsequent to system interaction, in ways that enable the user to assess the utility of the text in relation to the initial problem. At the situational level, '…users interact with the given situation or problem-at-hand which produced the information need and resulting question. The results of the search may be applied to the resolution or partial resolution of the problem.'[Will-99]

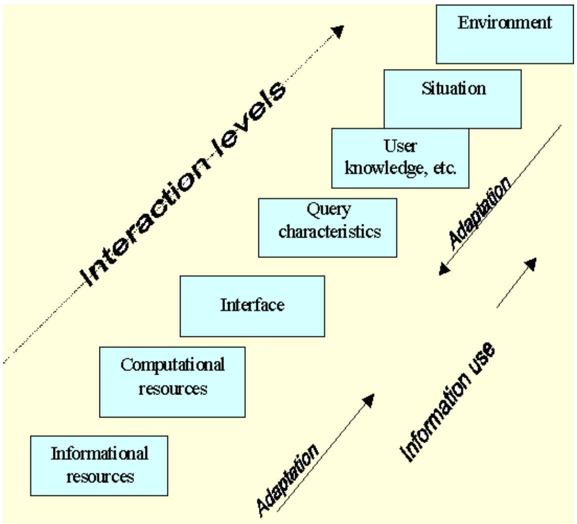


Figure 15*: Saracevic's model of stratified interaction [Will-99]*

2.2.3. Motivation of employees

A specific interest in workers' direct participation in the last twenty years or so has been driven mainly by economic arguments. Put simply, employee involvement increases the efficiency of organisations in two ways: by increasing firms' capacity to respond quickly to changes in the environment and by increasing workers' productivity. These two effects are a consequence of using better existing worker's knowledge, of promoting the acquisition and deployment of new skills among them, of increasing the information at their disposal and their discretionarily levels, and of a possible improvement of workers' motivation. By increasing individual responsibility and awareness of the business situation is also promotes a change of attitude towards work with greater acceptance of change and possibly, a different discipline of work [Mar-09].

Motivation Theories

Mayo

Elton Mayo (1880 – 1949) believed that workers are not just concerned with money but could be better motivated by having their social needs met whilst at work. He introduced the Human Relation School of thought, which focused on managers taking more of an interest in the workers, treating them as people who have worthwhile opinions and realising that workers enjoy interacting together [Tut].

Mayo conducted a series of experiments at the Hawthorne factory of the Western Electric Company in Chicago. He isolated two groups of women workers and studied the effect on their productivity levels of changing factors such as lighting and working conditions. He expected to see productivity levels decline as lighting or other conditions became progressively worse. What he actually discovered surprised him: whatever the change in lighting or working conditions, the productivity levels of the workers improved or remained the same. From this Mayo concluded that workers are best motivated by [Tut]:

- **Better communication** between managers and workers (Hawthorne workers were consulted over the experiments and also had the opportunity to give feedback)
- **Greater manager involvement** in employees working lives (Hawthorne workers responded to the increased level of attention they were receiving)
- **Working in groups or teams.** (Hawthorne workers did not previously regularly work in teams)

In practice therefore businesses should re-organise production to encourage greater use of team working and introduce personnel departments to encourage greater manager involvement in looking after employees' interests.

Maslow

Abraham Maslow (1908 – 1970) along with Frederick Herzberg (1923-) introduced the Neo-Human Relations School in the 1950's, which focused on the psychological needs of employees. Maslow put forward a theory that there are five levels of human needs which employees need to have fulfilled at work.

All of the needs are structured into a hierarchy and only once a lower level of need has been fully met, would a worker be motivated by the opportunity of having the next need up in the hierarchy satisfied. For example a person who is dying of hunger will be motivated to achieve a basic wage in order to buy food before worrying about having a secure job contract or the respect of others.

A business should therefore offer different incentives to workers in order to help them fulfil each need in turn and progress up the hierarchy. Managers should also recognise that workers are not all motivated in the same way and do not all move up the hierarchy at the same pace. They may therefore have to offer a slightly different set of incentives from worker to worker.

Figure 16: Maslow's hierarchy[Tut-]

Herzberg

Frederick Herzberg (1923-) had close links with Maslow and believed in a two-factor theory of motivation. He argued that there were certain factors that a business could introduce that would directly motivate employees to work harder (**Motivators**). However there were also factors that would de-motivate an employee if not present but would not in themselves actually motivate employees to work harder (**Hygiene factors**)

Motivators are more concerned with the actual job itself. For instance how interesting the work is and how much opportunity it gives for extra responsibility, recognition and promotion. Hygiene factors are factors which 'surround the job' rather than the job itself. For example a worker will only turn up to work if a business has provided a reasonable level of pay and safe working conditions but these factors will not make him work harder at his job once he is there. Importantly Herzberg viewed pay as a hygiene factor.

Herzberg believed that businesses should motivate employees by adopting a democratic approach to management and by improving the nature and content of the actual job through certain methods. Some of the methods managers could use to achieve this are:

- **Job enlargement** – workers being given a greater variety of tasks to perform (not necessarily more challenging) which should make the work more interesting.
- **Job enrichment** - involves workers being given a wider range of more complex, interesting and challenging tasks surrounding a complete unit of work. This should give a greater sense of achievement.
- **Empowerment** means delegating more power to employees to make their own decisions over areas of their working life.

Individual motivation

No workplace is more productive than a company that is filled with motivated employees [Sas-03]. When employees seem unmotivated, the problem is often not due to lack of drive, but rather the result of being tasked with responsibilities and duties that just don't suit the individual or their skill set. Good delegation in the workplace requires careful consideration of team members as individuals, and not a "one size fits all" group. You have a better chance of keeping their fire lit if you can match employees with assignments that fit their unique sensibilities [Sco-11].

Moreover, employees need to have a clear idea of what's expected of them, so that they can work toward the goals that contribute most to the long-term success of the business. The management team should recognize and reward top performers. In fact, studies show that most workers value clear, consistent feedback and acknowledgment as much as they do monetary compensation [Suc-11].

One benchmark company maintains a structure that facilitates communication and improves responsiveness to production challenges. In addition to reacting to problems more quickly, the company's structure increases accountability by establishing clear roles and responsibilities for all employees [Cha-03].

In order to motivate employees, the following measures could be useful [Sas-03]:

- Giving employees a clear understanding of their individual or team goals and how they fit into the bigger corporate picture. The goals need to be meaningful to the employee, measurable and achievable.
- Rewarding employees for achieving goals. Making the rewards something the employee values.

- Getting employees involved in decision-making about things that matter.
- Showing an interest in the work the employee is doing in achieving the goals from day to day on the job [Suc-11].
- Providing positive feedback.
- Using what motivates the employee; people are motivated by different things.
- Giving employees authority and let them know you expect responsibility.
- Contribute to ongoing job satisfaction and productivity by recognizing and rewarding employees for exceptional effort [Suc-11].

2.2.4. Specific roles methodologies

Management by Objectives

Management by objectives (MBO) is a systematic and organized approach that allows management to focus on achievable goals and to attain the best possible results from available resources. It aims to increase organizational performance by aligning goals and subordinate objectives throughout the organization [Mih-08].

Peter Drucker outlined MBO in 1954 in his book 'The Practice of Management'. The principle behind MBO is to make sure that everybody within the organization has a clear understanding of the aims, or objectives, of that organization, as well as awareness of their own roles and responsibilities in achieving those aims [Vad-01].

The managers of the various units or sub-units, or sections of an organization should know not only the objectives of their unit but should also actively participate in setting these objectives and make responsibility for them. MBO creates a link between top manager's strategic thinking and the strategy's implementation lower down. Responsibility for objectives is passed from the organization to its individual members [Vad-01].

Management by Objectives (MBO) operations are all compatible with empowerment, if you follow the main principle of decentralization: telling people what is to be done, but letting them achieve it their own way. To make the principle work well, people need to be able to develop personally. Further, different people have different hierarchy of needs and, thus, need to be managed differently if they are to perform well and achieve their potential [Vad-01].

The strategy of MBO consists in the following steps:

1. Cascading of organizational vision, goals and objectives
2. Setting a specific set of objectives for all the individuals within the organisation and an explicit time period. These objectives are mutually set and agreed upon by individuals and their managers.
3. Monitoring progress. Performance reviews are conducted periodically to determine how close individuals are to attaining their objectives.
4. After the explicit time period the performance is evaluated and some feedback is given.
5. Rewards are given to individuals on the basis of how close they come to reaching their goals.
6. A new operating period by MBO begins

Figure 16*: The five steps MBO process [Vad-01]*

Some of the important features and advantages of MBO are [Vad-01]:

- Motivation: Involving employees in the whole process of goal setting and increasing employee empowerment. This increases employee job satisfaction and commitment.
- Better communication and coordination: frequent reviews and interactions between superiors and subordinates helps to maintain harmonious relationships within the organization and also to solve many problems.
- Clarity and alignment of goals
- Subordinates tend to have a higher commitment to objectives they set for themselves than those imposed on them by another person.

The main disadvantages are [Vad-01]:

- The development of objectives can be time consuming, leaving both managers and employees less time in which to do their actual work.
- The elaborate written goals, careful communication of goals, and detailed performance evaluation required in an MBO program increase the volume of paperwork in an organization.

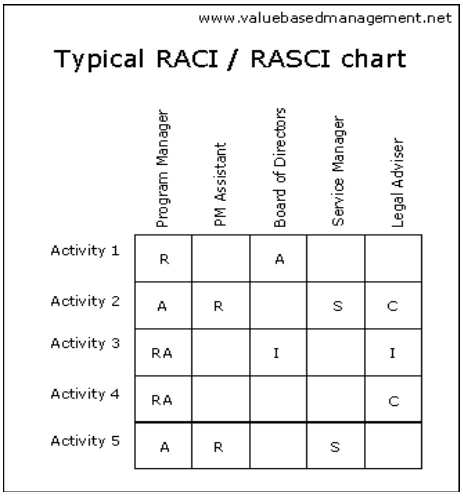
The RACI/RASCI chart

The RACI model is a relatively straightforward tool that can be used for identifying roles and responsibilities during an organizational change process. After all, transformation processes do not process themselves; people have to "do" something to make the processes happen. Therefore it is useful to describe what should be done by whom to make a transformation process happen. Instead of the term RACI, sometimes also the terms RASCI or RASIC are used. RASCI is an abbreviation for [Val 11]:

R= **Responsible**: owns the problem/project
A= to whom "R" is **Accountable**: who must sign off (Approve) on work before it is effective
S= can be **Supportive**: can provide resources or can play a supporting role in information
C= to be **Consulted**: has information and/or capability necessary to complete the work
I= to be **Informed:** must be notified of results, but need not be consulted

Typical steps in a RACI process: [Val 11]

1. Identify all of the processes/activities involved and list them down the left hand side of the chart.
2. Identify all of the roles and list them along the top of the chart
3. Complete the cells of the chart: identify who has the R,A,S,C,I for each process
4. Every process should preferably have one and only one “R” as a general principle. A gap occurs when a process exists with no “R” (no role is responsible), an overlap occurs when multiple roles exist that have an “R” for a given process.
5. Resolve Overlaps: in the case of multiple “R”s, there is a need to “zoom in” and further detail the sub processes associated with “obtain resource commitment” to separate the individual responsibilities.
6. Resolve gaps: The individual with the authority for role definition must determine which existing role is responsible or new role that is required, update the RASCI map and clarify with the individual(s) that assume that role.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Typical RACI / RASCI chart

	Program Manager	PM Assistant	Board of Directors	Service Manager	Legal Adviser
Activity 1	R		A		
Activity 2	A	R		S	C
Activity 3	RA		I		I
Activity 4	RA				C
Activity 5	A	R		S	

Figure 17: ***RACI/RASCI chart [Val-11]***

2.2.5. My understanding of a role

According to the Business Dictionary [Web-11] the terms role and roles are defined in the following way:

- *Role*: a prescribed or expected behaviour associated with a particular position or status in a group or organization.
- *Roles*: Jobs or positions that have a specific set of expectations attached to them.

In this thesis, the term role is defined basically by the specific tasks that a person might be in charge of, with its correspondent objectives and indicators. This role can be performed by different individuals.

2.3. Indicators and Performance Measurement Systems

Measuring the performance of a production system is essential to every manufacturing enterprise; in order to control an activity or process, its efficiency must be measured. This can be possible by means of indicators.

Decision making and management of complex issues requires methods for representing these issues by simple units of measure. These are called indicators: condensed information for decision-making [Ols-00]. Indicators refer to specific information. Since managers regularly require specific information to enable proper decision-making, indicators often play an important role. They quantify an element considered to be relevant to the monitoring or evaluation of a programme. Communication is the main function of indicators: they should enable or promote information exchange regarding the issue they address. Indicators always simplify a complex reality. They focus on certain aspects which are regarded relevant and on which data are available [EEA-03]..

Although the accuracy of mechanistic or physical measurements has advanced over the last years, measuring manufacturing performance is still a complex matter due to its multidimensional nature.

2.3.1. Characteristics of Indicators

Indicators can be described in many different ways depending on their specific purpose and what they measure. Some of the most common characteristics are explained below.

Quantitative/Qualitative

Quantitative indicators are those which are answered in numerical form. They differ along a continuum of the degree of precision of estimation required. They are widely used to assess progress towards stated targets [Lin-02].

Qualitative indicators are those which are answered in verbal form. They may assess observable 'facts' (e.g. whether houses are built out of brick or mud) or ideas and attitudes (e.g. whether or not women feel they have more self-confidence) [Lin-02].

The tension between the needs for subjectivity/participation and objectivity/measurement in evaluation is often played out in decisions about whether to use quantitative or qualitative indicators.In this thesis the indicators are going to be <u>quantitative</u>.

Direct/Proxy

Direct indicators are those which refer directly to the subject they have been developed for e.g. levels of savings in a savings and credit program. This is often the case with operational and more technical subjects. What the manager wants to know can be measured directly [Lin-02].

Proxy indicators are those which only refer in an indirect way to the subject. They are assumed to be related to direct impacts but may be easier to measure or assess e.g. levels of women's savings as a proxy indicator of poverty reduction or economic empowerment. There can be several reasons to formulate indirect indicators [Lin-02]:

- The subject of interest cannot be measured directly. This is particularly the case for more qualitative subjects, like behavioural change, living conditions, good governance, etc.;
- The subject of analysis can be measured directly, but it is too sensitive to do so, for example level of income or, in the context of an HIV/AIDS intervention, "safe sex";
- The use of an indirect indicator can be more cost-effective than the use of a direct one. As such, indirect indicators are very typical management tools. Generally, managers are not looking for scientifically reliable data but for management information. An indirect indicator may very well represent the right balance between level of reliability of information and the efforts needed to obtain the data.

The indicators defined in this document will try to be direct, but it will probably don't be possible for all of them, so proxy indicators will also be included.

SMART, SPICED and CREAM indicators

SMART indicators are specific, measurable, attainable, relevant and time-bound. The main considerations are the feasibility of collecting data which can be quickly and easily used at specific points in the project management cycle [Lin-02].

- **Specific**: Indicators should reflect those things the project intends to change, avoiding measures that are largely subject to external influences
- **Measurable:** Indicators must
  - be precisely defined so that their measurement and interpretation is unambiguous;
  - give objective data, independent of who is collecting the data
  - be comparable across groups and projects thus allowing changes to be compared and aggregated
- **Attainable**: Indicators should be achievable by the project and therefore sensitive to changes the project wishes to make
- **Relevant**: Indicators should be relevant to the project in question It must be feasible to collect data on the chosen indicators within a reasonable time and at a reasonable cost
- **Time-bound**: Indicators should describe by when a certain change is expected

SPICED indicators: subjective, participatory, interpreted, cross-checked, empowering, diverse. They focus more on relevance of indicators to different stakeholders and their accurate representation of complex realities where the subjective interpretation of various different stakeholders is important [Lin-02].

- **Subjective**: Informants have a special position or experience that gives them unique insights which may yield a very high return on the investigators time. In this sense, what may be seen by others as 'anecdotal' becomes critical data because of the source's value.
- **Participatory**: Indicators should be developed together with those best placed to assess them. This means involving a project's ultimate beneficiaries, but it can also mean involving local staff and other stakeholders.
- **Interpreted and communicable**: Locally defined indicators may not mean much to other stakeholders, so they often need to be explained.
- **Cross-checked and compared**: The validity of assessment needs to be cross-checked, by comparing different indicators and progress, and by using different informants, methods, and researchers.

- **Empowering**: The process of setting and assessing indicators should be empowering in itself and allow groups and individuals to reflect critically on their changing situation.
- **Diverse and disaggregated:** There should be a deliberate effort to seek out different indicators from a range of groups. This information needs to be recorded in such a way that these differences can be assessed over time.

In practice there can be tension between the participatory, subjective character of the SPICED indicator approach and the emphasis on objective measuring in the SMART approach, and evaluators may have to make effort to reconcile this by balancing SMART with SPICED requirements [Lin-02]. For our results the SPICED requirements should be prioritised in front of the SMART, although it would be better if both of them are balanced.

Whether the indicators are SMART or SPICED, or a mixture of the two, they should all be CREAM: clear, realistic, economical, adequate and easily monitored.

- **Clear:** precise and unambiguous
- **Realistic:** appropriate to the subject at hand
- **Economic:** available at reasonable cost
- **Adequate:** able to provide sufficient basis to assess performance
- **Monitored:** amenable to independent validation

2.3.2. Energy Performance Indicators

An Energy Performance Indicator (EPI) is an indicator related to energy measurements. Energy indicators can be generated according to many different formulations, each of which can be used to answer specific or general questions related to energy [Asi-00]. In general EPIs may be based on consumption, energy efficiency, cost or environmental (CO_2) measures [SEA].

Use of Energy Performance Indicators

As with any benchmarking exercise, it is important to compare your performance against other internal or external reference standards, to determine how well you are actually performing. EPIs can be used to develop relative measures of energy performance, track changes over time, and identify best energy management practices. The use of EPIs makes possible to [SEA]:

- Establish baselines and track performance
- Identify best practices and set targets
- Identify savings potential
- Prioritise your efforts
- Identify problems
- Communicate results and achievements [SEA]
- Evaluate the effectiveness of energy programmes
- Develop energy policies
- Supplement energy demand and supply forecast
- Develop intra and inter economy comparisons [Asi-00]

Changes in energy indicators can also be attributed to improvements in energy technologies. By monitoring energy efficiency indicators, policy-makers can determine the overall influence of the new production technologies on levels of energy consumption [Asi-00].

EPIs may not be solely technical measurements. Maybe it is necessary to communicate performance to other audiences within your organisation in a non-technical manner [SEA].

Indicators can be established in a variety of ways; however, the two main approaches are [SEA]:

1. Best Practice: a comparison against established practices considered to be the best in the industry or sector.
2. Past performance: comparison of current versus historical performance.

In general, best practice indicators relate to external comparisons, while past performance and other measures to compare performance between different sites or operational units etc., focus more on internal indicators. Separate indicators may also be used for fossil fuel and electricity. Provided the information is available, benchmarking can be carried out on any scale, even down to individual items of plant or equipment [SEA].

Whether internal or external comparisons are used, the EPI indicates if performance can probably be improved, energy savings made and environmental impacts reduced [SEA].

Units of measurement

Indicators can be denominated in either physical units, where energy is directly related to the physical quantity of output, or alternatively in economic terms, where energy consumption is linked to the monetary value of production [Asi-00].

The measurement of indicators, either in physical or monetary units, and the type of indicator to use, vary according to the nature of the analysis to be undertaken. Generally, indicators measured in monetary units are applied to the analysis of energy efficiency at a macro-economic level, while physical units are applied to sub-sectoral level indicators [Asi-00].

Physically based indicators are often preferable to those based on economic measures of output. Such indicators have the advantage that they are not affected by price fluctuations, can be directly related to individual processes and allow a well-founded analysis of improvement potentials [Asi-00].

Physical Indicators

Physical indicators calculate specific energy consumption relative to a physical measurement of production, such as tonnes of product. Physical indicators are concerned with mass and energy flows. This concept is unambiguous and physical indicators typically cover the manufacturing process [Asi-00].

The advantage of physical indicators is that there is a direct relationship between the indicator and the energy efficiency technology. For example, improvements in technologies will be indicated as savings in the specific energy consumption, and result in an indicator that assesses a lower specific energy requirement per tonne of output [Asi-00].

Since physical energy efficiency indicators are necessarily applied to the analysis of energy efficiency at less aggregated levels, problems associated with the structural effects lessen. However, to the extent that the product mix and energy source vary, some structural inconsistencies may still exist [Asi-00].

Value based indicators

Value based indicators measure the quantity of energy consumed relative to the economic/monetary value of the activity generated, denominated in a currency related unit, for example the quantity of energy consumed relative to the value added of steel sector production. Rather than expressing the output as a measured quantity, such as tonnes of steel, the value associated with production is measured generally in a monetary unit [Asi-00].

The key advantage of using economic value based energy efficiency indicators is that indicators can be compared across industries since the denominator (monetary value) is similar even though dissimilar products are produced. As energy efficiency indicators are constructed at more aggregated levels, economic energy efficiency indicators become increasingly common [Asi-00].

The most important limitation is that economic indicators incorporate a range of non-energy efficiency related influences, such as pricing effects [Asi-00]

Dimensionless

Ratios or indexes are relative measurements. This simplifies comparisons with other measures, among various types of information provision systems, and among different situations in relation to a particular mode of access or service.

Influence of external factors

As Figure 18 shows, indicators of energy efficiency can be constructed from aggregated international or national statistics through to output data from individual operating units within a plant [Asi-00].

At the highest level, there are only a few indicators of energy efficiency that can be constructed. As indicators of energy efficiency are calculated at more aggregate levels, the influence of external factors increases and it becomes increasingly difficult to account for these differences. Due to the large level of aggregation, these broad indicators often include many separate effects that can potentially bias the results. As the level of aggregation decreases (moving down the pyramid), the influence of changing structural effects and other factors also decline [Asi-00]

Clearly, moving further down the pyramid increases the understanding of the multitude of factors that affect more aggregated measurements of energy efficiency. However the quantity of data required (at the bottom of the pyramid) increases substantially, and the acquisition of data becomes increasingly laborious [Asi-00].

Determining the appropriate level of detail for the construction of energy efficiency indicators needs to reflect the goals of the specific analysis [Asi-00].

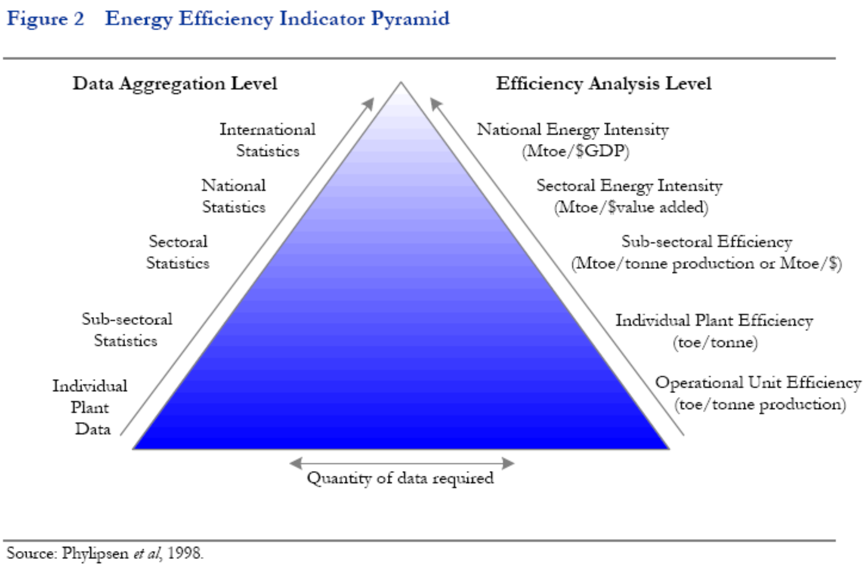

Figure 18: ***Energy efficiency indicator pyramid [Asi-00]***

Normalisation

EPIs may be 'normalised' to take account of a range of variables that affect energy consumption. Depending on whether you are dealing with industrial processes or buildings, influencing factors include weather, hours of use, occupancy levels, production levels [SEA].

In industry, the most common measure of performance is energy use per unit of production (specific energy consumption). It is often best to relate industrial EPIs to saleable product, as costs are often based on this measure. The calculation appears to be relatively straightforward; however, energy use does not always depend on production throughput. The less sensitive energy use is to production, the more sensitive the EPI will be to changes in production. In this respect it is important to identify the actions under your control that influence energy use and also the factors outside your control that may affect it. You may therefore need to adjust your EPI for changes in production output and other factors such as weather, shift patterns [SEA].

For buildings, heating energy consumption can be normalised for the influence of weather-related temperatures. This is carried out through the use of 'degree days', which provide a measure of the severity and duration of weather conditions. Information on the application of degree days is available from SEI. In some buildings, such as hotels, occupancy levels may influence consumption patterns. Whereas in other buildings, such as older hospitals, the building volume may be a factor to take into account. Such 'external' factors may need to be brought into the equation to arrive at meaningful performance indicators [SEA].

EPIs provide a broad measure of the performance of energy consumption and should be used with caution. If external factors are not accurately taken into account, then the resultant EPIs can mask actual trends in energy consumption and lead to erroneous decision making [SEA].

2.3.3. Attributes for indicators in this thesis

Indicators can have a lot of different attributes which describe different features or characteristics. Anyway, just the more relevant for the desired indicators must be defined. The indicators in this thesis are going to be defined by the following attributes:

Indicator title	Formula	Units	Role	Application		Period	Energy carrier
				Consumer	Process		

Table 1: Indicator's attributes

- **Indicator:** Title of the indicator that can be used as identification
- **Formula:** Mathematic calculation
- **Units:** Units of measurement
- **Application:** System boundaries
    - **Consumer** or group of consumers of the energy structure
    - **Process**
- **Period:** Analysed time period
- **Energy carrier:** Analysed energy carrier

These attributes were obtained from the predefined list of indicators that was given to the author. They make possible transform indicators in specific indicators, assigning a role and delimiting the system and time scope.

2.3.4. Performance Measurement System

Often discussed in the literature, performance measurement (PM) is defined in many different ways. Neely et al. (1995) define PM as "the process of quantifying the efficiency and effectiveness of action" and PMS as "the set of metrics used to quantify both the efficiency and effectiveness of actions". Rouse and Putterill (2003) define PM as "the comparison of results against expectations with the implied objective of learning to do better". In their view, the main reason for setting up a PMS is the objective of becoming better. This is supported by Dumond (1994), who considers "performance measures to be established to support the achievement of goals with the intent to motivate, guide and improve an individual's decision making." Many authors refer to a Performance *Management* System rather than a Performance *Measurement* System. In the eyes of Lebas (1995) and Amaratunga and Baldry (2002), measurement is not an end in itself, but a tool for more effective management. Results of performance measurement indicated what happened, not why it happened, or what to do about it. In order for an organisation to make effective use of its performance measurement outcomes, it must be able to make the transition from measurement to management [Eti-05].

Within the literature however, the term 'performance measurement' is used most frequently, which is why this terminology is also adopted in this paper. A PM is defined as "*the process of quantifying the efficiency and effectiveness of actions, in order to compare results against expectations, with the intent to motivate, guide and improve decision making*" and a PMS as "*the set of metrics used to quantify the efficiency and effectiveness of actions, and the corresponding guidelines for linking these metrics to strategy and improvement*" [Eti-05].

A wide range of factors distinguish effective performance measurement systems from less effective PMSs [Eti-05]:

- The performance measures on which the system is based should be relevant, balanced, and related to the company's strategy.
- PM should be based on financial as well as non-financial PI's, because quality or other non-financial goals are often part of a company's strategy.
- Measures need to be related directly to the organisation's mission and objectives in order to reflect the company's external competitive environment, customer requirements and internal objectives.
- PMS should specifically state how the objectives will be measured (frequency and responsible person)

In order to ensure that PMSs remain relevant, they should be reviewed periodically. Yet few organisations appear to have systematic processes in place for managing the evolution of their measurement systems. Organisations should identify whether their existing measurement systems are appropriate given their environment and objectives [Eti-05].

Many authors point out that a proper organisational and information system structure is a prerequisite for an effective PMS. A proper organisation structure includes involved leadership, open communication, and a reward system that is linked to performance measures. A highly developed information system is also an important part of the organisation structure. Performance measurement systems requiring regular reporting are best automated. The main benefit of using an IT platform for managing the PMS within an organisation is that the maintenance of the information contained within the systems becomes much simpler [Eti-05].

Finally, effective PMSs are linked to elements of human resource management, such as competence management; goal setting and sharing; feedback; and reward. Especially reward has been a hot topic recently and there is considerable debate as to whether performance measures should be linked to reward. Providing feedback to individuals with regard to where they stand on the performance measures is essential. This can enhance performance by providing motivation or information about the correctness and adequacy of work behaviour, and can also provide workers with a sense of accomplishment, competence and control [Eti-05].

Multi-levels indicators

Properly utilised, performance indicators should highlight opportunities for improvement within companies today. Performance measure should be used to highlight a soft spot in a company and then be further analyzed to find the problem that is causing the indicator to be low. Ultimately, they can point to a solution to the problem [Ter-05].

This implies that there should be multi-level indicators. One layer of indicators is at a corporate strategic level. A supporting level is the financial performance indicator for a particular department or process. A third level is an efficiency and effectiveness indicator that highlights the departmental functions that contribute to the efficiency and effectiveness of the department. The fifth level of indicator is the measurement of the actual function itself. The pyramid in figure X shows this tiered approach of performance indicators [Ter-05].

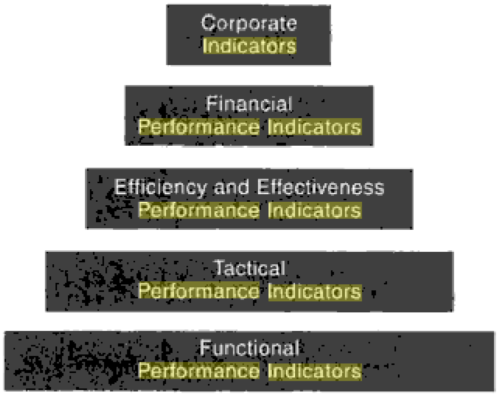

Figure 19: *Hierarchical Performance Indicators [Ter-05]*

General development of a Performance Measurement System

To prepare a consistent series of indicators of long-, medium-, and short-term potential benefits, one should produce a nested hierarchy based on broad mission statement, broad goals, broad objectives, and specific tasks [Mic-93].

An objective is defined as "*an end that can be reasonably achieved within an expected timeframe and with available resources*." A goal is used as a synonym for objective, although in general, a goal is broader in scope than an objective, and may consist of several individual objectives.

A target is "*the value of the indicator that policy makers regard as ideal and use as the basis for setting policy*."

Vision, mission and scope

A strategic vision is a view of an organization's future direction and business makeup. It is a guiding concept for what the organization is trying to do and to become. Whereas the focus of the company's mission tends to be on the present, the focus of a strategic vision is on a company's future [MSP-10].

Vision

Forming a strategic vision of what the company's future business makeup will be and where the organization is headed is needed so as to provide long-term direction. Strategic vision charts the course for the organization to pursue and creates organizational purpose and identity. Strategic vision spells out a direction and describes the destination [MSP-10].

<u>Project Vision:</u>

A project needs to have a vision that everyone in your team is familiar with, inspired by, and focused on to be successful today. That's because no project can make serious progress without a clear understanding of where it is going and what it is trying to achieve. It is too easy to start developing the solution before you fully understand the problem [Max-06].

A well-worded strategic vision has real value [MSP-10]:

1. It crystallizes senior executive’s own views about firm long-term direction and future: it clarifies the direction in which the organization needs to move
2. It guides managerial decision making.
3. It conveys an organizational purpose that arouses employee commitment
4. It brings unity to community: it provides a beacon lower-level managers can use to form departmental missions, set departmental objectives, and craft strategies.
5. It establishes meaning for today, hope for the future and a sense of continuity: it gives employees a larger sense of purpose, so they see themselves as “building a cathedral” rather than “laying stones.”
6. It empowers people and focuses their efforts: it creates enthusiasm and poses a challenge that inspires and engages people in the company.

Mission

A project vision requires a mission that leads to goals, those broad-based things that give the project general direction and purpose. The project goals, in turn, lead to a set of project objectives [MSP-10].

The mission statements define your company’s purpose or its fundamental reason for existing, but it should also serve as both a guide for day-to-day operations and the foundation for future decision-making. In other words, it should determine your primary business and organization purpose and be the roadmap in a strategic plan to empower your employees to be more effective. It should be specific, short, sharply focused and memorable. It should provide the framework for independent decisions and actions initiated by departments, managers, and employees into a coordinated, company-wide game plan [MSP-10].

Scope

It is important to define at the beginning the scope of the project so we can separate what is relevant to the project from that which is irrelevant. Defining the boundaries of a project can be extremely challenging. Which departments, factories, lines or modules will be affected by the project? Once the boundaries are defined one is able to select the things that are applicable to the project from those areas that are out of scope [Dan-11].

In terms of project implementation, the boundaries of a project are the reasonable limits of project work to determine what is included in the project and what’s not. The boundaries are defined as measurable and auditable characteristics and closely linked to project objectives. They create a holistic project perception, determine limits and exclusions of the project, and form the content of project scope in terms of expected results [Dan-11].

Project boundaries identification helps clearly understand where the project starts and ends. It allows improving the overall project management process and increase accountability level by redefining the principles of delegation and teamwork. Having clearly stated and identified project boundaries allows managers to make a project environment in which individuals and teams are enabled to manage their own activities and tasks to produce expected results, within a defined set of responsibilities and roles [Dan-11].

When you have set up accurate boundaries for your project, groups and individuals can show higher performance and overall accountability because they clearly know what they should do within the project and what is out of their duties. The identified project boundaries will help you with planning human resources for your project, setting up job requirements and defining team roles and responsibilities. You will gain opportunities for project improvements because individuals will recognize that their performance is based on how they manage their own part of duties in relationship to the entire group [Dan-11].

Communicating the Strategic Vision, the Mission and the Scope

The vision, mission and scope of our project could be perfectly defined and structured, but fail in their objectives because the communication of them was not clear. Workers have not understood the aim of our statement or they have forgotten it. It is very important that the whole company shares the motivation to achieve the goals of the project so that all workers move in the same direction. Therefore the way in which the vision and mission are communicated is essential to make the best of it [MSP-10].

- A well-articulated strategic vision creates enthusiasm. Managers need to communicate the mission and vision in words that induce employee buy-in, build pride, and create a strong sense of organizational purpose.
- Find it everywhere. When the mission statement is created, make it visible.

Hierarchy of objectives

Finding objectives

Firstly, one has to find the main goals of the project. How will be the mission and vision achieved? To identify the appropriate goals and objectives a general analysis and study of the project's aim should be carried out. This study might include [Eur-95]:

- Collection of the documentation required
- Stakeholders workshop
- Brainstorming
- Analysis of literature

Once different objectives have been identified, a list of these should be recorded.

Defining objectives

This section focuses on the logical analysis of projects in terms of the relationship between projects goals, objectives and specific action points. There should be a high level of internal coherence (i.e. correspondence or logical links) between objectives and, in particular, between the operational objectives (actions) and the more global objectives. The assessment of this requires a structured approach to objective hierarchies and cause and effect relationships [Org-08]:

<u>Classification of objectives</u>

From the literature and stakeholder workshops, it may be possible to identify a large variety of objectives but impossible to evaluate each individually, given resource constraints. It will therefore be necessary to identify a small number of key (higher level) objectives which can form the focus for evaluation. This can be achieved by informal or formalised processes. The informal process would be to revisit the hierarchy of objectives and to answer the question "why?" for each objective. This should achieve the result that several sub-objectives could be grouped under one main objective which could be the focus for evaluation [Org-08].

The issues of relevance and coherence imply that there needs to be some context which makes the objective meaningful. This may just be with respect to a currently existing situation, but usually implies that there are other objectives involved. Is the objective an end in itself, or a means to another end? If the question [Org-08]:

Why is this objective relevant/important?

can be answered with another higher-level objective (aims or goals) then this also needs to be considered in an evaluation. Similarly, within a hierarchy of objectives, if the question:

How can this objective be achieved?

can be answered with a lower-level objective then this represents a movement down a hierarchy of objectives to lower-level or sub-objectives.

By asking these questions the different objectives and goals can be classified, but not always will be so straightforward. The definition of the logical relationship is paramount in the classification. This task is a question of experience, because the decision of the evaluation team that two events are logically connected depends on the judgement of experts in the field under study, and managers responsible for the implementation of the strategy and policies. Each of the classifications by row should be explained by means of an interpretation expressed as an assumption [Eur-95].

Several situations can be encountered [Eur-95]:

- The row of the objective is explicit. This is often the case for the objective of the first row, also called the overall or long-term objective.
- The cause-and-effect link between two objectives is explicit, which facilitates the understanding of the interconnections between them.
- No indication is given about the objective's row (per se or in relation to others). The evaluator should refer to additional documentation in order to find an indication of a cause-and-effect link; if this task fails, it should be deduced and/or the evaluator should ask the assistance of experts.

Objectives Diagram

The objectives diagram illustrates the objectives classification, from the global objective to detailed operational objectives [Eur-95]:

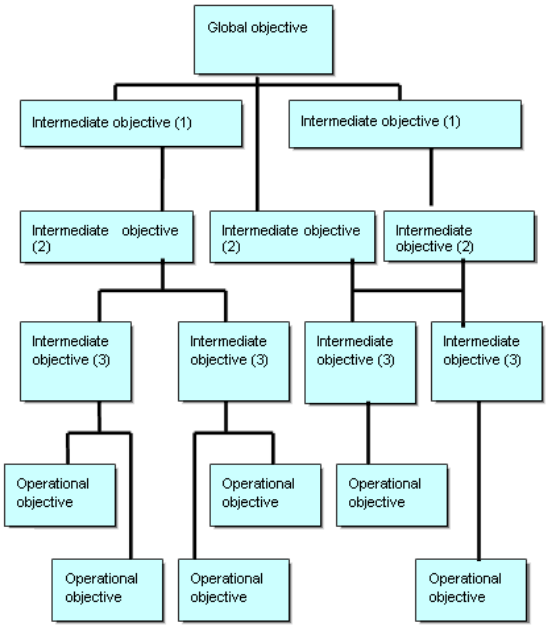

Figure 20: *Objective's Diagram [Eur-95]*

Usually, a long term and global strategic objective, assumed to be a first level objective, is fulfilled through the completion of a range of second level objectives. This is true even where the first level objective is straightforward. Each second level objective depends on the completion of several third level objectives, and so on, down to operational objectives. Therefore, an objective is usually understood as a means to achieve a superior level aim, while depending on the completion of subordinate means or objectives. The objectives system is the presentation of all the objectives of all levels with their respective links [Eur-95].

The construction of the diagram should start with the overall objective or the operational objectives. Usage has shown that these two types of objectives are more easily identified than intermediate objectives, which are also more difficult to rank. Thus, it is recommended that the roots of the diagram and the extremities of the branches are developed concurrently [Eur-95].

Objectives diagrams are established during the organisation stage, where reports and notes should be provided. At this stage, the diagram's construction must be precisely described. For the faithfully reconstructed objectives diagram, the sources of the objectives/effects (quotations, references to the original documentation) must be provided. References to documentation, interviews and expertise must support the objectives' location in the diagram, and the assumptions developed during the construction of the diagram must be explained [Eur-95].

Evaluation

After elaborating the hierarchy of objectives, it must be evaluated to guarantee that the objectives are suitable to develop indicators and to be assigned to different roles. Furthermore the all the objectives must be aligned with the company's main goals. There should be a checklist with the following questions [Eur-95]:

- Do the proposed global (top level) objectives correspond to the mission and vision? If not, which should be added or deleted?

- Do the proposed generic intermediate objectives reflect the implicit as well as explicit objectives? If not, which should be added or deleted?
- Are the specific operational objectives (action points) relevant for the main goals?
- Are the objectives SMART?
- Are documentary references and quotations provided in the report?
- Do the diagrams appear coherent?
- Are the relations between objectives explicit?
- Are hypotheses and uncertainties about the objectives' links clearly stated?

Defining impact statements

The term impact conveys the idea of wide-scope and long-term effects. By convention, medium term effects are called outcomes, and short-term effects results. The tool will refer to the term effect, so as to include the development assistance's range of outputs (results, outcomes and effects) [Eur-95].

Evaluations must take into account the effect system (interactions between outputs, results and impacts) linked to the project or the strategy to be assessed, and organise it. The information on expected effects may be contained in the action plan documents, may be known from research or, in the absence of direct evidence, may be predicted either from a sound theoretical perspective or based on expert judgement [Org-08].

Key challenges for this step are to be [Org-08]:

a. clear about cause and effect relationships, particularly if several different actions have similar effects
b. able to specify the scale and direction of the effect.

Defining a cause and effect relationship between the objective and the effect or measured phenomenon is highly difficult. The logical nature of the links between objectives and effects (impact statements) are based essentially on experience and research/investigation [Org-08].

Effects diagram

An effects diagram can be used to describe the theoretical organisation of the effect system which leads to the overall intended impact. It displays the classification of the results, outcomes and impacts of what is intended from the implementation of the objectives system. It connects the actual activities which have been planned, and the outputs which should produce direct results, to the medium-term intermediate impacts and the long-term global impacts. Such outputs can be called 'effects' and are linked together in a range of causal relations or synergies at the basis of the effect system [Eur-95].

Objectives diagrams and intended effect diagrams share the same rules of construction. The effect diagram is constructed from the conversion of each of the objectives into the corresponding intended effect [Eur-95]:

- The higher-order objective corresponds to the higher-order effect
- Intermediate objectives correspond to intermediate effects or outcomes
- Operational objectives correspond to results

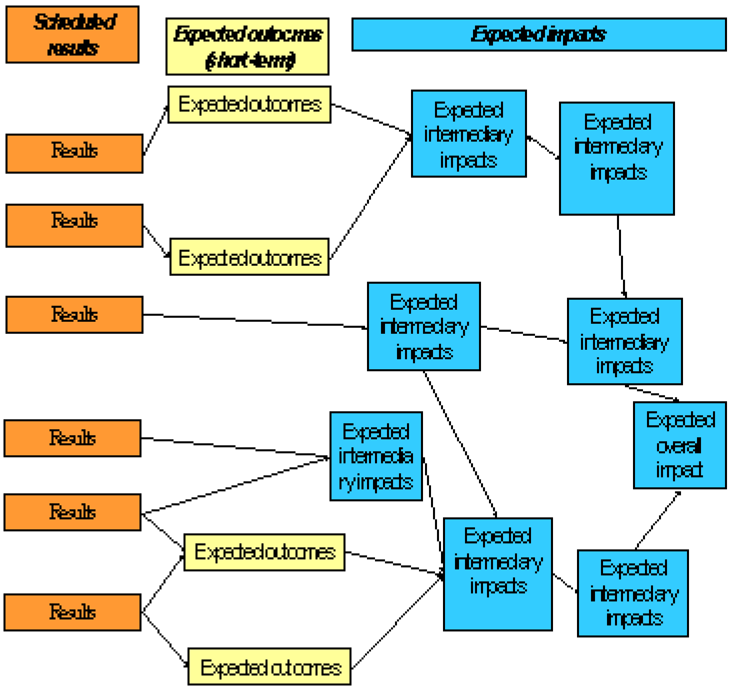

Figure 21:*Effects diagram [Eur-95]*

The objectives and effects illustrated in the diagrams are related to each other with horizontal or vertical links. These links are called 'logical' when expressing an inference relation or impact statement (induction or deduction) which has been validated by experience [Eur-95].

The logical links between effects can simultaneously be checked with [Org-08]:

- Recognised experts and stakeholders who have worked in diverse relevant situations
- Designers and implementing managers of projects included in the scope of the evaluation

Clustering impact statements

Experience has shown that the process of identifying objectives and impact statements can result in very large numbers of impact statements, needing to be grouped. In addition to the effects diagrams discussed above, there are a range of supporting techniques available that can be applied, including impact mapping, cross-impact matrices and statistical clustering [Org-08].

Impact Mapping

Impact mapping is well-suited to stakeholder participation. It is based on a group approach to [Org-08]:

a) Defining and validating all the effects
b) Weighting the impact statements in terms of their strategic importance to the project
c) Grouping them in terms of their conceptual proximity

Statistical software can be used to generate an impact map, taking account of the weightings and groupings prepared by each stakeholder [Org-08].

Defining indicators

There are different methods to move from impact statements to indicators. The most common are:

Direct Method

For some targets it seems obvious which kind of PIs are required to describe the objective's degree of fulfilment sufficiently. Usually these are objectives that aim for concrete measureable changes. For these objectives a direct derivation of the PI is possible like it is shown in figure [Sha-11].

An example is the objective "Less energy consumption". This objective is generally aiming for a reduction of energy used. Assuming that area of application and period is given, the derivation of a PI from the target occurs to be obvious [Sha-11].

To describe the degree of fulfilment an appropriate PI has to measure the amount of energy used in a specified area of application in a certain time interval. Afterwards this PI could be compared to a figure that was measured previously under the same restrictions or could be compared to a benchmark value from another industry partner. Hence a suitable PI would be "Energy consumption in application area in period" [Sha-11].

Critical Success Factor Method

There are also objectives where it occurs to be much more difficult to derive PIs that describe the objective's degree of fulfilment properly. Therefore the "Critical Success Factor" method known as a management tool from strategic management is used [Sha-11].

Originally the "Critical Success Factor Method" or "CSF"-method was developed by John F. Rockhart to "help executives clearly identify and define their information needs". A critical success factor "CSF" is a key area within a company where the company has to perform well to achieve a specific target (or mission like Caralli is calling it). Caralli explains further, that several CSFs might influence the fulfilment of one specific target. He states the example of a person that wants to lose weight and therefore has to consider certain critical success factors: improving the diet, regular activity and so on. To reach the final target of losing weight, the person has to perform well in the CSF (key areas). It is also important to mention that CSFs are not specific for only one target but also might affect other targets [Sha-11].

As explained above the CSFs affect the objective and hence have to be fulfilled. Once the CSF are defined, proper PIs have to be found that describe the degree of fulfilment of the respective CSF. The idea of this method is that once all CSF are fulfilled sufficiently it might be supposed that the target is reached as well [Sha-11].

An example is the target "Conscious treatment of energy". It is a qualitative objective and therefore it is difficult to measure, CSFs have to be defined. Feasible CSFs that describe this target sufficiently are [Sha-11]:

- Low energy consumption;
- High energy efficiency;
- Energy-conscious handling of energy by the company employees.

Possible proxy PIs that describe the degree of fulfilment of the respective CSFs could be [Sha-11]:

- Energy consumption in application area in period for the CSF "Low energy consumption" and the CSF "High energy efficiency";
- Average number of trainings related to energy consumption, efficiency or environmental protection per employee in period" for the CSF "Energy-conscious handling of energy by the company employees".

Selecting Key Performance Indicators

Many things are measurable. That does not make them key to the organization's success [Joh]. There is, contrary to popular belief, such a thing as too much information [Cha-10]. More information is not necessarily better and too much information can be confusing and can waste scarce resources. Indicators´ users will be overloaded with information and what is really important will be impossible to see.

In selecting Key Performance Indicators, it is critical to limit them to those factors that are essential to the organization reaching its goals. It is also important to keep the number of Key Performance Indicators small just to keep everyone's attention focused on achieving the same KPIs [Joh].

That is not to say, for instance, that a company will have only three or four total KPIs in total. Rather there will be three or four Key Performance Indicators for the company and all the different levels or units within it will have three, four, or five KPIs that support the overall company goals and can be "rolled up" into them. If a company Key Performance Indicator is "Increased Customer Satisfaction", that KPI will be focused differently in different departments. The Manufacturing Department may have a KPI of "Number of Units Rejected by Quality Inspection", while the Sales Department has a KPI of "Minutes a Customer Is on Hold before a Sales Rep Answers". Success by the Sales and Manufacturing Departments in meeting their respective departmental Key Performance Indicators will help the company meet its overall KPI [Joh].

Involving users in the development of the Performance Measurement System

A system of indicators has more chance of functioning when the suppliers and users of the information have been involved in its creation. In contrast, a closed group of specialists will be tempted to construct an expensive, technically ideal system that may never be operating satisfactorily [Eur-08].

As far as the users are concerned, explicit support from the highest level of the authority managing the programme has to be assured. It is then advisable to create a group of future users of the system, and to give it the job of defining the indicators [Eur-08].

A team should then be appointed to support the group and provide a secretariat. Typically the team members belong to the authority managing the programme. They should have the required human and financial resources. The team must, in particular, ensure that the system of indicators clearly reflects the programme objectives and favours comparability. It is preferable for the same team that is responsible for creating indicators to subsequently be responsible for the implementation of the system [Eur-08].

The main suppliers of information are the operators who implement the programme in the field. Their participation is likely to ensure that the system is pragmatic because they are familiar with the practical possibilities and limits of data collection [Eur-08].

It is also advisable to involve the operators in a preliminary test of the system of indicators. The recommended procedure starts with the selection of a few volunteer operators who will participate in the design of the system. These volunteers should represent all the components of the programme. They help to choose the indicators, to define them and to plan the information collection process. They express their needs in terms of information feedback. The test comprises an initial quantification of all the indicators by voluntary operators. The normal duration of such a test is a year. Depending on the conclusions of the test, and after introducing the necessary modifications, the system is validated. The definitions and the data collection and restitution procedures are clearly established, and a manual is written [Eur-08].

Information relating to the context is drawn from statistics. It is therefore advisable to involve an expert with recent and complete knowledge of exploitable statistical data, in designing the system. Depending on the case, this expert will belong to a statistics institute or a university or, if possible, to the institution running the programme. [Eur-08]

2.3.5. Energy related Performance Measurement Systems

No relevant energy related PMS has been found in literature. Energy management is a relative new concept, which has not yet been exploited. The different found approaches were focused just in plant-level indicators for benchmarking energy in different sectors and in environmental indicators for government policies. The main reasons are the difficulties and lack of measurement in lower levels.

2.3.5. Roles specific Performance Measurement Systems

It is obvious that the precise nature of the information required for decision-making varies with the type of decision to be made, the context of decision-making and the stakeholders involved. For instance, a private consumer may only want a simple signal that says whether a consumer product is “green” or not “green”, while an engineer engaged in product design needs more complex information that can guide specific design strategies [Ols-00]. That is the main reason why different roles need different indicators, and a PMS can help us to define them,

The following PMS were the most relevant considering indicators which facilitates decision-making to different roles with different tasks.

Performance Pyramid of Lynch/Cross

The Performance Pyramid System (PPS) was developed by Lynch and Cross (1991). In short, it is an interrelated system of different performance variables, which are controlled at different organisational levels. Strategic objectives flow down through the organisation with a reverse flow of information flowing upwards. Lynch and Cross use a pyramid-shaped “map” for understanding and defining the relevant objectives and measures for each level of the business organisation. The four levels of the PPS embody the corporate vision, accountability of the business units, competitive dimensions for business operating systems, and specific operational criteria [Eti-05].

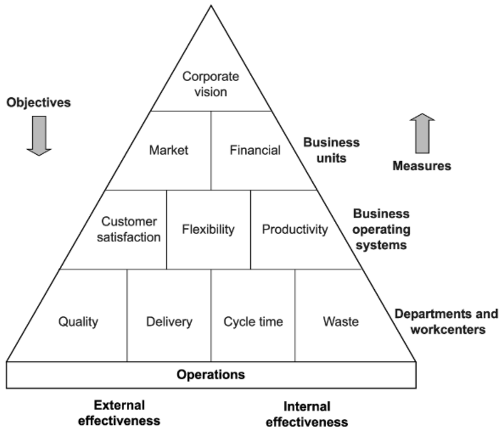

Figure 22: *The Performance Pyramid [Eti-05]*

According to Laitinen (2002), the purpose of the PPS is "to link an organisation's strategy to its operations by translating objectives from the top down (based on customer priorities) and measures from the bottom up". According to him, "the development of a firm's performance pyramid starts with the definition of an overall corporate vision (the highest or first level of objectives), which is then translated into individual business unit objectives at the second level. At the second level of objectives key market and financial measures are identified as ways of monitoring performance in achieving the vision. In order to attain these market and financial objectives, key measures of customer satisfaction, flexibility and productivity are also derived. These key measures at the third level are further converted into specific operational measures, which form the base of the pyramid. These measures (quality, delivery, cycle time and waste) relate to individual departments" [Eti-05].

Lynch and Cross (1991) claim that the performance pyramid is useful for describing how objectives are communicated down to the operational level and how measures are conveyed back up to higher levels. They also identify the use of the PPS in a feedback context, whereby it is used explicitly to monitor organizational performance. Finally, they argue that this model is equally useful for monitoring performance at the corporate, the SBU, the Business Operating Systems, and the departmental and work-centre levels of the organization. Although the original version of the PPS was not designed to cope with performance measurement at the individual level, later adaptations do specify its potential for measuring the performance of individuals and teams [Eti-05].

The Tableau de Bord

The Tableau de Bord (TdB) has gained widespread acceptance throughout the French business community. The TdB was introduced in France in the 1930s and was described as "being similar to a "dashboard" (i.e. the literal translation of "tableau de bord") used by "pilots" (i.e. managers) to guide organisations to their destinations". It was first developed by process engineers who were looking for ways to improve their production process by better understanding cause-and-effect relationships (the relationships between actions and process performance). The same principle was then applied at the top management level, to give senior managers a set of indicators allowing them to monitor the progress of business, compare it to the goals that had been set, and take corrective actions [Eti-05].

Giving managers a brief and to the point overview of key parameters to support decision making - has two important implications: First, the TdB cannot be a single document applying equally well to the whole firm; because each sub-unit, and in fact each manager, has different responsibilities and objectives, there should be one TdB for each sub-unit. These "dashboards" should be integrated in a nested structure, as illustrated in Figure 23. In this context, the firm's overall TdB would be translated into a series of documents supporting local decision making [Eti-05].

Secondly, the various TdBs used within the firm should not be limited to financial indicators. Operational measures often give better information on the impact of local events and decisions, and thus on cause-and-effect relationships, than overall financial indicators. From its origin, the TdB was conceived of as a "balanced" combination of financial and non-financial indicators and many authors have emphasized the need to use non-financial indicators. The development of a Tableau de Bord involves translating the unit's mission and vision into a set of objectives, from which the unit identifies its Key Success Factors, which then get translated into a series of quantitative Key Performance Indicators (KPIs) [Eti-05].

The TdB should primarily contain KPIs that are largely controllable by the sub-unit. At the same time, sub-units often need to collaborate on interdependent tasks and projects. Such areas of interdependence should be identified, and then reflected by choosing indicators that capture the interdependence and encourage sub-units to collaborate more effectively. Furthermore, most authors insist on including a learning perspective in the TdB, according to which the measures represent a basis for learning about the cause-and-effect relationships of actions. The basic idea is that, if realised performance does not meet the standard, the cause for this should be found and the problem solved (single-loop learning), but the path should also be questioned (double-loop learning) [Eti-05].

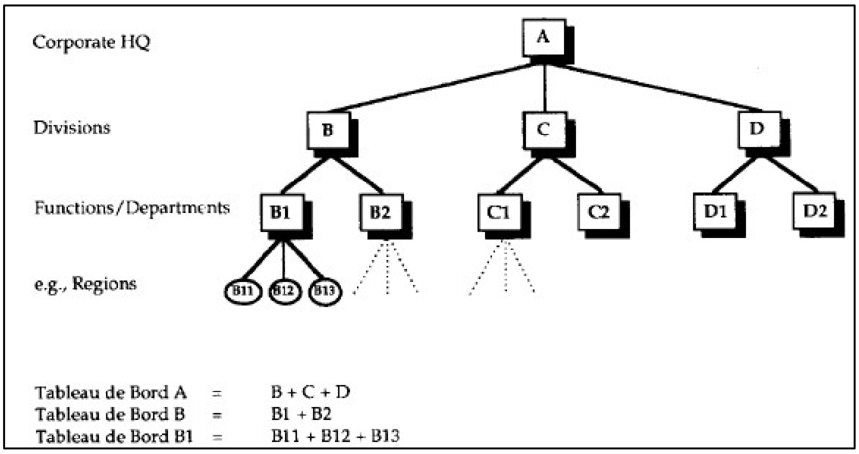

Figure 23: *The nested structure of the TdB [Eti-05]*

The biggest drawback perhaps of the TdB is its undefined structure. Because of its lack of predefined performance areas, there is a risk of managers implementing the TdB with a set of performance indicators that is not balanced in terms of financial and non-financial, lead and lag, strategic and operational, and related to effectiveness and efficiency [Eti-05].

3. Precedents for the current methodology

In the previous chapters the relevant subjects related to the thesis were analysed: energy, roles and indicators. A brief summary with the most important conclusions and problems is going to be presented in order to justify the current thesis and introduce the methodology.

3.1. Energy precedents

Analysing the history trends, it has been found that despite the recent energy efficiency improvements there still remains potential energy savings in the manufacturing industry. Energy management is a relative new science which can contribute considerably.

The major obstacle encountered is the lack of reliable available data at lower levels and the lack of relevant energy performance measurement systems.

Manufacturers will enjoy a wider range of energy management options by nurturing several key organizational attributes, including staff awareness, competence, leadership, commitment and removal of institutional barriers [NAM-05]. The main facts that would make possible energy efficiency improvements are:

- **A positive and productive staff:** Energy efficiency is very much dependent on the behaviour of line workers. Employee awareness of their impact on energy costs must be achieved. A positive, can-do attitude on the part of staff is helpful in attaining potential energy savings. Rewards and recognition can be harnessed to good effect [NAM-05].
- **Strength of engineering discipline and procedures:** Successful energy management depends on an ability to understand energy consumption. This leads to the necessity of measuring and monitoring energy at all levels in order to understand the main factors that influence energy consumption.
- **Information availability**: Firms in the productive sectors require information - to avail them of more efficient technologies and management methodologies - and so do policy-makers, so that the macro-economy functions efficiently [Asi-00].

3.2. Roles precedents

After reading the previous information, one can assume that there is a lot of information written about specific roles system. It seems that motivation and information behaviour have been deeply studied and both of them have some application for specific roles. Moreover different company structures have been developed which influence in the level of employee involvement. Finally a method which tries to align the company's goals with the personal objectives and one that assigns objectives to roles have been presented.

Some conclusions can be extracted:

- Motivated workers are more productive. This can be achieved by means of worker involvement and empowerment. Reward system linked to performance measures could also influence.

- The worker's goals must be aligned with the company's goals, and employees must understand how they contribute to achieving those objectives.
- The information needs of the different workers depend on the specific tasks and responsibilities they carry out.
- All individuals are different. They have different motivation's pyramids and they don't act in the same way in front of the same situations. Their reactions can be affected by the specific moment in time, their personal environment or other facts.

3.3. Indicators and Performance Measurement Systems precedents

The main indicator's characteristics were presented and energy performance indicators were analysed. EPIs play a fundamental role in the evolution of energy management in order to evaluate and monitor future energy efficiency practices. Furthermore the attributes and characteristics of the current thesis' indicators were established.

Besides performance measurement systems were introduced. No relevant energy related PMS was found and there are not many performance measurement systems focused on indicators which facilities decision-making to specific roles.

Information, in the abstract, means little to the engineer, the agriculturist, the farmer, the craftsman, or the doctor. Information must be subject oriented, or otherwise delimited, to be relevant for specific groups. Considering information for information's sake is a dead end [Mic-93].

The main requirements to develop an adequate PMS are:

- Employees should be involved defining the indicators
- It would be helpful to identify each proposed benefit and indicator according to its intended target user.
- The choice of indicators requires careful consideration. Indicators must be appropriate for decision-making and evaluations for each particular situation. Indicators must be relevant for decision-makers and should be linked strongly to the goals and objectives of stakeholders [Org-08].

3.4. Role specific set of energy related indicators

As it has been mentioned before not useful energy performance measurement system has been found in the literature, neither role specific PMS. The aim of this thesis is therefore to develop a role specific set of energy related indicators. Hence the indicators defined must be energy related and specific for the different roles.

A successful methodology would be very useful. The different advantages of implementing energy management have already been described and developing a set of energy indicators is essential to understand energy consumption and achieve energy efficiency improvements.

In the other hand, successful energy management depends on the staff's awareness. All workers must be involved in the new energy philosophy. They must be motivated and participate in the elaboration of the appropriate set of specific indicators

However, a single hierarchy of measures cannot reflect the whole value system of the organization which combines the goals of all stakeholders. It is therefore necessary to develop a hierarchy of measurements for each role. Once developed, these hierarchies can be interlinked to form one comprehensive performance measurement system. These measurement hierarchies are independent of the organization structure and represent logical chains of cause-and-effect relationships concentrating on business processes rather than functions [And-00].

4. Methodology

4.1. General Methodology

4.1.1. Methodology I

After reading all the previous chapters, one can assume that the aim of the thesis is to develop a set of energy related indicators for each specific role. As it has been explained, to make the most of the system the different roles must understand the purpose of the indicators and must be motivated to accomplish the targets. In order to achieve it, the best way is to involve all roles in the development of the specific objectives and the indicators.

The first methodology is based on chapters General development of a Performance Measurement System and Management by Objectives and mixes both main concepts. Ideally the best way of defining energy related indicator for each role would be:

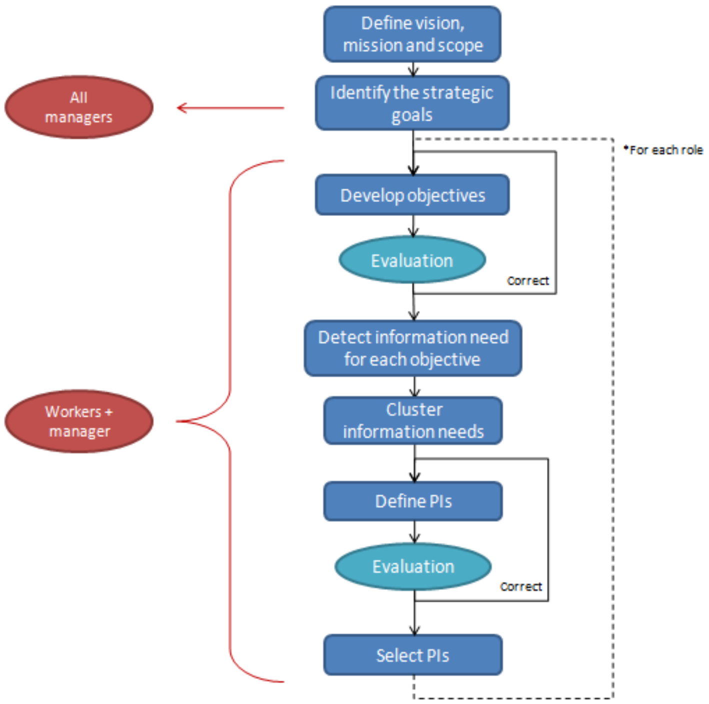

Figure 24: *Methodology I*

The different steps would be:

1. **Define vision, mission and scope**
2. **Identify strategic goals**
3. **Develop specific objectives**
4. **Detect information need for each objective**
5. **Cluster information needs**
6. **Develop PIS**
7. **Select PIs**

The specific objectives should be evaluated to ensure that they are aligned with the company's goals. Moreover, the defined performance indicators should also be evaluated to guarantee feasible results.

The disadvantages of the methodology would be the same as by MBO: high time consuming and increase the volume of paperwork in an organization.

In this thesis it is not possible to develop the methodology due to the necessity of employee involvement. That is the reason why a second methodology has been developed. Although it is not so worker-dependant, in a practical application the results would be much more accurate if the different workers participate in it.

4.1.2. Methodology II

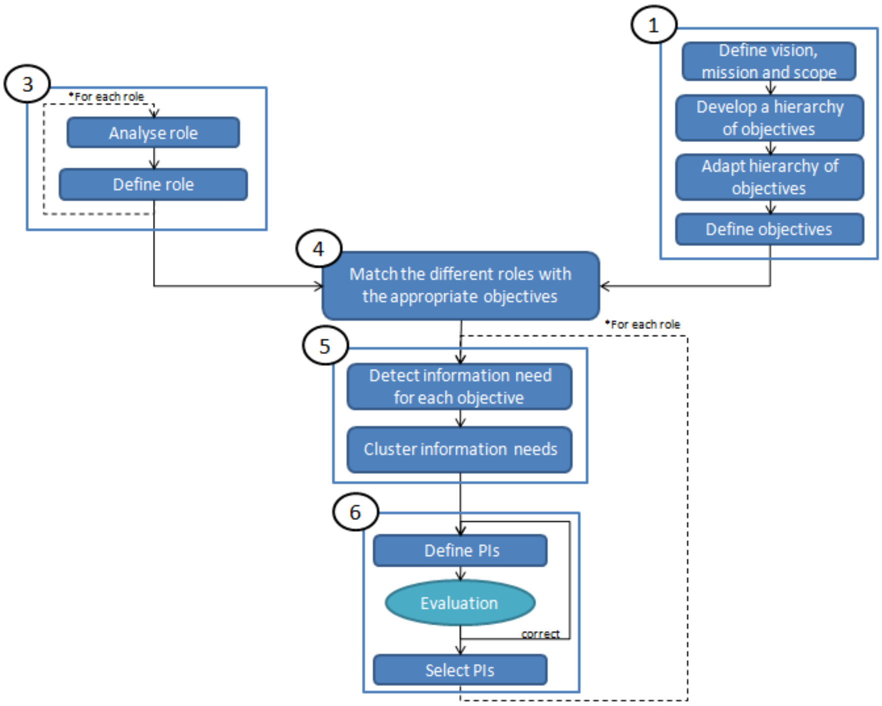

Figure 25: *Methodology II*

The aim of the thesis is to develop energy related indicators. Hence all the purposes should somehow be energy related. A predefined energy related objectives system, which is supposed to include all the most common and relevant energy related goals, was provided. See 8.1. Appendix 1: Energy related Hierarchy. All the methodology is based on this hierarchy.

Moreover, the methodology is an adaptation of the first one. It has a new branch which includes role's analysis and makes possible to have a specific role focus without needing the continuous involvement of the different roles. This fact conducts to a potential advantage: the process can be designed for an automatic solution where the roles just supervise the results but are not implied in the whole process. It is important to highlight that the specific roles should be the ones that conduct the methodology due to motivation and information behaviour factors, which are explained in chapters Information Behaviour and 2.2.3. Motivation of employees.

The most remarkable step is the matching of the different roles with the different objectives, which makes possible the automatic application.

The methodology has a data requirement: it needs an energy consumption structure to perform all the steps correctly and achieve useful results. See 4.4.1. Methodology input data for more information.

The different steps are going to be explained in detail in the following chapters.

4.2. Step by step used Methodology

4.2.1. Developing a Hierarchy of objectives

Defining vision, mission and scope and developing a specific hierarchy of objectives

Developing a good hierarchy of objectives is one of the most important points in order to define indicators at role level. The indicators must measure our objectives, so if a successful set of indicators is desired they must be based on a reliable set of clearly specified objectives. The hierarchy of objectives must be based on the project's vision, mission and scope. Therefore, the first step in every project is to define them consciously.

How to define the vision, mission and scope, as well as how to develop a hierarchy of objectives can be found in chapter General development of a Performance Measurement System.

Adapting hierarchy of objectives and defining objectives

The general hierarchy must be modified according to the project's hierarchy of objectives and requirements, creating a new specific hierarchy of objectives. The relevant objectives must be selected and known sub-objectives could be added.

Once the hierarchy is developed, the goals must be redefined like:

VERB	VARIABLE	OF	FACTORY LEVEL

Table 2: *Objective's definition*

- **Verb:** maximise/minimise
- **Variable:** a variable factor which has to be somehow measurable (physically or by a quantitative index)
- **Company factor:** a factor within a company that can be influenced by energy goals

Company	External	Customer
		Company's image
	Internal (Factory)	Equipment
		Human
		Process
		Product
		Organization
		Inputs
		Outputs

Tabla 3: *Company factors*

The objectives of the predefined energy related hierarchy have already been defined. See 8.2. Appendix 2: Explanation of the attached Excel file "GeneralData". It is very important to reflect about the definition of our goals to ensure reliable results.

The current system's goals must then be introduced in the objective's template. Two more categories must be filled in to establish the relationships between the goals and the consumers related to them. See 8.2. Appendix 2: Explanation of the attached Excel file "GeneralData".

Objectives					
Verb	Variable	Factory factor	Number	Contributes to	Consumer

Table 4: *Objectives' template*

- **Verb, variable, factory factor:** objective's definition
- **Number:** identification of the objective (automatically filled)
- **Contributes to:** immediate higher level objectives (it permits to link the objectives)
- **Consumer:** consumer or groups of consumer selected from the energy consumption structure, which are related to the objective

4.2.2. Analysing roles

In order to develop role specific indicators, we must be able to find which roles are related to the project´s objectives. It is necessary to have an accurate description of each role to ensure a successful matching. Different methods to analyse and understand the different roles are described in chapters Study of the user's environment and Study of the user.

Roles description

Once the role has been examined in depth, the role must be described. The role description needs to communicate clearly and concisely what tasks the job entails. For this methodology the following categories should be included:

- Title of the role
- Tasks' inventory

Tasks Inventory

A tasks' inventory is a list of the discrete activities that make up a specific job in a specific organization [Dav-10]. A general task inventory has already been developed based on use cases of the automotive and semiconductor industry and on job offers' descriptions.

In the list all the most relevant duties around consumers in the manufacturing industry can be found. The different activities that seem to logically go together are grouped together for a better understanding. See 8.2. Appendix 2: Explanation of the attached Excel file "GeneralData".

The tasks are described following these rules:

- use of an action verb
- description of the object of the action
- relationship with consumers: how the task influences the consumers

To define a specific task inventory, the adequate tasks of the general inventory have to be selected and assigned to each role. Furthermore an additional category must be filled:

Role description			
Role	Tasks' inventory		
	Verb	Object	Consumer

Table 5: *Roles' template*

- **Role:** Title of the role
- **Verb and object:** Task selected of the general task inventory
- **Consumer:** Consumer or group of consumer selected from the energy consumption structure, which are influenced by the task.

4.2.3. Assigning Roles to Objectives

Currently the project´s hierarchy of objectives and the roles description have been developed. There is just something missing: knowing which role is responsible for each objective. This step is based on the RACI chart explained in chapter 2.2.4. Specific roles methodologies.

In order to achieve an automatically assignment, a predefined table has been developed, where the objectives of the general energy related hierarchy are matched with the tasks of the general tasks' inventory that are influenced by the objective. The result of this matching is a little list of tasks assigned to each objective. See 8.2. Appendix 2: Explanation of the attached Excel file "GeneralData".

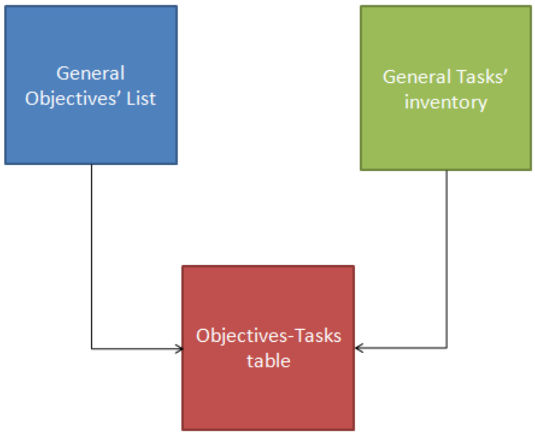

Ilustración 26: *Assignment process*

At this point the specific assignment can be done. Each task of each role will be looked up in the predefined table, finding the objectives which are related to the task. Thus every task of each role will have some goals assigned, or not if the task is not relevant for the specific objectives.

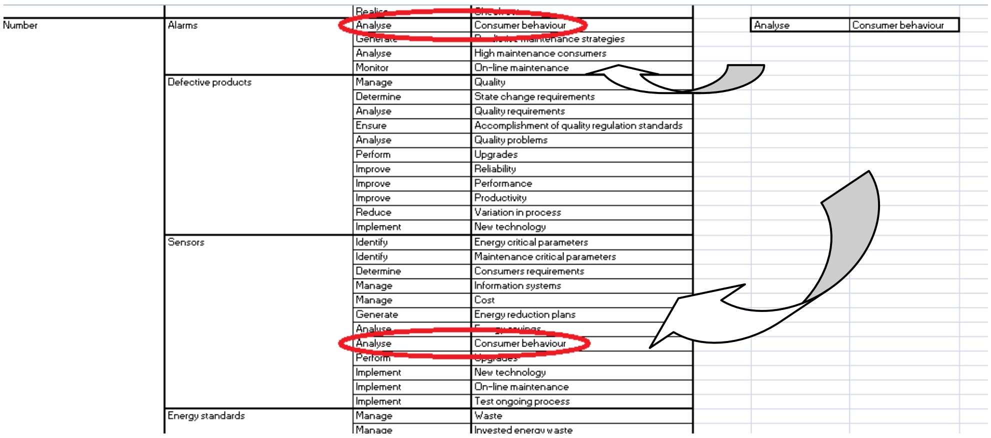

Figure 27*: Looking up tasks in the predefined table*

There is now just one thing left: the consumer. After the assignment it could be possible that a task related to consumer A is assigned with an objective related to consumer B. This error must be solved or the roles will be matched with wrong goals. In order to validate the matching process, every task-objective assignment must be filtered by the consumers. Every task and every objective have a consumer assigned that can be compared by following the energy consumption structure, resulting four different options:

- Task's consumer coincide with objective's consumer → Assignment OK
- Task's consumer contributes to the energy consumption of the objective's consumer → Assignment OK
- Objective's consumer contributes to the energy consumption of the task's consumer → Assignment OK
- Task's consumer and objective's consumer are in different branches → Assignment NOT OK

Once the assignment is filtered every role will have some tasks matched to some objectives. The role's objectives will be the sum of all the goals matched to all the tasks of the role. In addition, all roles are going to have the objective "maximise energy awareness of personnel" assigned.

These results can be better visualised if we reconstruct a hierarchy of objectives for each role.

4.2.4. Identifying and clustering information needs for each role

The needed information of every role for accomplishing the objectives must be identified with the purpose of defining indicators. This step is one of the most important. The needed information is the one related to the effects of our project activities; it is the information that has to be measured in order to evaluate the accomplishment of the objectives [Org-08].

Hopefully, with the definition of the objective the needed information has already been determined. The variable which has to be measured has already been defined and the specific company factor, too. In others words, the information need is equivalent to the objective. Hence the objectives definition is so important.

Clustering Information needs

The idea of grouping information needs is to allow the assessment of many individual actions to be narrowed down to a few key impacts and a small number of indicators. For example, a goal may contain separate actions (objectives) relating to research, advice, training and standards, all of which have a common impact. On this basis, one indicator can be selected to represent the common impact, rather than a separate indicator for each action. At the same time, the research, advice, training and standards actions may also have impacts in other areas, such as profitability, so this allows multiple effects to be assessed [Org-08].

In order to facilitate an automatic selection of the most important objectives for each role, the following rules have been established:

- The number of tasks that contribute to each objective is going to be counted
- The higher level junction of the role's hierarchy is going to be determined and selected as the final objective. The upper objectives are not going to influence in the selection.
- For all the different branches, one objective is going to be selected. The default goal selection will be the one with more tasks assigned. If there are more objectives with the same number of tasks, the higher level one will be selected.

These rules are based on the following arguments:

- The amount of tasks that contribute to an objective could be a sign of the importance of the objective. More reliable evidence could be found if the tasks were accompanied by priorities.
- The different objectives in every branch are supposed to have similar purposes.
- The higher junction is the objective where the different branches coincide. The upper goals are supposed to have a close relationship with it, but this one is more specific than the others ones.

This selection should be verified by the specific role and modified if he decides that the objectives selected are not the most relevant for him.

4.2.5. Defining indicators

Indicator must show the evidence that the expected changes are happening in reality, either on the social/environmental/economic side or on the business side and help to find out the expected and unexpected short-term and longer-term results. Indicators are an effective way to help to answer the question 'how does the role know…?' [Nef-09]

- …that the activities have happened?
- …that the immediate intended results are created?
- …that they are leading to longer-term change?
- …that these longer-term changes will help to reach the mission in the broader sense?

Once there are just a few objectives selected for each role, the indicators will be derived according to the role's profile. This step has not been developed as an automatic process, but it could be done. See more information about it in chapter 6.2. Critical Review.

For each objective of each role, a few indicators are going to be defined based on the Indicators' list provided, taking into account the role's tasks and following the methods explained in chapter General development of a Performance Measurement System.

The indicators' attributes were established based on the predefined list of indicators. The methodology has not been enough developed to fill all the attributes. Just the attributes "Indicator's title", "Formula", "Unit" and "Consumer" are going to be included.

Moreover all the roles will have a special indicator to measure "energy awareness of personnel" that represents the fulfilment of the role's energy related objectives.

Evaluation and selection of Performance Indicators

To select just the few more relevant indicators for each role, the indicators must be evaluated. The indicators must accomplish the requirements of our project and must be useful for a future application. There are two main factors for evaluating the relevant indicators:

1) Data requirements
   i) **Availability**: has the indicator ever been quantified or is data potentially available? If no data is, or ever can be, available, the value of the indicator is reduced. [Org-08]
   ii) **Freshness**: how soon after the relevant time period will the data become available? If the process of statistical data collection, analysis and reporting is slow, the data may not be available at an appropriate time to be useful for evaluation or subsequent policy decision-making. [Org-08]
2) Representation of the objective
   i) **Sensitivity**: how clearly does the indicator respond to any effects that might be generated by the project? If the effect is small, for example because the indicator is submerged by other, less relevant factors, then it may not show any effect. [Org-08]
   ii) **Accuracy**: how well does the indicator represent the objective?
   iii) **Accomplishing initial requirements**

These two criteria can be scored using a scale 0 to 3 (where 0 is no, 1 is low and 3 is high quality with respect to the criterion).

This step must be performed by the specific role, which will have enough knowledge to determine how well the indicator represents the objective. Furthermore, the responsible for information systems or data measurements should also complement the evaluation about the data requirements.

Once the evaluation is done, the most appropriate indicators can be selected, obtaining the final results of the methodology

Defining new PIs (when necessary)

After the evaluation maybe there are some indicators that cannot be measured, so perhaps it is necessary to define some new ones, but only if the resting indicators are not enough for the role´s objectives. There are two possible ways to define new indicators:

- Define other indicators that describe the same effect

- Select another effect and define some indicators for it

4.3. Automatic Version

The following figure shows the algorithm that should follow an automatic application of the methodology, focusing in the user's interaction with the methodology.

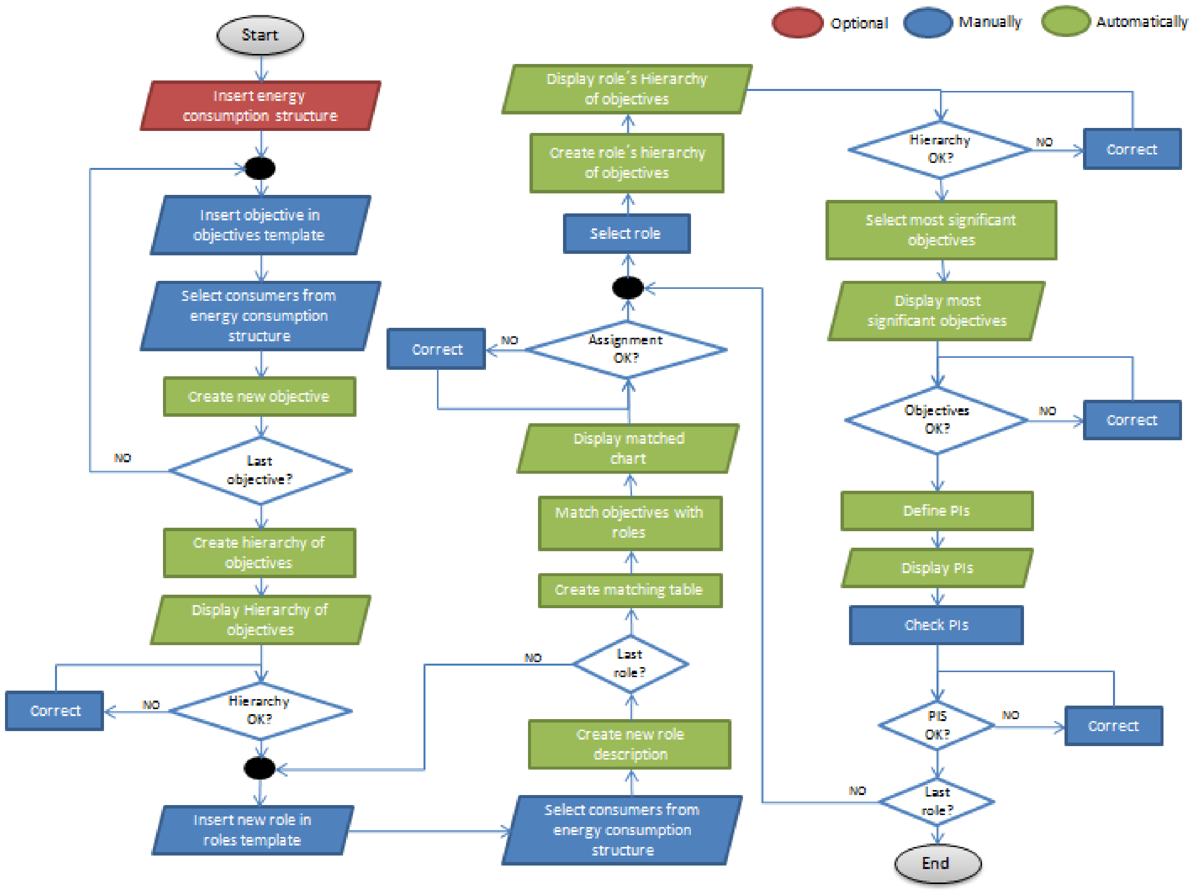

Figure 28: *Methodology's algorithm*

The green boxes represent the actions that should be automatically performed; the blue ones, the tasks that the application's user is responsible for. The insert of the energy structure is highlighted in red, because this step maybe is not necessary if the application can gain access directly to the data, as long as it already exists.

4.4. Data requirements

4.4.1. Methodology input data

Energy consumption structure

An energy consumption structure is needed to describe roles and objectives, and validate the assignment. For this reason, it should be the first thing to elaborate if it does not exist.

The energy consumption structure is a diagram which shows how all the different consumers contribute to the total consumption of the factory.

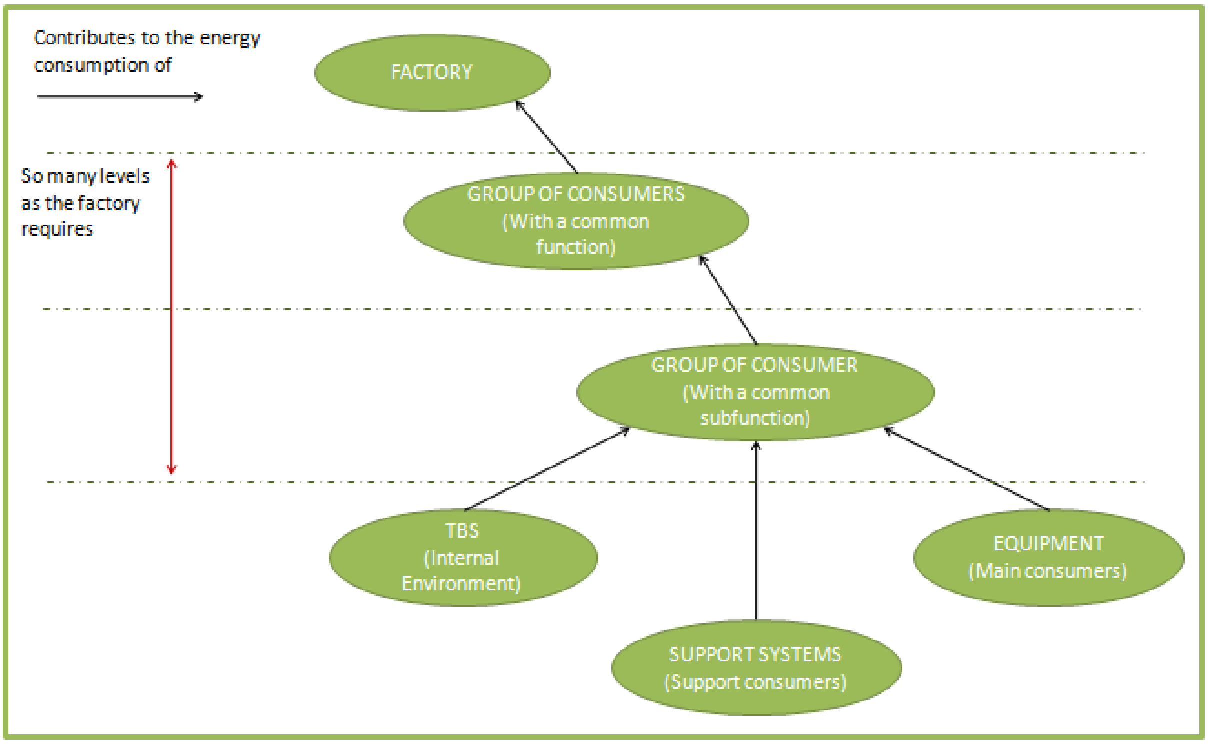

Figure 29: *Energy consumption structure*

The higher level of the structure is the factory consumption. This consumption can be divided in several groups of consumer with different purposes. For example, a factory could be divided in different lines which produce different products. Every group of consumers could be divided into more specific groups of consumers depending on the factory structure. A final level should be determined, where different consumers contribute to perform a function. These consumers could be classified in Technical Building Services (HVAC, lights, etc.), support systems (cutting fluid system, compressed air system, etc.) and equipment (machines which perform the main activities).

Moreover it should be specified whether the consumers can be switched off alone or not.

4.4.2. Indicators' Data

This thesis has not gone in depth into data issues. Anyway, some global facts have been studied.

Data sources

The data needed to quantify or describe the selected indicators may be derived from a range of sources, including documents relating to the programme, interviews with key stakeholders, administrative (monitoring) data, specially commissioned surveys and research. General statistics or research literature will also provide contextual data [Org-08].

However, it is important that, where possible, the indicators and systems for data collection are established from the outset, so that baseline data can be obtained to allow changes to be assessed. *Ex-post* evaluation, in the absence of such advance planning, will be limited to only variables for which data happens to be available and may therefore be seriously limited in scope. New indicators may require new or innovative data collection methods, so that indicators are not limited to data that is collected currently or historically [Org-08].

The data requirements for the construction of energy efficiency indicators vary according to the depth of analysis. As more detailed and comprehensive analysis is conducted, the data requirements also increase [Asi-00].

Imperfections in the quality of the data set can sometimes be improved through careful adjustments. Most often these adjustments aim to account for external influences that result in biased data, and remove these effects either from the data set, or the calculation of the energy efficiency indicator [Asi-00].

Data Measurement

Data consistency relates to the way in which the data is measured, and is required to ensure that energy efficiency indicators are comparable. When data is collected as a series (over a period of time) the methodologies should not change [Asi-00].

The temporal scale at which the indicator has to be measured and at which it will be used for decision-making and evaluation, need to be considered. For each indicator, the scale of measurement must be compared with the scale at which the evaluation or decision is being made. Temporal scales need to be considered similarly [Org-08].

A final requirement of the indicator's data is that it has to be validated. Data validation is particularly important to ensure the accuracy of the energy indicators, and also serves as a useful error checking mechanism [Asi-00]. Steps should be taken to ensure data gathered is reliable. For example, sample checks could verify the data.

The usefulness and effectiveness with which energy indicators can be used is subject to a number of stipulations, particularly in relation to the availability and quality of data [Asi-00]. Starting from afresh, it will be necessary to collect a minimum of one year's consumption data before any meaningful global comparisons on energy performance can be made. However, monitoring of the EPIs generated is an ongoing process [SEA].

Data description

The following data table can be used for assessing the quality of indicator's data [Org-08]:

A. *Technical information*
   1. Data source
   2. Description of data
   3. Consumer
   4. Temporal coverage
   5. Methodology and frequency of data collection
   6. Methodology of data manipulation

B. *Quality information*
   7. Strength and weakness
   8. Reliability, accuracy, robustness, uncertainty
   9. Comparability over time

5. Application

The methodology explained in the previous chapter was applied for an automotive industry use case. Previously, the use case was analysed in depth in order to understand the most important issues and find the missing information.

Regretfully the methodology could not be applied in the best way because no roles were involved and the knowledge of the use case was not accurate enough. The application should be carried out by the runners of the project, but it was not possible.

Furthermore, an energy consumption structure could not be developed because of missing information. Hence the consumer-filter in the assignment of objectives to roles could not be done automatically, but manually. Nevertheless, the relevant consumers for the use case were classified in order to achieve the assignment of roles and objectives.

Energy consumption structure						
Factory	Group of consumer with a common function	Group of consumers with a common subfunction		Consumers	Equipment/Support/TBS	switchable with
Factory	Machining line	Cutting fluid structure	Pumps	Missing	Support	Missing
		HVAC structure	Missing	Missing	TBS	Missing
		Light structure	Missing	Missing	TBS	Missing
		Washing machines		WM1	Equipment	Missing
				WM2	Equipment	Missing

Table 6: *Use case energy consumption*

5.1. Developing a hierarchy of objectives

The first step of the methodology is to define the vision, mission and scope of our project. It is not possible to determine the vision and mission because the driving force behind the project is not involved in the application. By the same token, the hierarchy of objectives is not developed.

However, the scope of the application can be defined:

Scope: Cylinder head machining line of the use case's factory

The general energy related hierarchy is modified in the following way based on the use case information.

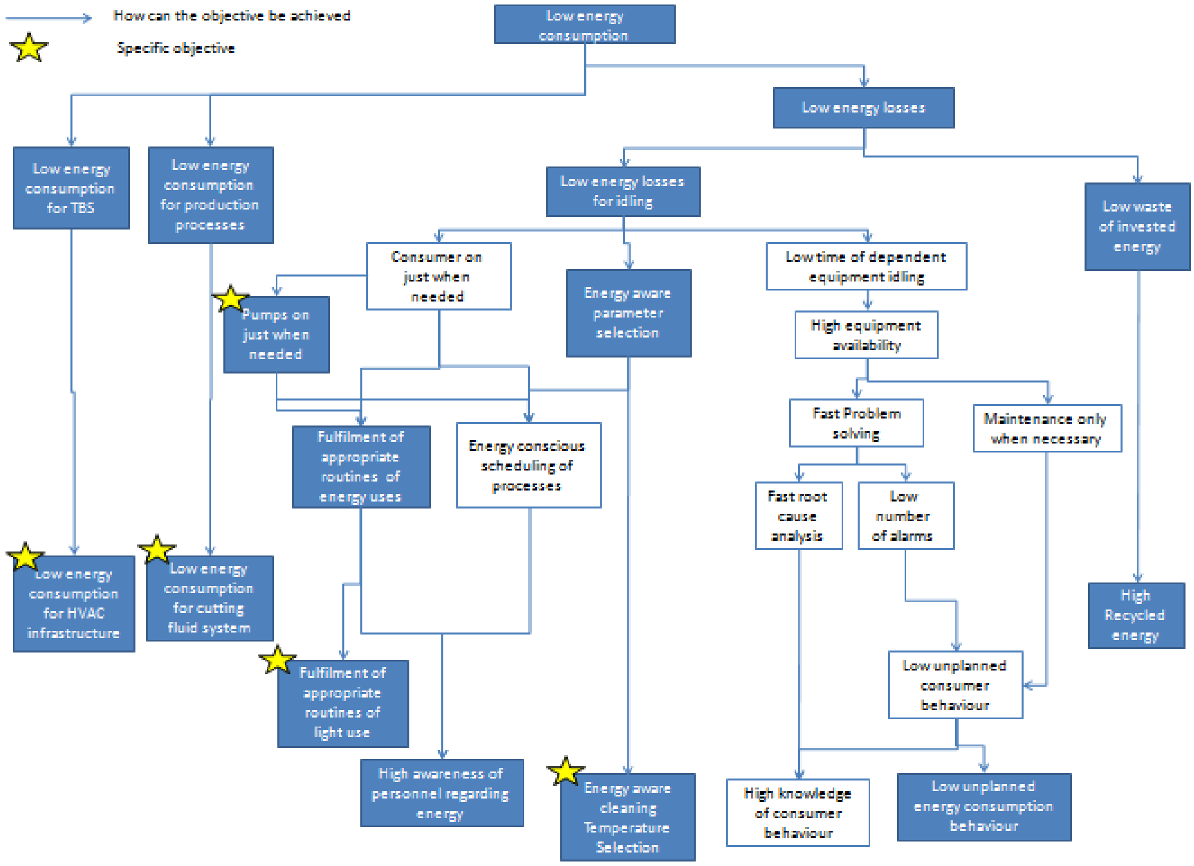

Figure 30: *Specific Hierarchy of objective according to Use Case*

Basically, the use case is focused in the reduction of energy consumption. Therefore just the relevant objectives are selected. Some objectives are moved from one branch to another, specifically, “energy aware parameter selection” due to the use case’s requirements. Moreover sub-objectives are added, which are highlighted with a yellow star.

Once the hierarchy is developed, the objectives' template is filled with all the goals.

Objectives					
Action	Variable	Factory factor	Number	Contributes to	Consumer
Minimise	Energy consumption	Factory	1		Machining line
Minimise	Energy consumption	Losses	2	1	Machining line
Minimise	Energy consumption	Idling	3	2	Machining line
Minimise	Energy consumption	Production	4	1	Support systems/Equipment
Minimise	Waste	Invested energy	5	2	Machining line
Minimise	Time	Idling	6	3	Machining line
Minimise	Time	Dependent consumers idling	7	3	Machining line
Maximise	Energy awareness	Parameter selection	8	3	Machining line
Maximise	Energy awareness	Consumer's plan	9	6 8 25	Machining line
Maximise	Energy awareness	Consumer's use routine	10	6	Machining line
Maximise	Energy awareness	Personnel	11	9 10	Machining line
Maximise	Time	Consumers availability	12	7	Machining line
Minimise	Time	Problem solving	13	12	Machining line
Minimise	Time	Maintenance	14	12	Machining line
Minimise	Time	Problem root analysis	15	13	Machining line
Minimise	Number	Alarms	16	13	Machining line
Maximise	Accuracy	Planned consumers behaviour	17	14 16	Machining line
Maximise	Accuracy	Planned energy consumption behaviour	18	17	Machining line
Maximise	Recycling	Invested energy	19	5	Machining line
Maximise	Knowledge	Consumers behaviour	20	15 17	Machining line
Minimise	Energy consumption	Technical Building Services	21	1	TBS
Minimise	Energy consumption	Production	22	4	Cutting fluid structure
Maximise	Energy awareness	Consumer's use routine	23	10	Light structure
Minimise	Energy consumption	Technical Building Services	24	21	HVAC structure
Maximise	Energy awareness	Parameter selection Cleaning Temperature selection	25	8	Washing machines
Minimise	Time	Idling	26	6	Pumps

Table 7: *Use case's objectives' templates*

The new sub-objectives are added in dark blue. These objectives have to be defined in the same way as the general objectives. If it is not possible the objective must be modified until an appropriate definition is found.

The column "consumers" is highlighted as a supposition because it was not possible to find precise information about it. This supposition must be done to follow the methodology steps or the assignment will not be possible.

5.2. Analysing roles

The roles of the use case must be introduced in the roles template. To describe a role we need to define a title that can be used as identification. Furthermore, some according tasks from the general tasks' list are selected. No new task is going to be added.

Role	Main tasks around energy consumers		
	Action	Object	Consumer
Maintenance engineer	Perform	Manual Maintenance	Machining line
	Analyse	High maintenance consumers	Machining line
	Determine	State transition	Machining line
	Determine	Faults diagnosis	Machining line
	Analyse	Problem root	Machining line
	Realise	Check out	Machining line
Department manager	Monitor	Energy consumption	Machining line
	Generate	Production run plan	Machining line
	Generate	Maintenance plan	Machining line
	Determine	Production available time	Machining line
	Manage	Waste	Machining line
	Monitor	Production run plan	Machining line
Shift Leader	Determine	State transition	Machining line
	Manage	Quality	Machining line
	Manage	Safety	Machining line
	Generate	Specific run plan tasks	Machining line
Production Engineer	Monitor	Production uniformity	Machining line
	Monitor	Production run plan	Machining line
	Provide	Technical assistance	Machining line
Team Leader			Machining line
Mechanic	Perform	Manual Maintenance	Machining line
Electrician	Perform	Manual Maintenance	Machining line
Production planner	Generate	Production run plan	Machining line
	Generate	Maintenance plan	Machining line
	Coordinate	All Planning	Machining line
	Determine	Production available time	Machining line
	Identify	High consuming consumer	Machining line
	Monitor	Energy consumption	Machining line
Operator	Perform	Operating	Equipment
	Perform	Set up	Equipment
	Perform	Stand by	Equipment

Table 8: *Use case's roles' template*

The consumer's column is again highlighted because it is also a supposition.

The role “team leader” has not selected any task, so it can’t be assigned to any objective.

5.3. Assigning roles to objectives

The assignment is supposed to be automatically, and that is the reason why the objective’s definition is so important to achieve an appropriate matching.

The results of this step are some objectives assigned to each role’s task.

Role Description	Main tasks around energy consumers			Assignment							
Role	**Action**	**Object**	**Consumer**								
Maintenance engineer	Perform	Manual Maintenance	Machining line	1	2	7	12	13	10	0	0
	Analyse	High maintenance consumers	Machining line	7	12	13	15	14	16	20	17
	Determine	State transition	Machining line	1	2	3	6	10	0	0	0
	Determine	Faults diagnosis	Machining line	7	12	13	15	0	0	0	0
	Analyse	Problem root	Machining line	7	12	13	15	0	0	0	0
	Realise	Check out	Machining line	1	2	7	12	13	10	0	0
Department manager	Monitor	Energy consumption	Machining line	1	2	3	4	21	0	0	0
	Generate	Production run plan	Machining line	9	0	0	0	0	0	0	0
	Generate	Maintenance plan	Machining line	7	12	14	9	17	0	0	0
	Determine	Production available time	Machining line	9	0	0	0	0	0	0	0
	Manage	Personnel	Machining line	11	0	0	0	0	0	0	0
	Manage	Waste	Machining line	2	5	19	0	0	0	0	0
	Monitor	Production run plan	Machining line	9	17	0	0	0	0	0	0
Shift Leader	Determine	State transition	Machining line	1	2	3	6	10	0	0	0
	Manage	Quality	Machining line	0	0	0	0	0	0	0	0
	Manage	Safety	Machining line	0	0	0	0	0	0	0	0
	Generate	Specific run plan tasks	Machining line	3	6	7	12	9	0	0	0
Production Engineer	Monitor	Production uniformity	Machining line	0	0	0	0	0	0	0	0
	Monitor	Production run plan	Machining line	9	17	0	0	0	0	0	0
	Provide	Technical assistance	Machining line	13	15	20	0	0	0	0	0
Team Leader	Manage	Personnel	Machining line	0	0	0	0	0	0	0	0
Mechanic	Perform	Manual Maintenance	Machining line	1	2	7	12	13	10	0	0
Electrician	Perform	Manual Maintenance	Machining line	1	2	7	12	13	10	0	0
Production planner	Generate	Production run plan	Machining line	9	0	0	0	0	0	0	0
	Generate	Maintenance plan	Machining line	7	12	14	9	17	0	0	0
	Coordinate	All Planning	Machining line	9	0	0	0	0	0	0	0
	Determine	Production available time	Machining line	9	0	0	0	0	0	0	0
	Identify	High consuming consumer	Machining line	1	2	4	20	18	0	0	0
	Monitor	Energy consumption	Machining line	1	2	3	4	21	0	0	0
Operator	Perform	Operating	Equipment	1	2	3	4	6	10	0	0
	Perform	Set up	Equipment	1	2	3	4	6	10	0	0
	Perform	Stand by	Equipment	1	2	3	4	6	10	0	0

Table 9: *Assignment*

Highlighted in yellow in table 9, one can see all the objectives assigned to the tasks.

The results can also be displayed as a table or hierarchy of objectives for each role. The following chapters show just the results for the role "maintenance engineer." See 8.3. Appendix 3: Explanation of the attached Excel file "UseCaseApplication" and 8.4. Appendix 4: Roles' Hierarchy of objectives to find the other roles' assignments.

Objectives					
Action	Variable	Factory factor	Number	Contributes to	Consumer
Minimise	Energy consumption	Factory	1	0	Machining line
Minimise	Energy consumption	Losses	2	1	Machining line
Minimise	Energy consumption	Idling	3	2	Machining line
Minimise	Time	Idling	6	3	Machining line
Minimise	Time	Dependent consumers idling	7	3	Machining line
Maximise	Energy awareness	Consumer's use routine	10	6	Machining line
Maximise	Energy awareness	Personnel	11	9 10	Machining line
Maximise	Time	Consumers availability	12	7	Machining line
Minimise	Time	Problem solving	13	12	Machining line
Minimise	Time	Maintenance	14	12	Machining line
Minimise	Time	Problem root analysis	15	13	Machining line
Minimise	Number	Alarms	16	13	Machining line
Maximise	Accuracy	Planned consumers behaviour	17	14 16	Machining line
Maximise	Knowledge	Consumers behaviour	20	15 17	Machining line
Maximise	Energy awareness	Consumer's use routine	23	10	Light structure
Minimise	Time	Idling	26	6	Pumps

Tabla 10: ***Maintenance engineer's objectives***

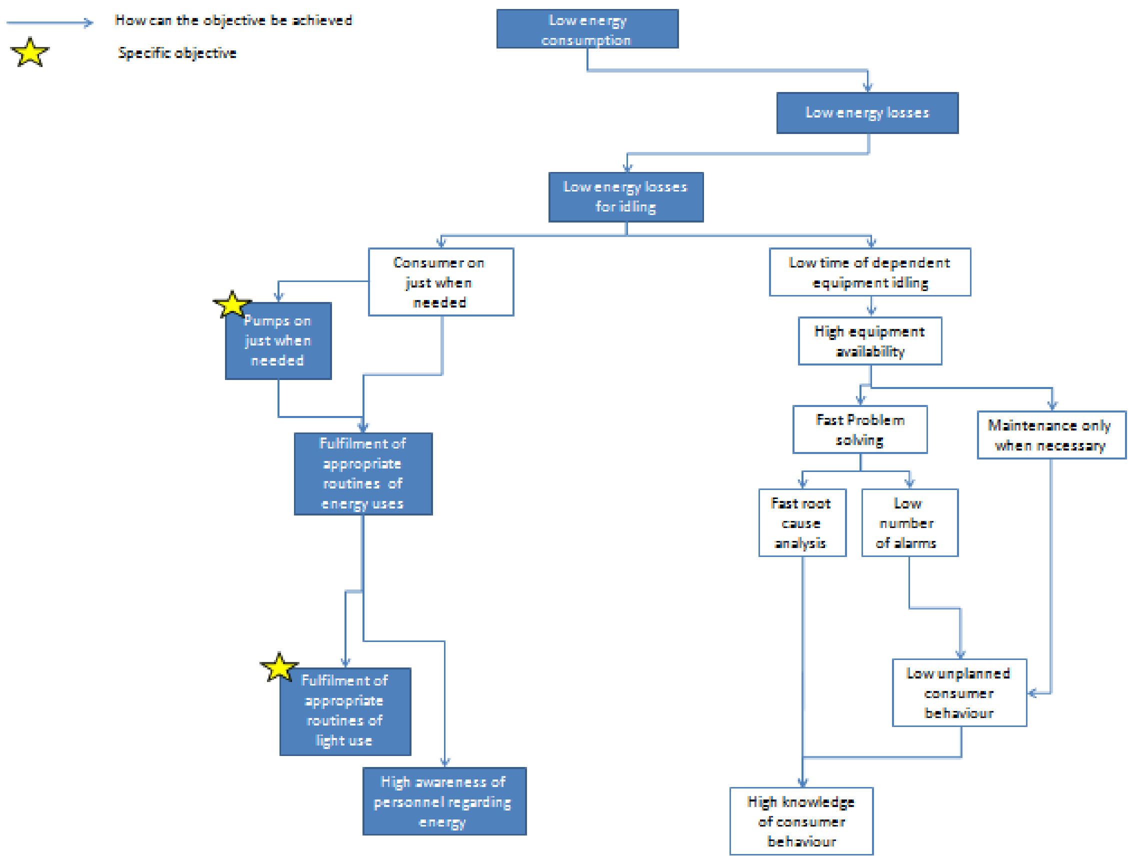

Figure 31: *Maintenance engineer's hierarchy of objectives*

5.5.1. First conclusions

At this point one can assume the first conclusions: Is there any objective with no role assigned? Is there any role with no objectives assigned?

In this application we have found an objective, and its sub-objective, which have not been matched: "maximise energy awareness of parameter selection." In the other hand, the role "team leader" has logically no objective assigned because it has not selected any task. The roles "mechanic" and "electrician" seem to perform exactly the same tasks, so from now on they are going to be considered as the same role.

However, this assignment cannot be validated due to the fact that all the consumers have been supposed.

5.4. Identifying and clustering information needs for each role

The selection of objectives is also automatic, following the clustering rules. For the role "maintenance engineer" the following objectives are selected:

Objectives						
Action	Variable	Factory factor	Number	Contributes to	Consumer	Contributing tasks
Minimise	Energy consumption	Factory	1	0	Machining line	3
Minimise	Energy consumption	Losses	2	1	Machining line	3
Minimise	**Energy consumption**	**Idling**	3	2	Machining line	1
Minimise	Time	Idling	6	3	Machining line	1
Minimise	**Time**	**Dependent consumers idling**	7	3	Machining line	**5**
Maximise	**Energy awareness**	**Consumer's use routine**	10	6	Machining line	**3**
Maximise	Energy awareness	Personnel	11	9 10	Machining line	1
Maximise	**Time**	**Consumers availability**	12	7	Machining line	**5**
Minimise	Time	Problem solving	13	12	Machining line	4
Minimise	Time	Maintenance	14	12	Machining line	1
Minimise	Time	Problem root analysis	15	13	Machining line	3
Minimise	Number	Alarms	16	13	Machining line	1
Maximise	Accuracy	Planned consumers behaviour	17	14 16	Machining line	1
Maximise	Knowledge	Consumers behaviour	20	15 17	Machining line	1
Maximise	**Energy awareness**	**Consumer's use routine**	23	10	Light structure	**3**
Minimise	Time	Idling	26	6	Pumps	1

Tabla 11: *Maintenance engineer's objectives' selection*

The objective highlighted in yellow represents the higher junction. The different colours represent the different branches of the objectives' hierarchy. In bold letters the objectives with more tasks are emphasised. The default selection brings out the higher objective with more tasks in every branch.

In this case, the application's author has decided to change the selected goal of the red branch for the second possibility, having as a result the following selection:

Objectives						
Action	Variable	Factory factor	Number	Contributes to	Consumer	Contributing tasks
Minimise	Energy consumption	Factory	1	0	Machining line	3
Minimise	Energy consumption	Losses	2	1	Machining line	3
Minimise	**Energy consumption**	**Idling**	3	2	Machining line	1
Minimise	Time	Idling	6	3	Machining line	1
Minimise	**Time**	**Dependent consumers idling**	7	3	Machining line	**5**
Maximise	**Energy awareness**	**Consumer's use routine**	10	6	Machining line	**3**
Maximise	Energy awareness	Personnel	11	9 10	Machining line	1
Maximise	**Time**	**Consumers availability**	12	7	Machining line	**5**
Minimise	Time	Problem solving	13	12	Machining line	4
Minimise	Time	Maintenance	14	12	Machining line	1
Minimise	Time	Problem root analysis	15	13	Machining line	3
Minimise	Number	Alarms	16	13	Machining line	1
Maximise	Accuracy	Planned consumers behaviour	17	14 16	Machining line	1
Maximise	Knowledge	Consumers behaviour	20	15 17	Machining line	1
Maximise	**Energy awareness**	**Consumer's use routine**	23	10	Light structure	**3**
Minimise	Time	Idling	26	6	Pumps	1

Table 12: *Maintenance engineer's modification*

5.5. Defining indicators

A few indicators are defined for each selected objective of each role. Every colour represents the different selected objectives. The indicators are based on the given proposal set mentioned in, although some new ones have been added.

Indicator	Formula	Units	Consumer
Idling energy	Idling energy consumption	Kwh	Machining line/pumps
Idling losses	Energy consumption – not idling energy consumption	Kwh	Machining line/pumps
% idling energy	Idling energy consumption/total energy consumption*100	dimensionless	Machining line/pumps
%losses for idling	Idling energy consumption/non value adding energy consumption*100	dimensionless	Machining line/pumps
ON/OFF routines efficiency	Consumer needed energy consumption/Energy consumption*100	dimensionless	Machining line/light structure
Maintenance energy routines efficiency	Ideal energy consumption for maintenance/total energy consumption for maintenance*100	dimensionless	Machining line
%Maintenance process consumption	Energy consumption for maintenance process/energy consumption for maintenance*100	dimensionless	Machining line
%Consumer consumption meanwhile maintenance	Consumer energy consumption meanwhile maintenance/total consumer consumption*100	dimensionless	Machining line
Consumer dependent idling consumption	Consumer energy consumption meanwhile maintenance/consumer idling consumption *100	dimensionless	Machining line

Table 13*: Maintenance engineer' indicators*

These indicators must be evaluated so that the few more relevant can be selected. It is not possible to evaluate the viability of the data measurement. Hence, the indicators are just selected according to how well they describe the objective.

The term "ideal" is equivalent to "best practice".

Please note that the evaluation process is done under the author's criteria and not the specific role, who is the one that have the adequate knowledge.

The final results, which show a few indicators for each role, are shown in the table below:

Role	Indicator	Formula	Unit	Consumer
Maintenance engineer	% idling energy	Idling energy consumption/total energy consumption*100	dimensionless	Machining line/pumps
	Maintenance energy routines efficiency	Ideal energy consumption for maintenance/total energy consumption for maintenance*100	dimensionless	Machining line
	%Consumer consumption meanwhile maintenance	Consumers energy consumption meanwhile maintenance/total consumer consumption*100	dimensionless	Machining line
Department manager	Consumers energy consumption	Energy consumption	Kwh	Factory
	Consumers specific consumption	Energy consumption/amount of products produced	Kwh/unit	Factory/Machining line/support systems/Equipment
	%Energy consumption per group of consumers	Group of consumers' energy consumption/total factory energy consumption*100	dimensionless	Machining line/support systems/Equipment/TBS
	%Recycled energy losses	Recycled energy/energy losses*100	dimensionless	Factory/Machining line
	Planned energy accuracy	Planned energy consumption/energy consumption*100	dimensionless	Factory/Machining line/Support systems/Equipment
	Planning energy awareness	Energy data used for planning/all data used for planning*100	dimensionless	Factory/Machining line/Support systems/Equipment
Shift leader	% idling energy	Idling energy consumption/total energy consumption*100	dimensionless	Machining line/pumps
Production engineer	Consumers consumption meanwhile problem solving	Consumers energy consumption meanwhile problem solving	Kwh	Machining line
Mechanic/ Electrician	Maintenance energy routines efficiency	Ideal energy consumption for maintenance/total energy consumption for maintenance*100	dimensionless	Machining line
	%Consumer consumption meanwhile maintenance	Consumers energy consumption meanwhile maintenance/total consumer consumption*100	Kwh	Machining line
Production planner	Consumers specific consumption	Energy consumption/amount of products produced	Kwh/unit	Factory/Machining line/support systems/Equipment
	%Energy consumption per group of consumers	Group of consumers' energy consumption/total factory energy consumption*100	dimensionless	Machining line/support systems/Equipment/TBS
	% idling energy	Idling energy consumption/total energy consumption*100	dimensionless	Machining line
	Planning energy awareness	Energy data used for planning/all data used for planning*100	dimensionless	Factory/Machining line/Support systems/Equipment
	Planned energy accuracy	Planned energy consumption/energy consumption*100	dimensionless	Factory/Machining line/Support systems/Equipment
Operator	Consumer energy efficiency	consumer ideal energy consumption/ consumer energy consumption*100	dimensionless	Equipment
	Specific energy consumption per production hour	energy consumption/production hours	kwh/ production h	Equipment
All Roles	Fulfilment of energy objectives	fulfilled energy related objectives/energy related objectives	dimensionless	Roles

Table 14: ***Final indicators for each role***

5.6. Application's conclusion

At this point an assessment of the application use case can be done. Before analysing the application's results two main facts should be stressed:

- The application was not performed by the specific role, but by the author. This might lead to wrong selections or suppositions because of lack of knowledge of the specific role's tasks and responsibilities.
- The application was conducted with the available use case's information. Gaps or contradictions could not be checked.

The main repercussion of not involving roles during the application was that the checking and modification of the objectives' selection was conducted by the author who maybe has not done the best choice. In the same way, the indicators were also selected by the author. Moreover, the indicators were not supervised by the responsible for the measurement, so it is not definitive that they are cost-effective.

Some more problems were derived from missing information:

- The specific hierarchy of objectives was not checked by the use case partners. All the results are based on this hierarchy, thus if something is not right it will influence all the results.
- The specific consumers could not be specified, so the tasks and objectives' consumers were supposed. This fact implies that the assignment is not really reliable because the consumer filter was supposed. It is possible that a task related to the equipment has been matched with an objective that is just influenced by the support systems.
- The objective "maximise energy awareness of parameter selection" and its sub-object have not been matched. The main reason is that there was no task related to the goal in the roles description, so it could not be assigned.
- The role "team leader" has not been assigned because there are no relevant tasks around consumers in its description.
- The roles "mechanic" and "electricians" have the same tasks in their description so they have been considered as the same role, although that they probably are in charge of different tasks.

However, a final set of indicators has been defined. It cannot be determined whether the results are useful or not for the use case, but they seem to accomplish the established requirements. The different roles have different indicators influenced by their specific tasks. For example, the "department manager" and the "production planner" have more high level and planning indicators, whereas the "operator" or the "maintenance engineer's" indicators are more related to performance and energy use.

In order to improve the current indicators, it would be necessary to look for the missing information mentioned before and to involve the specific roles.

6. Conclusion

In this thesis a methodology for defining a role specific set of energy related indicators was developed considering the state of the art challenges. The methodology was designed in order to permit a future automatic application for computer science. Regretfully all the steps do not accomplish this requirements due to time limitations, so it would be necessary to invest more effort in the methodology in order to improve and check the current gaps.

Despite the limitations, the methodology introduces a new concept of Performance Measurement System combining energy related indicators with roles specific indicators, which facilitate decision-making and measure performance. Furthermore, it ensures that the roles' objectives are aligned with the company's main goals.

The methodology development includes some additional deliverables:

- List of predefined general energy related objectives
- List of general tasks around consumers
- Table of general tasks assigned to general energy related objectives
- Objectives' template
- Roles' template

Finally the methodology was applied considering a specific use case in the automotive industry. The main difficulties of the application were the lack of reliable information and of roles' involvement, although that some acceptable indicators were defined.

In the following, a critical review about the methodology is given by the author. Afterwards, an outlook is provided regarding the next steps for the actual implementation in a company and the necessary adaptations.

6.2. Critical Review

The methodology and its automatic application present some potential improvements.

6.2.1. Methodology Critical Review

The current methodology presents the following gaps:

- There is a need to define a properly formalised energy consumption structure, which accomplish the requirements mentioned in chapter 4.4.1. Methodology input data. It would be useful if the structure also included energy carriers for each consumer, to determine more accurate indicators.
- It is not possible to include completely new objectives or tasks due to matching problems. This fact delimits the scope of the possible applications.
- The tasks' template should be modified including two extra fields "Importance" and "Frequency". The "Importance" column would make possible to insert some priorities within the tasks in order to achieve a more accurate objectives selection for each role once the assignment is done. Moreover, an additional "Frequency" field, which describes how often every task is performed, would help to define the indicator's attributes.

- The indicator's definition is not complete enough. It could present two extra fields "Period" that should be related with the new field "Frequency" of the roles' template; and "Energy carrier" that would be related with the energy consumption structure.
- A final step is missing: to determine specific targets for each objective. Without targets the indicators are meaningless.

6.2.2. Automatic Application Critical Review

In terms of a future automatic application, the methodology should be carefully revised in the following steps.

- The possible addition of new objectives and tasks should be studied to increase the scope of the application.
- The assignment process was done in Excel which is not the best program for this type of applications.
- The energy consumption structure should be also included automatically in the assignment.
- The derivation of the indicators was not prepared for an automatic application, although it could be possible. The author proposes to assign to all the predefined objectives a list of a few predefined indicators (which could be relevant for the objective measurement). These indicators could be adapted by means of specifying the attributes.
  Once the step "clustering information needs" is done for the roles, with a few objectives selected as a result, the predefined indicators will also appear. Each role could choose which indicators of the list are the most suitable for its tasks
- The visualisation of the different steps and results will be very important to facilitate the understanding and the performance of the application.

6.3. Implementation within a use case

A methodology to develop a specific roles' set of energy related indicators has been designed. To guarantee a feasible implementation the following requirements should be accomplished:

- The specific hierarchy of objective should be carefully developed and evaluated. Afterwards, the definition of the objectives in the "objectives' template" must be reflect.
- The energy consumption structure must be provided
- The roles' description must be detailed enough to ensure a successful matching
- The specific roles have to be involved in the indicators definition. This is the most important requirement. The specific roles are the ones that have a higher knowledge about their own tasks and responsibilities. They are the ones that can offer a better roles' description selecting the appropriate tasks and afterward the indicators. They can also check and modify the results. Furthermore, the roles would be more motivated and more committed to accomplish the objectives.
- A higher manager should be also involved, to ensure that the assignment of objectives is aligned with the company main goals
- The responsible for the data measurements should determine the feasibility of the indicators.

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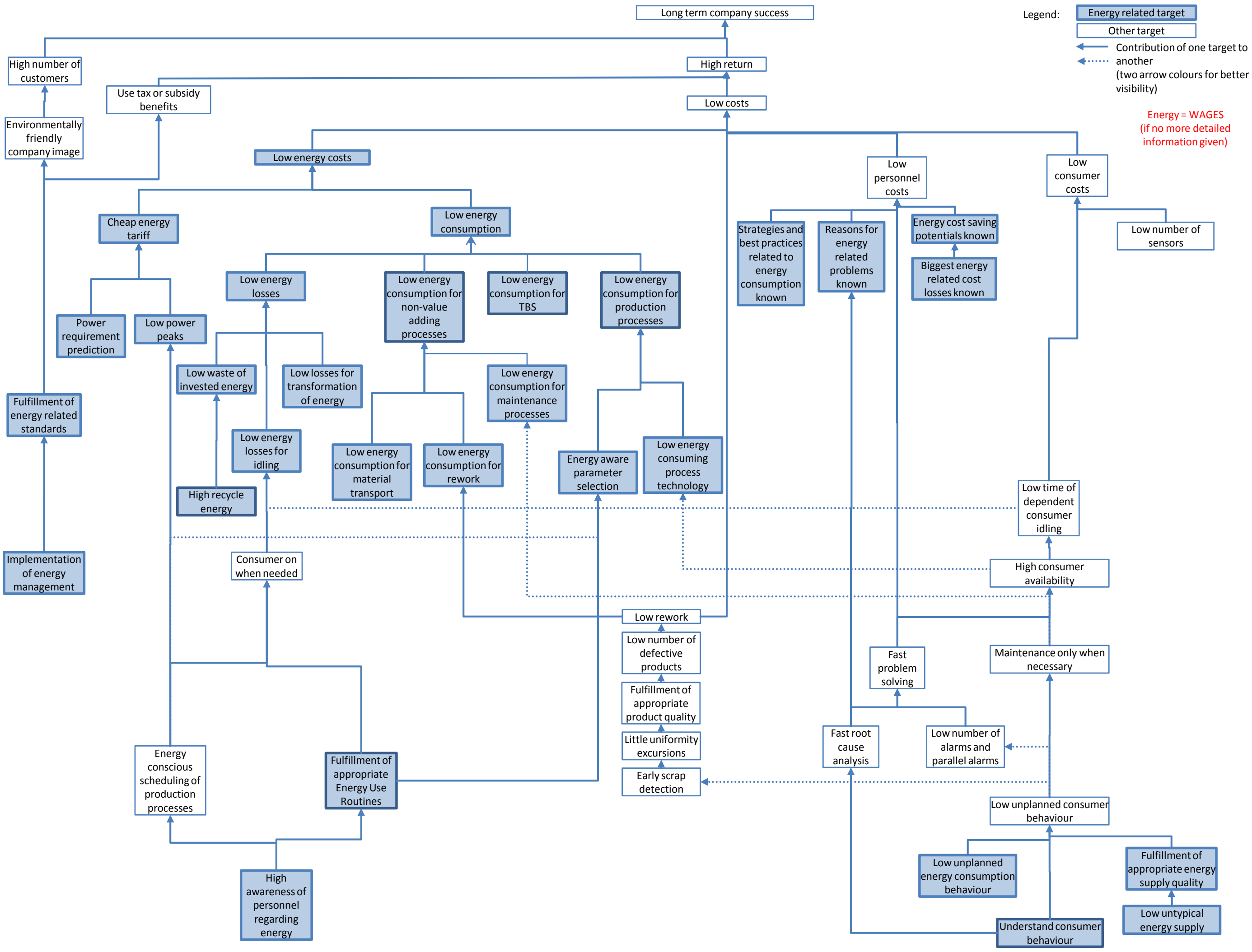
8. Appendixes

8.1. Appendix 1: Energy related Hierarchy



8.2. Appendix 2: Explanation of the attached Excel file “GeneralData”

The Excel file “**GeneralData**” includes all the data and tables required to perform an application following the methodology.

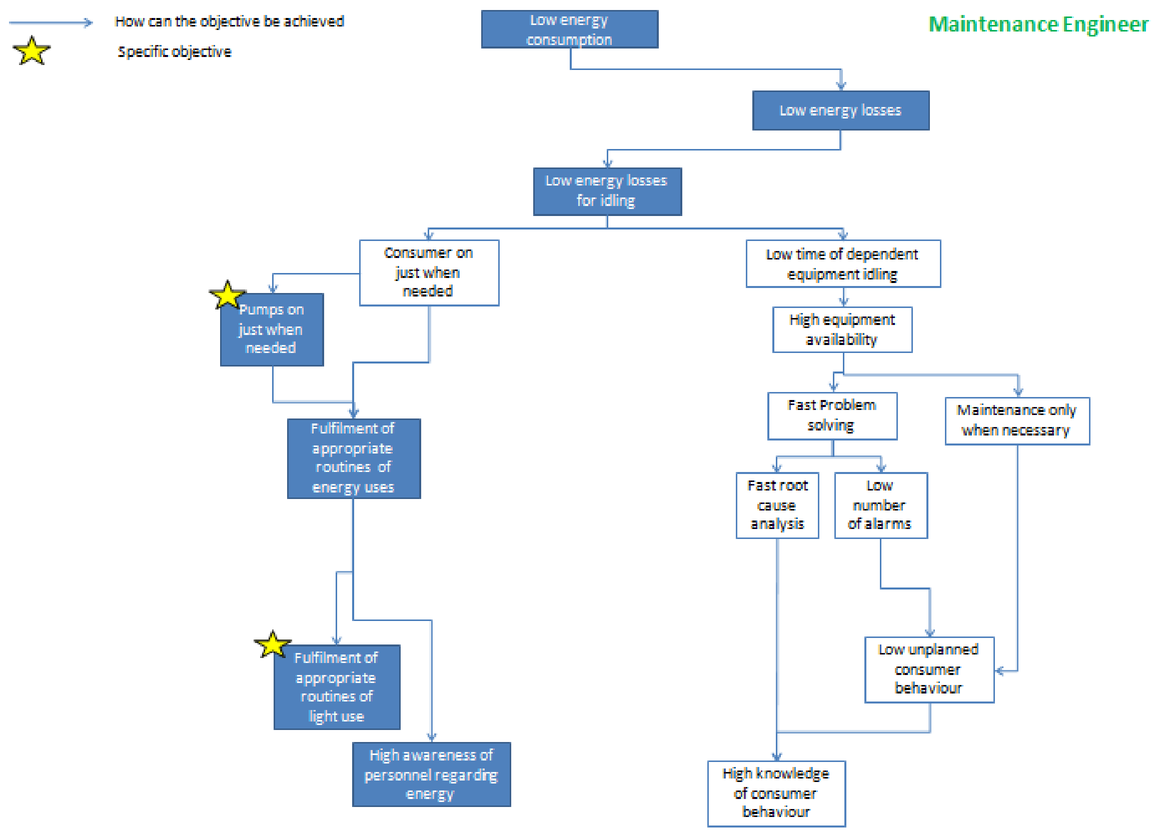
- In the tab “**Objectives**” one can find the formal definition of all the objectives or the general energy related hierarchy.
- The tab “**Taskslist**” contains all the considered tasks around consumers.
- The tab “**Tasks-Objectives**” includes the predefined matching of tasks from the “Taskslist” with the objectives from “Objectives”
- Tab “**Objectives template**” is the template where the objectives of future applications should be defined.
- In tab “**Roles template**” one can find the roles’ template where the future roles’ descriptions will be introduced.

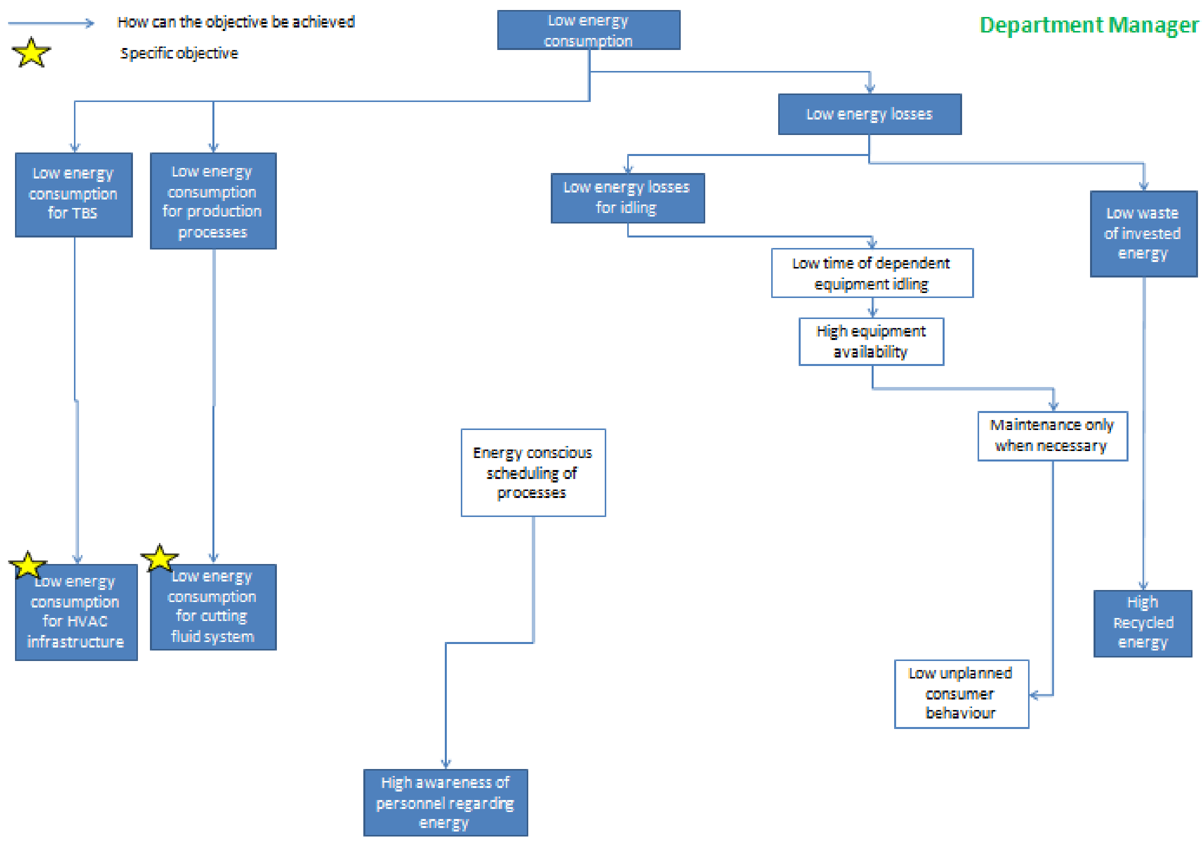
8.3. Appendix 3: Explanation of the attached Excel file “UseCaseApplication”

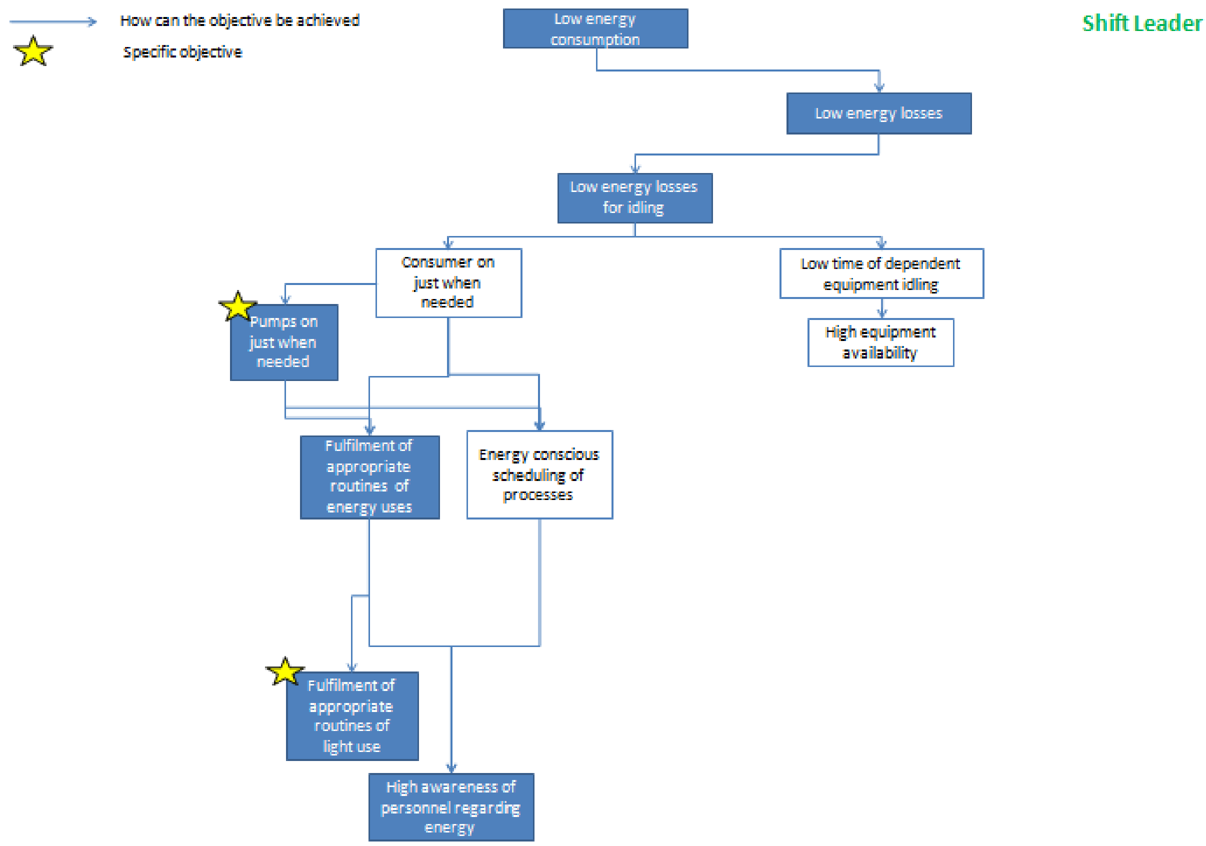
The Excel file “**UseCaseApplication**” contains all the application’s steps.

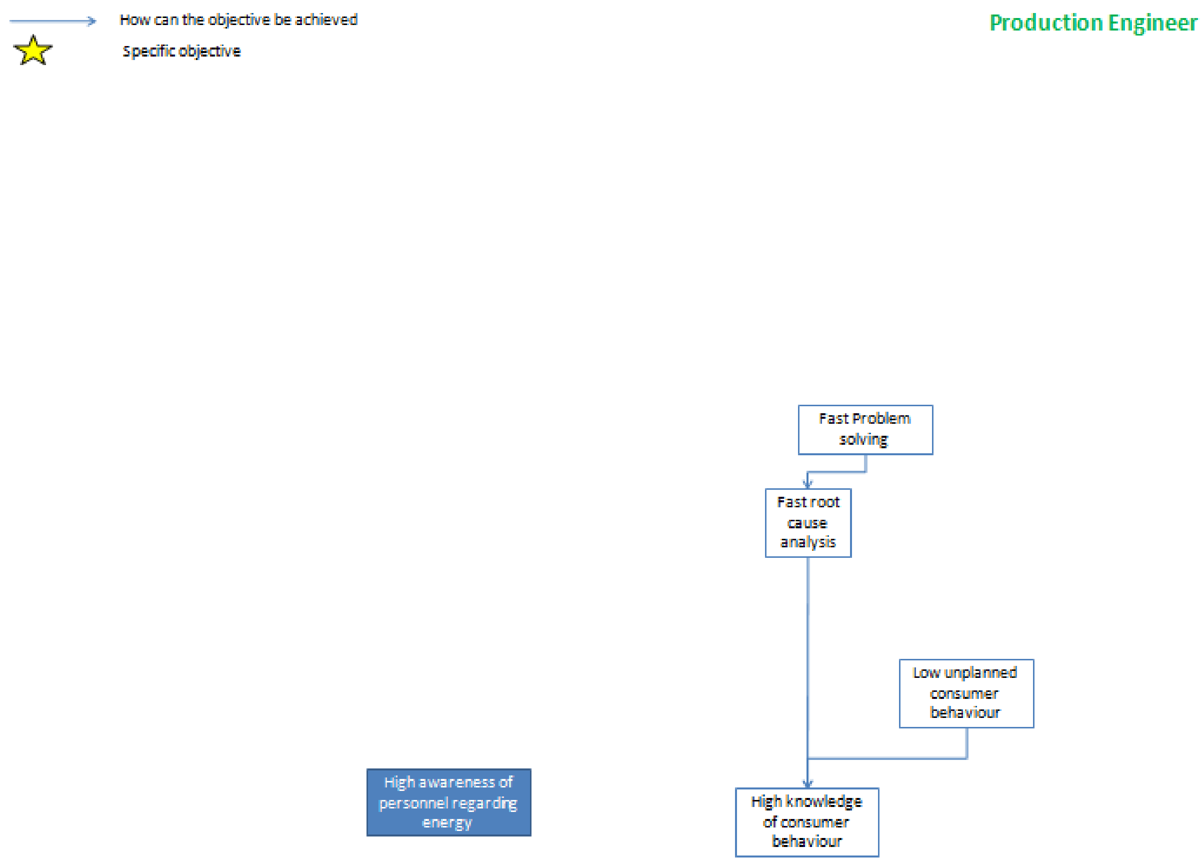
- The tab “**Objectives**” includes the filled objectives’ template with the use case information.
- The tab “**Obj-tasks**” is an auxiliary tab in order to make possible the excel assignment. Actually it is the equivalent to the tab “Tasks-Objectives” in the “GeneralData” file.
- The tab “**Roles Desc**” contains the filled roles’ template with the use case information. In the same tab, the automatic assignment has been realised.
- The following tabs are named with the roles’ titles and include the specific results for each of the roles considered in the use case application. These results are the matched objectives, the selection of the most relevant objectives and the little list of indicators for each selected objective.
- In the tab “**Indicators summary**” all the indicators defined for all roles are put together in a table. The evaluation of the indicators in order to select some of them is done in this tab.
- The tab “**Final indicators**” contains the final result of the application, with the indicators defined for each role.

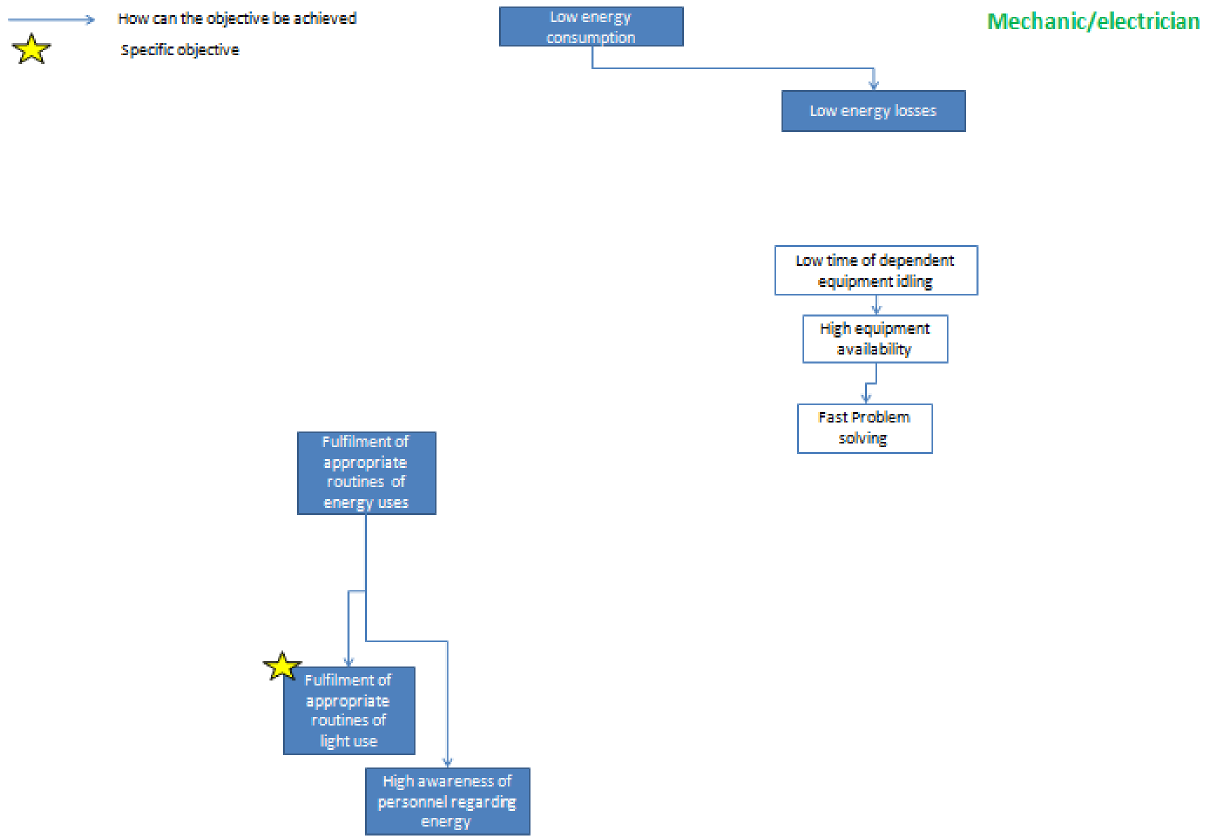
8.4. Appendix 4: Roles' Hierarchy of objectives

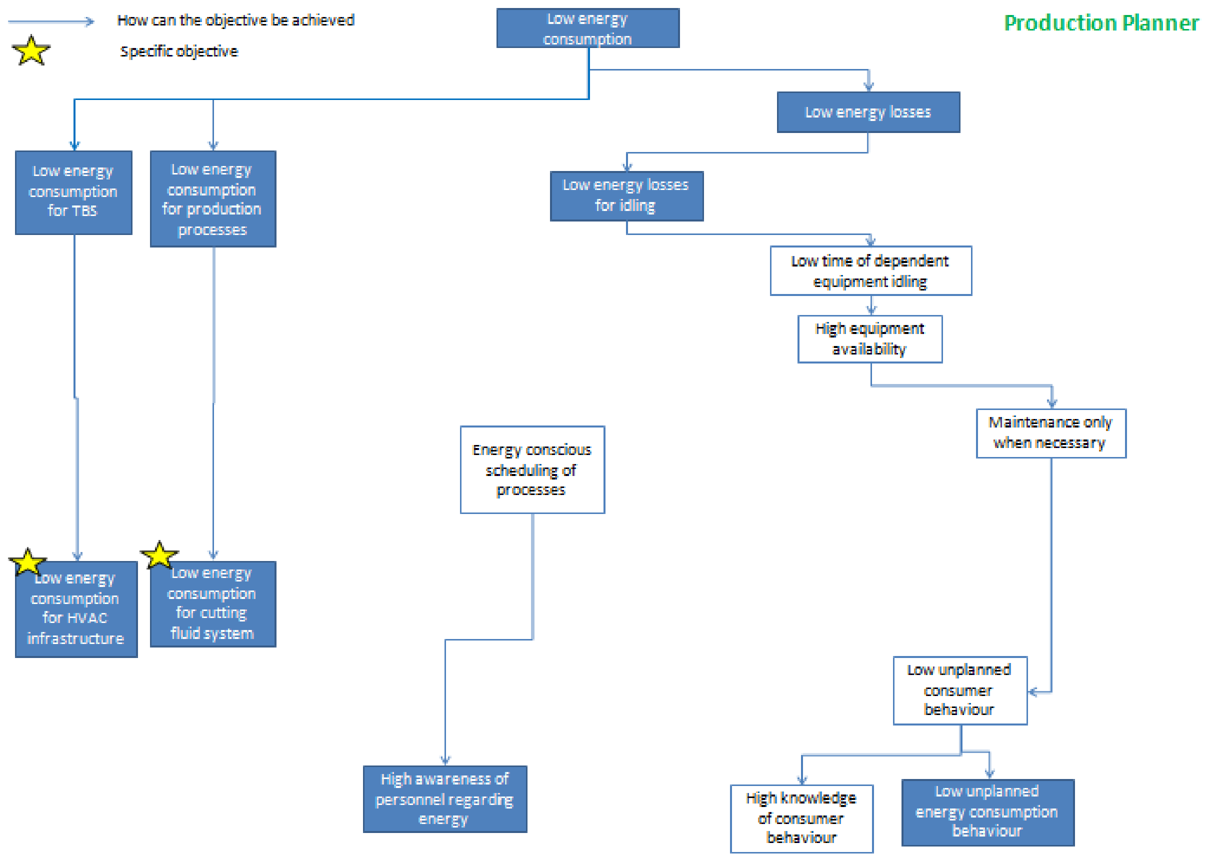


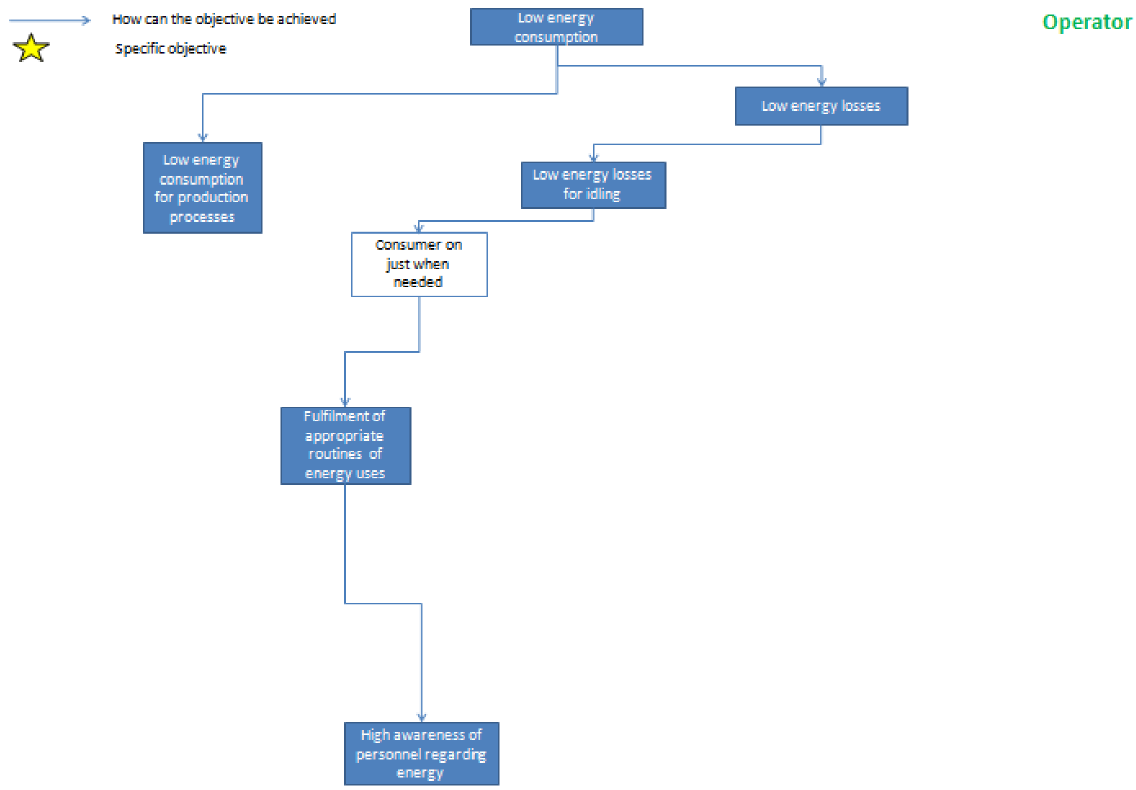



How can the objective be achieved
Specific objective
Shift Leader
Low energy consumption
Low energy losses
Low energy losses for idling
Consumer on just when needed
Low time of dependent equipment idling
High equipment availability
Pumps on just when needed
Fulfilment of appropriate routines of energy uses
Energy conscious scheduling of processes
Fulfilment of appropriate routines of light use
High awareness of personnel regarding energy


How can the objective be achieved
Specific objective
Production Engineer
Fast Problem solving
Fast root cause analysis
Low unplanned consumer behaviour
High awareness of personnel regarding energy
High knowledge of consumer behaviour


How can the objective be achieved
Specific objective
Low energy consumption
Mechanic/electrician
Low energy losses
Low time of dependent equipment idling
High equipment availability
Fast Problem solving
Fulfilment of appropriate routines of energy uses
Fulfilment of appropriate routines of light use
High awareness of personnel regarding energy


How can the objective be achieved
Specific objective
Low energy consumption
Production Planner
Low energy losses
Low energy consumption for TBS
Low energy consumption for production processes
Low energy losses for idling
Low time of dependent equipment idling
High equipment availability
Maintenance only when necessary
Energy conscious scheduling of processes
Low energy consumption for HVAC infrastructure
Low energy consumption for cutting fluid system
Low unplanned consumer behaviour
High awareness of personnel regarding energy
High knowledge of consumer behaviour
Low unplanned energy consumption behaviour



8.5. Appendix 5: Predefined list of indicators

Indicator name	Scope	Variable reference	Applicable for generation of Knowledge / Awareness / Prediction
Power	Energy consumption	application, period, energy carrier	K, A, P
Energy consumption	Energy consumption	application, period, energy carrier	K, A, P
Specific energy consumption	Energy consumption	application, period, energy carrier	K, A, P
Energy costs	Energy costs	application, period, energy carrier	K, A, P
Specific energy costs	Energy costs	application, period, energy carrier	K, A, P
Energy losses	Energy efficiency	application, period, energy carrier	K, A, P
Energy efficiency	Energy efficiency	application, period, energy carrier	K, A, P
Percentage of energy consumption value adding	Energy efficiency	application, period, energy carrier	K, A, P
Energy traceability	Energy traceability	application, period, energy carrier	K
Critical energy consumption situation	Energy traceability	period, application, energy carrier	K, A, P