Maintenance Management Initiatives towards Achieving Sustainable Development

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Abstract. As sustainable development is a concept more and more popular, the need to provide its practical application has emerged. The way to help companies improve their economical, environmental and social performance is by minimizing waste. It means less waste generated and increase waste reusage or recycling; using resources such as materials, water and energy at the highest possible efficiency; avoiding or at least improving management of metalworking fluids, lubricating oils and hydraulics oils. Other goals are improved environmental, health and safety performance, adopting lean manufacturing and other sustainable engineering techniques, as well as improved working conditions. The achieve reduction of waste at production site best practice in manufacturing and maintenance processes are needed. The aim of this chapter is to present how well performed maintenance management can help to achieve sustainable development of a company.

Keywords: maintenance management, resources availability, environment

1 Introduction

Sustainable development is a very broad idea and it has numerous interpretations [6]. The term "sustainable development" was used for the first time in the Brundtland report developed by World Commission on Environment and Development, also called Brundtland Commission, in 1987. There, it was defined as a process aiming for aspirations of contemporary generation development and for providing the chance to meet these aspirations by future generations as well. Thus sustainable development is about reaching a balance between economic, social, and environmental goals, as well as people's participation in the planning process in order to gain their input and support [22] For company sustainable development means adoption of business strategy and actions which contribute to satisfying present needs of company and interested parties, as well as simultaneous protection, maintenance and strengthening of human and environmental potential which will be needed in the future [20]. Manufacturing businesses can contribute to this effort by designing products and production systems that have an insignificant or

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optimally low impact on the natural environment in terms of resource depletion, waste emissions, energy usage, and other impacts [16].
Environment protection, as well as including social interest in business activity is issues extremely important for entrepreneurs thinking seriously about long-term activity on the market.

In the past, environmental concerns about business have generally concentrated on large manufacturing organizations. It has been said that this is because "small businesses are written off as a group that is too expensive to reach, while attention is concentrated on the easier to reach large businesses" [17]. Nowadays, a significant number of SMEs (66.25%) saw environmental sustainability as important or vital to their future business activities [9].

2 Concept of "Green" Manufacturing

Green, or sustainable, manufacturing is defined by Allwood [1] as a method to "develop technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste". The term "green", often used interchangeably with "environmentally-safe". To achieve the "green" status, enterprises should, among others: improve manufacturing processes, use clear energy sources and use lower impact materials [8] (Fig. 1).

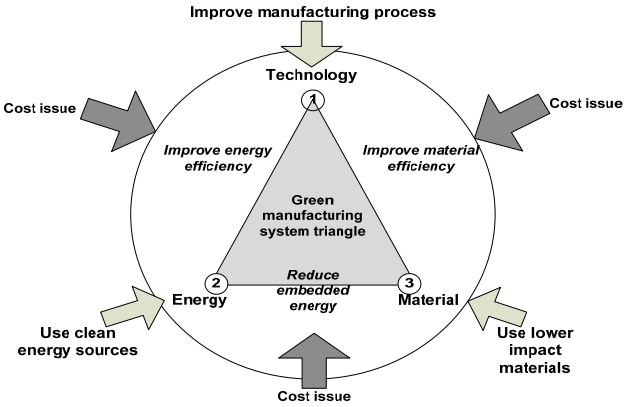


Fig. 1. Green manufacturing system triangle, *Source:[8]*

Manufacturing firms that have gone green are finding that it saves them thousands of dollars each year. Going green will cut down energy costs and can even save money on insurance rates. Experts predict that green manufacturing will be the most popular trend in the next years.
By implementing lean manufacturing companies can reduce wasted products and impact on the environment costs by 70% or more. And, however the goal of lean

manufacturing is limitation of waste by elimination of activities performed to create a product or a service but not adding them any value, analyzing results of lean manufacturing application one can say it is close to the idea of green manufacturing, which is a new approach to the way of doing business.

Sustainable (including green) manufacturing uses both technological and non-technological solutions, from selection of materials and production processes to organizational mission, structure, and performance reporting which is measuring, disclosing, and being accountable to internal and external stakeholders for organizational performance towards the goal of sustainable development.
So called Performance Indicators (proposed by Global Reporting Initiative – GRI) are divided to economical, environmental and social. Each category includes information concerning approach to management and dedicated set of basic and supplementary indicators.

The Aspects in the Environment Indicator set are structured to reflect the inputs, outputs, and modes of impact an organization has on the environment. Energy, water, and materials represent three standard types of inputs used by most organizations. These inputs result in outputs of environmental significance, which are captured under the Aspects of Emissions, Effluents, and Waste. Biodiversity is also related to the concepts of inputs to the extent that it can be viewed as a natural resource. Each aspect cover some indicators, for instance:

- Aspect: Materials: materials used by weight or volume. percentage of materials used that are recycled input materials,
- Aspect: Energy: direct and indirect energy consumption by primary energy source, energy saved due to conservation and efficiency improvements, Initiatives to provide energy-efficient or renewable energy-based products and services, and reductions in energy requirements as a result of these initiatives.
- Aspect: Water: total water withdrawal by source, water sources significantly affected by withdrawal of water, percentage and total volume of water recycled and reused.
- Aspect: Biodiversity: Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas.
- Aspect: Emissions, Effluents, and Waste: total direct and indirect greenhouse gas emissions by weight, other relevant indirect greenhouse gas emissions by weight, Initiatives to reduce greenhouse gas emissions and reductions achieved.

Nowadays, there is over 2500 reports registered and revealed by the companies such as ABB, Bombardier, Coca Cola, 3M or Vodafone. Reports can be used for purposes like benchmarking and assessing sustainability performance, demonstrating how the organization influences and is influenced by expectations about sustainable development; and comparing performance within an organization and between different organizations over time.

Machine maintenance in a production company is a key issue; however, in a process approach it is usually classified as an auxiliary process for the production.

Meanwhile, the process can have a fundamental impact on the amount and cost of production, quality of the final product, safety of people and the environment. Additionally, it is a process results of which can be analyzed in countable values, and assets are comparatively easy to manage. All that makes maintenance in companies applying so called good engineering practices not only a cost-generator which should be avoided but also an active approach which can contribute to company's development and become an integral part of green manufacturing called "green maintenance".

3 "Green" Maintenance

Maintenance has been seen as a way to help to maintain production as efficient as possible. But, by this way, it is seen as a cost that, by consequence, diminishes the profits of companies. This implies that the maintenance has been managed as an activity less important and less valuated when compared with other activities in the companies, namely with production [11]. A better environment can be achieved through the reduced emission of pollutants, the optimization of green energy production and the optimization of maintenance interventions, which is an important contribution in getting equipment functioning as efficiently and effectively as possible and, of no less importance, to minimize the downtime caused by faults [12].

Maintenance departments do not have direct influence on energy and other medias use as they are emerging from technologies applied, however they can greatly influence it. Thus, they have influence on natural environment. What factors are among their responsibilities? Which elements of exploitation system can be positively influenced by maintenance departments?

It shows that there are plenty of opportunities, including simple service and fixing activities such as alignment or balancing or using advanced technical diagnostics methods, influencing lubricating or purchasing policy and maintenance strategy.

For example, unconcentricity of shafts may lead to energy use increased by 12%, and not well-matched or used clutch may lead to 4% losses. Exchanging traditional belts to high-efficiency belts of new generation in belt-transmissions provides energy savings by 2-4%. Making decisions concerning use of electric engines EFF1 leads to increasing efficiency by 26% compared to traditional electric engines.

Using energy-saving bearings in drives of machines and devices allows decreasing friction by 30%, and machines are capable to increase their maximum speed by 15%. Elimination of leaks in pneumatic installations, exchange of air preparing modes to the ones of high quality, use of connectors and wires characterized with low flow resistance, optimization of condensed air net system leads to energy savings by 10%. The next factor is choosing suitable condensers and their proper exploitation, especially in terms of condenser oil and its contaminations. They can be used for industrial, usable and heating water heating up. In hydraulic

systems losses are generally consequence of hydraulic oil flow resistance. New generation filters should be applied as they are characterized with low flow resistance, i.e. filters with glass fiber or metal net insert.

Maintenance departments are also responsible for definition of maintenance strategy which is defined as an interrelationship description between maintenance echelons (on-site, in a repair shop, at the manufacturer, etc.) and indenture levels (subsystem, circuit board, component, etc.) including their maintenance actions [21]. The maintenance echelon is characterized by the personnel skill, the available means and the location. When the indenture level depends on the complexity of an item structure, the accessibility to its sub-items, personnel ability level, test and measure means safety considerations, etc. Miscellaneous strategies have been put forward for maintenance amongst which the most important ones are corrective, preventive, opportunistic, condition-based and predictive maintenance that considering each one's relevant industry each of them has advantages and disadvantages [7]; [15]; [2]; [14]; [18]; [19]

Strategies believed to be the most efficient include TPM (Total Productive Maintenance), RCM (Reliability Centered Maintenance), RBI (Risk Based Inspection) and RBM (Risk Based Maintenance) [3] . Proper maintenance strategy is directly connected with limiting negative influence on natural environment by:

- Providing regular monitoring of machines work parameters with technical diagnostics tools. High level of technical services planning can be achieved only when planning is based on reliable operational data. Consequently, production machines and devices condition monitoring is crucial for supporting sustainable management of manufacturing operations.
- Elimination of serious failures with formalized cause-effect analysis. Analysis of risk and decreasing uncertainty in reliability of machines and devices assessment Has become critical methods in strategic decisions making process, striving for technical safety providing (including its environmental aspects) and costs minimization. Risk analysis usually requires application of some tools including: FMECA, FMEA, RCA, FTA etc. [5]
- Preventing production cycle breakdowns by focusing on Overall Equipment Effectiveness (OEE).

Three elements consist on OEE. The first element of the OEE measure – availability, is concerned with the total stoppage time resulting from unscheduled downtime, process set-up and changeovers, and other unplanned stoppages. In simple terms, it is the ratio of actual operating time to the planned operating time, and takes into account the theoretical production time against which unplanned downtime is highlighted. The second element of the OEE calculation is ``performance rate''. This measures the ratio of the actual speed of the equipment to the ideal speed. Performance efficiency is the product of the operating speed rate and net operating rate. The operating speed rate of equipment refers to the discrepancy between the ideal speed and its actual operating speed. The third element of the OEE calculation is the “quality rate", and is used to indicate the proportion of defective production to the total production volume. It should be noted, however, that the quality rate involves defects that occur only in that designated stage of production, usually on a specific machine or production line.

Research done by the authors in food industry enterprises proves that the following factors have the greatest impact on the OEE coefficient (because of influencing readiness coefficient): product development time, assortment changing time etc., hence, the factors not connected with maintenance processes. Thus, OEE is a general measure of efficiency of machines and devices utilization including aspects connected with efficiency of all interested parties, which are maintenance departments (losses caused by failures, lower efficiency and quality losses caused by poor technical condition etc), production department (setups, product development, work organization, workstation maintenance) and other departments, responsible for logistics, purchasing, training, organization, construction and technology development etc.. Thus, to increase OEE, cooperation between all departments is necessary, as well as including LCA approach in all the actions taken.

4 The case study

Poznan Brewery, along with Tychy and Bialystok Brewery are joint and create Kompania Browary S.A. in Poznan – a company which is a leader of Polish brewery industry and a part of SABMiller, the second in the world beer producer. As a consequence, the 10 priorities of sustainable development has been created to prove their responsible approach to business (fig. 2)

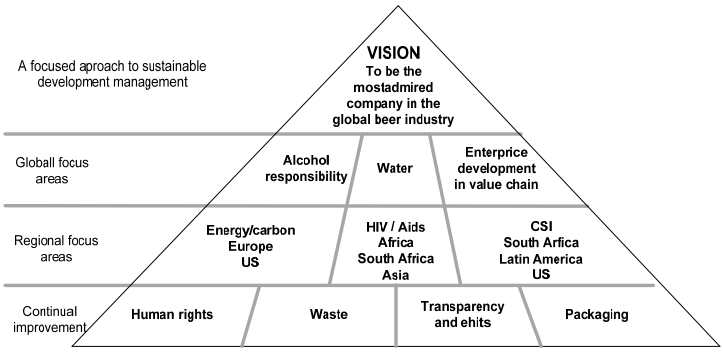


Fig 2. Ten sustainable development priorities
Source: http://www.sabmiller.com/files/reports/2010_SD_report.pdf

To monitor and measure progress, they have developed the Sustainability Assessment Matrix (SAM). This is a bespoke management system that enables to monitor the performance of operating businesses against the 10 sustainable development priorities. Each priority has a 'stairway' that plots a course through four levels of performance from minimum standard to best practice.

Each operation is required to complete an online assessment every six months. The results are collated to create a 'scorecard' for each business and region and, ultimately, for the group. The scorecards are assessed internally by regional and group CARACs (Corporate Accountability and Risk Assurance Committee is a sub-committee of the SABMiller plc board and is responsible for overseeing progress against our 10 sustainable development priorities) and is analyzed continuously to be an important element of the planning process. To facilitate sharing of best practice and consistency of assessment, teams from different countries review each other's scorecards through detailed in-country reviews and benchmarking exercises. Each business scorecard is also reported on website publicly.

In July 2009 SABMiller launched the 'Sustainable Development Way' which aims to ensure a consistent approach around the world and provides a credible point of reference for the business. In Kompania Piwowarska S.A. for each SD priority, goals and the way they should be evaluate have been defined (table 1).

Table 1. Goals and their evaluation modes: Water and Energy&Carbon

	Goals	**Evaluation**
Energy	Optimization of energy use Carbon Footprint – implementation of tools enabling assessment of influence of business decisions on CO2 emissions (f.ex. packages, distribution strategy) assessment of energy use in the supply chain	energy use ratio renewable energy use air pollution management (CO2 mainly), including emissions trade monitoring CO2 emission Energy management (ratios defined, measured and analyzed in core process of organization)
Water	Optimization of water use. Assessment of risk of lack of water for beer production caused by local conditions. Assessment of water use in the supply chain	water use ratio sewage quality brewery's demand on water vs local societies' demand on water and opportunities of water supplies in the next 10 years water use in the supply chain

According to the SAM model applied, priorities are assessed and reported every six months (fig.3).

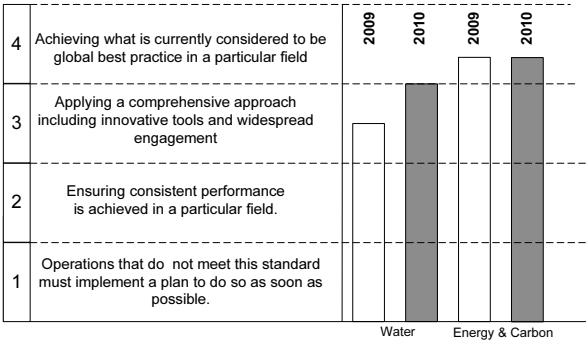


Fig. 3. Measuring achievements in Poznan Brewery for "Water" and "Energy&Carbon" priorities

Poznan Brewery benefit from implemented and continuously improving Integrated Risk Management System (IRMS), which meets requirements of Risk and Functioning Continuity Management programs of SABMiller and requirements of the following standards: ISO 9001:2008, ISO 22000:2005, ISO 14001:2004, OHSAS 18001:2007, PN-N 18001:2004.

WCM strategy realization (in SABMiller called ”Manufacturing Way”) in all the areas of the enterprise activity is strictly connected with realized and improved since 2000 TPM strategy. The model, the concept was based on, includes also pro-environmental activities and aspects.

The examples of pro-environmental activities realized according to “Manufacturing Way” strategy (IRMS is the element of this strategy), in which maintenance staff has been taken part in are listed and presented below.

Environmental Management System

Since 2001, beer producer from Poznan has been certified with Environmental Management System certificate ISO 14001. Its concern about natural environment is appreciated by f.ex. by the following rewards: "Panteon Polskiej Ekologii" (Polish Ecology Pantheon) by Minister Ochrony Środowiska (Minister of the Environment) and "Firma Przyjazna Środowisku" (Environment Friendly Enterprise) by President of Polish Republic. By realization of environmental policy of Poznan Brewery, goals and tasks for all the functional areas of the company are established. Departments of Techniques and Maintenance support realization of predefined goals. The examples of environmental goals and activities planned to provide these goals are presented in the table below.

Table 2. Environmental goals and their realization

Environmental goal	Improvement of chemicals in warehouses management.
Realization	Production Department and Techniques Department.
Planned activities:	1. Audit of chemicals storage conditions 2. Moving central warehouse of chemicals to the location meeting safety requirements (investment project) 3. Definition of optimal amount of chemical stored at hand 4. Development and implementation of instruction on safe storage of chemicals in production departments 5. Environmental failures risk assessment 6. Definition of procedures in case of failures 7. Training for all the operators and maintenance staff 8. Audits of CIP washing installations in terms of failure risk
activities taken by maintenance department to provide tasks 8 realization	1. Audits of installation dosing condensed chemicals and washing substances 2. Repairs necessary (identified thanks to audits) 3. Detailed analysis of reliability of all the elements of installation and identification of critical ones 4. Verification of preventive work plans based on analysis performed (frequency of audits and their range) 5. Verification of checklists for operators, mechanics and maintenance automatics (increased frequency of installation controls) 6. Additional covers and securities for pumps dosing condensed chemicals was planned as an investment and is being realized.

Example of activities in „water" and „energy" areas

One of the programs launched as a part of excellence strategy „Manufacturing way" in Poznan Brewery is the "Ideas campaign", aimed to motivate employees by promotion of operational excellence, exceptional commitment and achievements. The program has been organized by the Production Development Department. Each employee can present an idea individually or as a part of a team, and the condition to be met to be the part of the Program is presentation and/or realization of an idea which brings added value:

- According to the definition presented in the Program
- And is coherent to strategy and goals of the company,
- Is realistic and implementable.

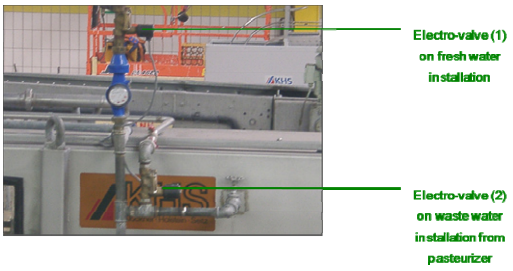
Presentation of an idea requires filing in a project card which can be downloaded from a computer system. After the card is correctly filled in, it is passed to a manager responsible for the area in which the idea is meant to be realized. The manager is to check whether the idea meets the requirements and gives it the status. The manager is responsible for realization of the idea accepted, organizes resources, assigns jobs and coordinates work, or in any other way provides the idea realization. After the idea is implemented the manager changes its status in the computer system on „realized", lists the results achieved and the members of implementation team with the jobs and roles they had. The decision on reward and its size is made by head of the department and managers team and experts, if necessary. Final acceptance of reward is done by the CEO responsible and the criteria for rewarding an idea are the following: cost reduction, efficiency improvement (of processes, time, work organization); opportunity of using the idea in other departments; products and services quality improvement, Safety and Hygiene of Work improvement, operational excellence and/or exceptional commitment and/or extraordinary achievements and other, bringing benefits to the enterprise.

Employees of the Techniques Department and Maintenance Department take part in the Program by presenting their own ideas or realizing ideas presented by other employees, f.ex. from Production Department. In the table 3 one of the ideas presented by L3 maintenance staff and results obtained are introduced.

Tab 3. Example of an activity realized in a program „Ideas campaign"

Water saving activities
Description of the problem and actions taken by the Maintenance Department for L3 (bottling)
Usage of fresh water on L3 crate washer and high sewage emission has made us search for a cheaper solution assuming that quality and efficiency of crate washing remain unchanged or even higher. Having observed the technical solutions on a packaging line which uses significant amounts of water during production process, one has noticed an analogy between the pasteurizer and the crate washer. Water used at the end of pasteurization process for cooling bottles is also used on regular basis for filling up pasteurizer zones, and water surplus is eliminated by the overflow pipe into the canal. We have come to the conclusion that is a wonderful opportunity to use the water surplus from the pasteurizer for crate washing. Close distance between these machines makes the modification quick and cheap. Savings of fresh water are huge. Crate washer during production time used fresh water from water installation. Water was constantly supplied to the final section of spraying section. Internal system of baths allowed to use this water in the section just before rinsing. Water surplus was directed to a canal. Crate washer used approx. 160-

180 m3 of water per day (24 hours of production). Crate water supply installation system has been equipped with 2 additional electro-valves to which a signal is sent from a water level sensor installed in water tank and synchronized with a water pump.



Results
Water usage before modification: **160 - 180 m^3/24h**
Water usage after modification: 40 - 60 m^3/24h
Water savings: 120 m^3/24h
Additional benefit which have been achieved is higher crate washing efficiency by using water from pasteurizer at approx. 50°C.

The project presented above supports water strategy implemented and used in SABMiller, which is based on the 5Rs (pRotect, Reduce, Reuse, Recycle and Re-distribute) idea, a comprehensive, risk-based approach to managing water in business and in the value chain (fig.4).

Fig. 4. The '5R' model of water responsibility.
Source: http://www.sabmiller.com/files/reports/2010_SD_report.pdf

Examples of energy saving activities taken by the Techniques Department and the Maintenance Department are presented in the table 4.

Tab 4. Energy Saving Activities - examples

Activity	Description
Combined Energy Systems 1	– REVAP = double energy savings from CO_2 evaporation: – CO_2 evaporation ↔ intermediary circuit ↔ glycol cooling – Estimated electrical energy savings per year: 400 MWh – Estimated thermal energy savings per year: 1200 GJ
Frequency converters for big electrical motors	– Installed on both air and NH_3 compressors gives precise and optimal capacity adjustment for „last in queue" drive.
Close-loop condensate systems	– Monitored and maximized amount of returned condensate together with improved quality: – Quantity → % of returned volume – Quality → content of contaminants (corrosion, iron)

	– Energy → temperature
Dew point controlled condensation	– Ammonia condensing pressure optimization by using dew point based control to reshape Carnot-cycle curves.

Water and energy use is monitored systematically. For critical (in terms of water use) machines and devices, measures are taken every day by Chef of Production while energy use is checked once a week. Once a week, there is a meeting scheduled for Chef of Production and Maintenance Manager to analyze the measures taken. If the use measured is higher than predefined for each device standard, the team for planning corrective actions is appointed. Water and energy measuring systems help to identify areas for improvement (fig.5).

Fig. 5. Water measuring systems

Example of actions in "Lubricants management" area

For production lines of verified structure, reliability analysis is very important as the results obtained allow to identify the devices and elements which are the weakest elements often causing failures and breakdowns. Well-organized audits supported with proper diagnostics tools result in improved production lines operating.

The Techniques Department of Poznan Brewery employs experts in diagnostics who are responsible for implementation and realization of diagnostics program. Each of the experts is responsible for accepted diagnostic program with predefined diagnostics range and frequency. The following diagnostics techniques are applied in Poznan Brewery: vibro-accoustics, thermovision (f.ex. controlling parts of machines, controlling devices and others,)oil examination, faradic currents measuring, steam dehydrators examinations.

Oil examination is performed every six months for predefined transmissions. The goal of examination is one hand identification oil quality and on the other searching the oil for metallic elements to check whether elements of transmission are not used. Diagnostics program is predefined in SAP class software implemented in the company. The system generates orders for diagnostics automatically, however if the employees responsible for diagnostics decide that the condition of the machine requires intervention, they create a note in SAP and send it to the planner responsible for the area given, and he creates an order in the system plan-

ning the necessary activities. Before diagnostics was implemented, the good practice of maintenance was changing the oil according to transmission producer recommendations (once a year for mineral oils). Since 2004 diagnostics techniques have been commonly used, i.e. oil samples analysis. In the fig 6 oil use before and after diagnostics was implemented is compared.

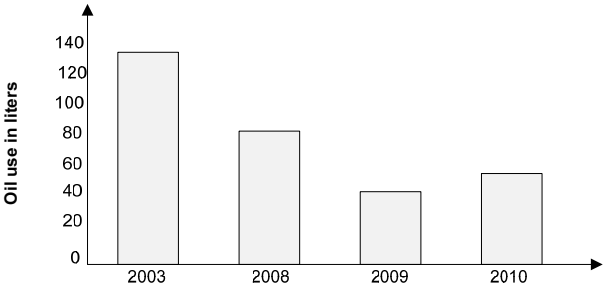


Fig. 6. Oil use compared

Better maintenance, supported by IT system (in 2000 MAXIMO was implemented, since 2007 performance has been monitored with SAP), results in increased efficiency of equipment and decreased emission of pollution, energy use and water use as well. These are only some reasons to say that maintenance in Poznan Brewery helps the environment.

5 Summary

Sustainable maintenance is a system organized in a way supporting pro-environmental approach to organization management. Environment-friendly maintenance system is combined of all the maintenance processes and includes service strategy selection (reactive, preventive, pro-active etc), purchasing materials and raw materials necessary to realize services, storing the materials mentioned before and performing services planned and unplanned, as well as utilization of used materials, exploitation fluid and lubricants.

Realization of "green" maintenance in an organization should be focused on three areas:

- assessment of influence of functional failures of machines and other devices on natural environment, selection of proper service operations and monitoring system using technical diagnostics tools and suitable software; such approach enables f.ex. identification of situations in which energy use is excessive and can be limited to decrease operational costs.
- Design for "green" maintenance. Decisions concerning new machines, devices, installations purchasing or modernization of infrastructure existing

should be based on environmental issues. Project assessment should be referred to total lifecycle cost, which enables identification of financial gains or losses emerging from predefined service and maintenance practices providing an excellent level of reliability, accessibility and maintainability.

– Sustainable lifecycle management – from concept design of new machines, devices and installations to sales. All units (departments) of an enterprise should be included and motivated to efficient management of their assets during whole period of exploitation. Lifecycle management in reference to environmental aspects requires knowledge of impact of all the components and materials installed in production system on natural environment, and of energy use as well as of amounts of waste and harmful side-products generated.

"Green" maintenance is unavoidable choice for sustainable development of enterprises and implementation of "green" maintenance is suppose to provide numerous economical, environmental and organizational benefits (table 5)

Tab 5. Potential benefits from using „Green maintenance" practices

Economical: • Decreased environmental fees (f.ex. thanks to waste segregation or lower use of energetic medias) • Decreased amount of exploitation materials used (f.ex. decreased use of oils or lubricants caused by applying technical diagnostics) • Decreased CPU of products manufactured (f.ex. thanks to decreased use of energy in production processes) • Decreased risk of potential failures • Decreased penalties for failures thanks to preventive and pro-active maintenance.
Organizational: • Improved communication between organizational units thanks to benefiting from interdisciplinary teams • Increased efficiency of services performed (f.ex. thanks to performing services on time and implementation of preventive and pro-active services) • Increased awareness of employees (f.ex. thanks to training programs organized for employees) • Better planning of services thanks to diagnostic tools use • Developing external communication procedures and efficient procedures of dealing with failures • Improved relations with business environment and administration involved
Environmental: • Decreased amount of waste generated • Decreased technological medias use (f.ex. thanks to modernization of facilities and machines) • Decreased use of lubricants • Elimination or decreasing penalties for illegal or inappropriate practices • Decreased disturbances and nuisance for local societies (f.ex. noise or other emissions) • Reduction of scarce or not-renewable natural resources use – gas, oil

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