UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ
FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA
PROGRAMA MULTIDISCIPLINARIO DE POSGRADO EN CIENCIAS AMBIENTALES
AND
TH KÖLN – UNIVERSITY OF APPLIED SCIENCES
INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

THE PLANNING PHASE OF AN ENERGY MANAGEMENT SYSTEM ACCORDING TO ISO 50001: ELABORATION FOR THE ROBERT BOSCH PLANT IN SAN LUIS POTOSI, MEXICO

THESIS TO OBTAIN THE DEGREE OF
MAESTRÍA EN CIENCIAS AMBIENTALES
DEGREE AWARDED BY UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ
AND
MASTER OF SCIENCE
NATURAL RESOURCES MANAGEMENT AND DEVELOPMENT
DEGREE AWARDED BY TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

PRESENTS:
CLARA HASSELBRING (11103670)

CO-DIRECTOR OF THESIS PMPCA:
DR. ISRAEL RODRÍGUEZ TORRES

CO-DIRECTOR OF THESIS ITT:
PROF. DR. JOHANNES HAMHABER

ASSESSOR:
DR. CIRO ALBERTO NÚÑEZ GUTIÉRREZ

SAN LUIS POTOSI, MEXICO AUGUST 15TH 2016

Technology
Arts Sciences
TH Köln

THE PLANNING PHASE OF AN ENERGY MANAGEMENT SYSTEM ACCORDING TO ISO 50001: ELABORATION FOR THE ROBERT BOSCH PLANT IN SAN LUIS POTOSI, MEXICO

PROYECTO REALIZADO EN:

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPIS AND SUBTROPICS (ITT)

AND

PROGRAMA MULTIDISCIPLINARIO DE POSGRADO EN CIENCIAS AMBIENTALES (PMPCA)

CON EL APOYO DE:

CONSEJO NACIONAL DE CIENCIA Y TECNOLOGÍA (CONACYT)

CENTERS FOR NATURAL RESOURCES AND DEVELOPMENT (CNRD)

PROGRAMM ZUR STEIGERUNG DER MOBILITÄT DEUTSCHER STUDIERENDER (PROMOS)

LA MAESTRÍA EN CIENCIAS AMBIENTALES RECIBE APOYO A TRAVÉS DEL PROGRAMA NACIONAL DE POSGRADOS (PNPC - CONACYT)

Technology
Arts Sciences
TH Köln

Erklärung/ *Declaración*

Name/*Nombre*: Clara Hasselbring

Matrikel-Nr./ *N° de matricula*: **11103670 (TH Köln)/ 0242747 (UASLP)**

Ich versichere wahrheitsgemäß, dass ich die vorliegende Masterarbeit selbstständig verfasst und keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Schriften entnommen sind, sind als solche kenntlich gemacht.

Aseguro que yo redacté la presente tesis de maestría independientemente y no use referencias ni medios auxiliares a parte de los indicados. Todas las partes, que están referidas a escritos o a textos publicados o no publicados son reconocidas como tales.

Die Arbeit ist in gleicher oder ähnlicher Form noch nicht als Prüfungsarbeit eingereicht worden.

Hasta la fecha, un trabajo como éste o similar no ha sido entregado como trabajo de tesis.

San Luis Potosí/ Köln, den/ *el* 23.08.2016

Unterschrift/ *Firma*: ____________________

Ich erkläre mich mit einer späteren Veröffentlichung meiner Masterarbeit sowohl auszugsweise, als auch Gesamtwerk in der Institutsreihe oder zu Darstellungszwecken im Rahmen der Öffentlichkeitsarbeit des Institutes einverstanden.

Estoy de acuerdo con una publicación posterior de mi tesis de maestría en forma completa o parcial por las instituciones con la intención de exponerlos en el contexto del trabajo investigatición de las mismas.

Unterschrift/ Firma: ____________________

Acknowledgments

First of all I would like to thank my family in Germany and Mexico, especially my Dad and Husband, as well as my friends distributed all over the world for their unconditional love and support throughout this journey. I love you!

I also want to express my sincere gratitude to my thesis committee Prof. Dr. Johannes Hamhaber, Dr. Israel Rodríguez as well as Dr. Ciro Nuñez for their motivation, valuable input and knowledge. The present project would not have been finished without the constant and valuable collaboration and professional advice from all of you. You not only helped me grow academically but also professionally. A very special thank you is also needed for Roberto Moreno for your immense patience and help during the data collection and processing period and for letting me take over your office from time to time.

Additionally I want to acknowledge the time and effort invested by all administrative staff members of the ENREM program in Germany (ITT) as well as in Mexico (PMPCA) for helping us with all formalities over and over even though you have already explained it a 100 times before. I would also like to thank CONACYT, PROMOS and CNRD for their financial support during this master program.

Additionally, I thank everyone forming part of the Robert Bosch plant in San Luis Potosi for giving me the opportunity to carry out my investigation project. I especially want to thank the HSE team (Jaime Perez, Ana Coronado, Paulina Guzman, Rocío López, Johana Martinez, Andrea Arellano) for their support and trust throughout this project as well as the MOE 3 team for making the data collection possible and providing me with all necessary information and orientation.

Last but not least I want to thank the amazing people I got to know throughout this master program and that I can now call my friends for your constant support and guidance in the best and worst. This awesome time wouldn’t have been the same without you!

Abstract

At present, energy and energy efficiency (EE) related topics are becoming increasingly important due to a growing energy demand and decreasing resource availability. Especially in relation to industrial activities and development, EE measures are arousing interest among decision-makers. Given this background, tools such as energy management systems (EnMS), frequent energy audits and international certifications can contribute to the achievement of continuous energy savings and improve an organization's overall energy performance.

In this context, the following study seeks the elaboration of the planning phase of an EnMS according to the international standard ISO 50001 for the Robert Bosch Automotive Systems plant in San Luis Potosi, Mexico (Bosch SLP). In order to do this, different activities were performed such as interviews with management directives and operational staff members, revision and documentation of already existing energy data as well as the acquisition of new energy data through multi-channel power meter measurements. Some aspects were solely performed on process level while others were established on plant level.

According to the objectives proposed in the study the first part focuses on all important concepts related to energy management. Models such as the Plan-Do-Check-Act (PDCA) cycle related to ISO 50001 are presented. Additionally an overview of the Mexican as well as the European Union's legal frameworks regarding energy audits and EnMS is given.

Throughout the thesis, general guidelines for the implementation of an EnMS are described, displaying the planning phase of the PDCA cycle. After presenting the Robert Bosch GmbH as a whole and the Bosch SLP plant in greater detail, the guidelines proposed by the ISO 50001 norm are applied to the study case.

In this context, energy policies for Bosch SLP are elaborated and a potential distribution of responsibilities is assigned to the different department managements. Subsequently a detailed energy audit has been completed on process level and data was used to identify opportunity areas and establish an energy baseline, energy management objectives and targets. Already existing energy data from utility bills was reorganized and analyzed in order to realize an energy review on plant level. As a final step of the planning phase an action plan was proposed, however, solely on plant level, since the overall goal for the future should be to duplicate the detailed energy audit throughout the plant. As part of the action plan, a variety of recommendations regarding suitable energy savings measures and activities, needed for the implementation of an EnMS, were suggested.

Key words: Energy efficiency, Energy management, Energy management systems, ISO 50001, PDCA cycle

Resumen

En la actualidad, los temas relacionados con energía y eficiencia energética (EE) están adquiriendo mayor importancia debido a la creciente demanda de energía y la disminución de la disponibilidad de recursos. La medición de la EE en las actividades industriales está despertando el interés de los tomadores de decisiones. Teniendo en cuenta estos antecedentes, herramientas tales como sistemas de gestión de la energía (SGEn), auditorías energéticas frecuentes y certificaciones internacionales pueden contribuir a la consecución de un ahorro de energía continua y a la mejora del rendimiento energético global de una organización.

En este contexto, el siguiente estudio tiene por objeto la elaboración de la fase de planeación de un SGEn de acuerdo con la norma internacional ISO 50001 para la planta de Robert Bosch Sistemas Automotrices en San Luis Potosí, México (Bosch SLP). Con este antecedente, diferentes actividades se llevaron a cabo como entrevistas con directivos de la administración y miembros del personal de operación, revisión y documentación de los datos energéticos ya existentes, así como la adquisición de nuevos datos de energía a través de un analizador de energía. Algunos aspectos se analizaron únicamente a nivel de proceso, mientras que otros, a nivel de planta.

De acuerdo con los objetivos propuestos en el estudio la primera parte se centra en todos los conceptos importantes relacionados con la gestión de la energía. Se presentaron modelos como el ciclo Planificar-Hacer-Verificar-Actuar (PDCA por sus siglas en inglés) en relación con la norma ISO 50001.

A lo largo de la tesis, se describe una guía general para la implementación de un SGEn, mostrando la fase de planificación del ciclo PDCA. Después de la presentación de la Robert Bosch GmbH en su conjunto y la planta de Bosch SLP con mayor detalle, las directrices propuestas por la norma ISO 50001 se aplican para el caso de estudio.

En este contexto, las políticas energéticas para Bosch SLP se elaboraron y una distribución potencial de las responsabilidades fue asignada a los diferentes departamentos. A continuación se realizó una auditoría energética detallada a nivel de proceso y los datos obtenidos fueron utilizados para identificar áreas de oportunidad y establecer una línea de base de energía, así como objetivos y metas de gestión de energía. Los datos de energía ya existentes de facturas de servicios públicos se reorganizaron y se analizaron, con el fin de realizar una revisión de la energía a nivel de planta. Como paso final de la fase de planificación se propuso un plan de acción, únicamente a nivel de planta ya que el objetivo general para el futuro debería ser duplicar la auditoría energética detallada para toda la planta. Como parte del plan de acción, se sugirieron una variedad de recomendaciones relativas a las medidas de ahorro de energía y actividades adecuadas, necesarias para la ejecución de un SGEn.

Palabras claves: Eficiencia energética, Gestión energética, Sistemas de gestión de la energía, ISO 50001, ciclo PDCA

Abbreviations

Bosch SLP	Robert Bosch Automotive Systems plant, San Luis Potosi
BPS	Bosch Production System
CFE	Comisión Federal de Electricidad
CLP	Customer Service, Logistics and Planning
CNC	Computer Numeric Control
CO_2	Carbon dioxide
CONUEE	Comisión Nacional para el Uso Eficiente de la Energía
CTG	Controlling
DIN	Deutsches Institut für Normung
EB	Energy baseline
EDL-G	Gesetz über Energiedienstleistungen und andere Energieeffizienzmaßnahmen
EE	Energy Efficiency
EMAS	Eco-Management and Audit Scheme
EMO	Energy Management Officer
EMS	Environmental Management System
EnMS	Energy Management System
EnPI	Energy Performance Indicator
ER	Energy representative
EU	European Union
FCM	Facility Maintenance
GHG	Greenhouse gas
GmbH	Gesellschaft mit beschränkter Haftung
HACCP	Hazard analysis and critical control points approach
HSE	Health, Security and Environment
HRL	Human Resources Local
HVAC	Heating, Ventilation and Air Conditioning
I	Current
ICO	Information Communication
IEA	International Energy Agency
ISO	International Organization for Standardization
KG	Kommanditgesellschaft
km	Kilometer
kVA	kilovolt ampere
kW	kilowatts
kWh	kilowatt hour

LED	Light-emitting diode
LGEEPA	Ley General del Equilibrio Ecológica y la Protección al Ambiente
LP gas	Liquid petroleum gas
MAE	Machinery and equipment
MC	Machining Center
MOE	Manufacturing, Organization and Engineering)
MS	Management System
n/a	not applicable
n.a.	not available
NOM	Norma Oficiales Mexicana
OFE-C	Office of Executive - Commercial
OHSAS	Occupational Health and Safety Assessment Series
P	Active power
PDCA	Plan, Do, Check, Act
PF	Power factor
PL	Production line
ppm	parts per million
PROFEPA	Procuraduría Federal de Protección al Ambiente
QM	Quality Management
QMS	Quality Management System
S	Apparent power
S.A. de C.V.	Sociedad Anónima de Capital Variable
SCADA	Supervisory Control and Data Acquisition
SEGAM	Secretaría de Ecología y Gestión Ambiental
SLP	San Luis Potosi
SME	Small and medium-sized enterprise
TEF	Technical Functions
TM	Top Management
UNIDO	United Nations Industrial Development Organization
USA	United States of America
V	Voltage

Table of Content

Acknowledgments I

Abstract II

Resumen III

Abbreviations IV

Table of Content VI

List of Figures IX

List of Tables XI

1 **Introduction** 1
  1.1 **Problem statement** 1
  1.2 **Justification** 3
  1.3 **General objective** 5
    1.3.1 Specific objectives 5
  1.4 **Scope and methodology of the thesis** 6

2 **Conceptual framework** 9
  2.1 **Introduction to energy management** 9
  2.2 **Main norms and standards for energy management around the world** 10
  2.3 **Management Systems** 12
  2.4 **Energy Management and Energy Management Systems** 13
  2.5 **ISO 50001** 15
  2.6 **PDCA-cycle** 17
  2.7 **General requirements of ISO 50001** 18
    2.7.1 Legal requirements Mexico 26
    2.7.2 Legal requirements European Union (Germany) 27
  2.8 **Limitations of ISO 50001** 28
  2.9 **Detailed approach of research project** 28

3 **Application of ISO 50001 (planning phase)** 30
  3.1 **Preparation of PDCA cycle** 31
    3.1.1 Definition of scope and boundaries of the system 31
    3.1.2 Management responsibility 31
    3.1.3 Energy management officer 32
    3.1.4 Energy policy 32
  3.2 **Energy planning** 33

3.2.1 Legal and other requirements 34
3.2.2 Energy review 35
3.2.2.1 Top-down and bottom-up analysis 35
3.2.2.2 Identification of main energy consumers 36
3.2.2.3 Collection of energy consumption data 36
3.2.2.3.1 Power demand profile 37
3.2.2.3.2 Analysis of energy-utility bills 38
3.2.2.3.3 Periodic meter readings 38
3.2.2.3.4 Recording clip-on ammeter 39
3.2.2.3.5 Basic and multi-channel recording power meters 40
3.2.3 Energy baseline (EB) 41
3.2.4 Energy Performance Indicators (EnPIs) 42
3.2.5 Energy objectives and targets 43
3.2.5.1 (Strategic) objectives 44
3.2.5.2 (Operational) targets 44
3.2.6 Action plans 45

4 Industrial case study description 47
4.1 Introduction of the company – Robert Bosch GmbH 47
4.2 Environmental protection – Robert Bosch GmbH 48
4.3 Robert Bosch Mexico 50
4.3.1 Industrial plant in San Luis Potosi, Mexico 51
4.3.2 Environmental protection – Bosch SLP 53

5 Research results of ISO 50001 – planning phase 57
5.1 Preparation Bosch SLP 58
5.1.1 Definition of scope and boundaries Bosch SLP 58
5.1.2 Management responsibility Bosch SLP 60
5.1.3 Energy management officer Bosch SLP 61
5.1.4 Energy policy Bosch SLP 62
5.2 Energy planning Bosch SLP 62
5.2.1 Legal and other requirements Bosch SLP 62
5.2.2 Energy review Bosch SLP 63
5.2.3 Collection of energy consumption data Bosch SLP 66
5.2.4 Energy baseline Bosch SLP 71
5.2.5 Energy performance indicators Bosch SLP 76
5.2.6 Energy objectives and targets Bosch SLP 83
5.2.7 Action plan Bosch SLP (Recommendations) 87

5.3 Final company report 90

6 Steps towards the full implementation of ISO 50001 in Bosch SLP 92

6.1 Progress of the planning phase in Bosch SLP 92

6.2 Other phases of ISO 50001 98

6.2.1 Do phase 98

6.2.2 Check phase 99

6.2.3 Act phase 101

6.3 Assumptions regarding the successful implementation of an EnMS 102

Conclusions and recommendations 104

References 110

Annex I 118

Annex II 121

Annex III 127

List of Figures

FIGURE 1: ENERGY MANAGEMENT SYSTEMS 14
FIGURE 2: ISO 50000 FAMILY 17
FIGURE 3: MODEL ENERGY MANAGEMENT SYSTEM 18
FIGURE 4: ISO 50001 PROCESS MODEL BASED ON PDCA CYCLE DEMONSTRATING THE DIFFERENT LEVEL OF APPLICATION 29
FIGURE 5: METHODOLOGY FLOW CHART 30
FIGURE 6: ENERGY AUDITING AND PLANNING PROCESS 34
FIGURE 7: RECORDING AMMETER SET-UP FOR SINGLE PHASE MEASUREMENTS 39
FIGURE 8: RECORDING MULTI-CHANNEL POWER METER FOR THREE PHASE MEASUREMENTS 40
FIGURE 9: RELATIONSHIP BETWEEN OBJECTIVES, TARGETS AND ACTION PLAN 43
FIGURE 10: S.M.A.R.T. OBJECTIVES AND TARGETS 44
FIGURE 11: FORMULATION OF ENERGY TARGETS AND OBJECTIVES 45
FIGURE 12: ROBERT BOSCH GMBH LOGO 47
FIGURE 13: SECTORIAL PERCENTAGE REGARDING THE CORE SECTORS OF THE COMPANY 48
FIGURE 14: ROBERT BOSCH GMBH INDUSTRIAL SITES IN MEXICO 51
FIGURE 15: BOSCH SLP INTERNATIONAL CUSTOMERS FOR THE CHASSIS SYSTEMS CONTROL DIVISION 52
FIGURE 16: BOSCH SLP INTERNATIONAL CUSTOMERS FOR THE GASOLINE SYSTEMS DIVISION 52
FIGURE 17: PRODUCTS AND BUSINESS UNITS BOSCH SLP 53
FIGURE 18: ISO 50001 PROCESS MODEL BASED ON PDCA CYCLE DEMONSTRATING THE DIFFERENT LEVEL OF APPLICATION 58
FIGURE 19: BOSCH SLP PLANT OUTLINE 59
FIGURE 22: ELECTRONIC THROTTLE BODY BEFORE 60
FIGURE 23: ELECTRONIC THROTTLE BODY AFTER ROUGHING PROCESS 60
FIGURE 24: ORGANIZATION CHART BOSCH SLP 61
FIGURE 25: INFORMATION PLATE HÜLLER HILLE SPECHT Z500 BOSCH SLP 65
FIGURE 26: ENERGY UTILITY BILL BOSCH SLP 67
FIGURE 27: DEMAND PROFILE OF TOTAL MONTHLY ENERGY CONSUMPTION IN CORRELATION TO COST 68
FIGURE 29: CONNECTION OF DRANETZ POWER GUIDE 70
FIGURE 30: POWER DEMAND PROFILE FOR THE MC 1 PRODUCTION LINE IN BOSCH SLP ... 71
FIGURE 31: ENERGY CONSUMPTION PER UNIT PRODUCED 77
FIGURE 32: TOTAL AVERAGE POWER FACTOR BOSCH SLP PLANT 78

FIGURE 33: TOTAL AVERAGE POWER PER HOUR MC 1 PRODUCTION LINE BOSCH SLP 79
FIGURE 34: TOTAL AVERAGE POWER FACTOR MC 1 PRODUCTION LINE BOSCH SLP 80
FIGURE 35: ENERGY COST PER HOUR OF CONSUMPTION MC 1 PRODUCTION LINE BOSCH SLP 81
FIGURE 36: PRODUCTION MC 1 PRODUCTION LINE BOSCH SLP 82
FIGURE 37: COST PER UNIT PRODUCED MC 1 PRODUCTION LINE BOSCH SLP 83
FIGURE 38: PROGRESS OF ISO 50001 PLANNING PHASE FOR BOSCH SLP 96

List of Tables

TABLE 1: HISTORY OF ENERGY MANAGEMENT SYSTEMS 11
TABLE 2: COMPARISON OF ISO 50001, ISO 14001 AND ISO 9001 MANAGEMENT SYSTEMS 15
TABLE 3: ISO 50001 REQUIREMENTS 19
TABLE 4: INFORMATION OBTAINED FROM DEMAND PROFILE........ 37
TABLE 5: INSTALLATION PROCEDURE OF RECORDING CLIP-ON AMMETER 39
TABLE 6: INSTALLATION PROCEDURE OF BASIC AND MULTI-CHANNEL RECORDING POWER METERS........ 41
TABLE 7: PRINCIPLES OF WORK SAFETY AND ENVIRONMENTAL PROTECTION ROBERT BOSCH GMBH 49
TABLE 8: ENVIRONMENTAL POLICY BOSCH SLP 55
TABLE 9: ENERGY POLICY FOR BOSCH SLP 62
TABLE 10: LEGAL ENERGY REGISTER BOSCH SLP 63
TABLE 11: BOSCH SLP PLANT ELECTRICAL ENERGY REVIEW 2015........ 64
TABLE 12: ENERGY BASELINE BOSCH SLP – PLANT LEVEL 73
TABLE 13: ENERGY BASELINE BOSCH SLP – AREA OR SECTOR LEVEL........ 74
TABLE 14: ENERGY BASELINE BOSCH SLP – PROCESS LEVEL 75
TABLE 15: ENERGY RATE AND SCHEDULE APPLICABLE FOR BOSCH SLP 80
TABLE 16: ENERGY MANAGEMENT OBJECTIVES TEMPLATE 86
TABLE 17: ACTION PLAN BOSCH SLP (PART 1) 88
TABLE 18: ACTION PLAN BOSCH SLP (PART 2) 89
TABLE 19: SELF-EVALUATION CHECKLIST ISO 50001 PLANNING PHASE BOSCH SLP 93
TABLE 19: DETAILED OVERVIEW OF DO PHASE PROCEDURES 99
TABLE 20: DETAILED OVERVIEW OF CHECK PHASE PROCEDURES 100
TABLE 21: DETAILED OVERVIEW OF ACT PHASE PROCEDURES........ 102

1 Introduction

1.1 Problem statement

In current times, energy has become a global issue and a high-profile focal point of public discussions. Especially industrial activities and consequently economic growth are highly dependent on a secured energy supply. Due to a growing global energy demand accompanied by rising energy costs, energy efficiency (EE) is an important priority for the global economy. EE and conservation measures not only have impacts on an improved energy performance, or on the reduction of operating costs, but also contribute to the creation of environmentally friendly processes; therefore they are very interesting for many industrial companies (ISO, 2015). According to the International Energy Agency (IEA), EE is considered as one of the most important and least costly concepts for the reduction of greenhouse gas (GHG) emissions (IEA, 2008).

Industrial activities play an important role in the context of environmental pollution causing severe impacts on ecosystems as well as on society with local, regional and global effects especially, if preventive measures are not taken into account. Those impacts can be primarily triggered by high resource consumption on the one hand, and high emission rates on the other (HALILA & TELL, 2013). Most carbon dioxide (CO_2) emissions in the manufacturing sector are generated directly through CO_2 intensive processes, or indirectly through the consumption of fossil fuels such as coal, petroleum or natural gas for energy production, that release high percentages of CO_2 (FISCHEDICK et al., 2014).

The pressure on companies to act sustainably increases rapidly due to new environmental requirements as well as market competition and consumer behavior. Companies need to be aware of their environmental impact in order to respond to legal changes, and to meet the demand for environmentally friendly products and production techniques (RADONJIC & TOMINC, 2007). In order to reduce CO_2 emissions and high production costs, enterprises are constantly searching for possibilities to implement best practices, for example through the implementation of energy saving measures or energy efficient processes (KISSANI & MOKRINI, 2013).

To achieve a sustainable development it is a key to implement the use of cleaner energy resources, and more energy efficient processes in the industrial sector while simultaneously keeping it profitable. The implementation of energy management systems (EnMS) can be an important and cost-effective tool to contribute to the reduction of industrial energy consumption, and simultaneously CO_2 emissions. EE has played an important role in different industrial sectors in the past decades, but still counts with a high potential that can be exploited in the future (FISCHEDICK et al., 2014; WORRELL et al., 2009). The IEA mentions the importance of EE for a sustainable energy future and states some benefits associated with the topic that are specified as follows:

- Reduction of energy consumption
- Increase in economic growth
- Creation of job opportunities
- Creation of investment opportunities
- Reduction of GHG emissions and air pollutants
- Decrease in fuel expenditures
- Improvement of energy security (IEA, 2014)

An important challenge for the future will be to increase the efficiency of production, distribution, and consumption of energy that will then contribute to the reduction of costs as well as decrease environmental impacts. For that reason, it can be stated that EE has benefits on economic competitiveness, the environment and health (KRARTI, 2000).

As part of the opening gap between increasing pollution rates and self-recovery processes of the environment, the focus on environmental management has become more intense over the last decades. The investment in the implementation of GHG reduction programs is often promoted by consumer preferences, costs, competitiveness and government regulation (BERNSTEIN et al., 2007). Growing complexity, extent and significance of environmental questions also take part in the increasing importance of energy management as part of an environmental management strategy (WAGNER & SCHALTEGGER, 2002).

The Robert Bosch GmbH has taken the decision to define climate protection as a corporate goal, integrating CO_2 reduction programs in different production locations around the world. The company's target is to reduce relative CO_2 emissions (total CO_2 emissions (t) in relation to internal activity) by 35% compared to 2007, and improve EE by 20%, both until 2020 (Bosch, 2015b, 2016b, B. SCHWAGER, personal communication, March 18th, 2016).

The Robert Bosch Mexico Automotive Systems plant in San Luis Potosi, Mexico (Bosch SLP), is participating in the reduction goal of the company, and is investing in the elaboration of CO_2 reduction measures. Environmental certifications such as, *ISO 14001* and *Industria Limpia* are improving the environmental performance of the Bosch SLP plant, however, those certifications do neither evaluate energy consumption nor CO_2 emissions of individual processes. Basic actions such as the replacement of the lighting installations have already been implemented, nonetheless, are not sufficient for noticeable changes in energy consumption. Thus, the present study will elaborate the planning phase of an EnMS in the Bosch SLP plant, exemplary demonstrating a detailed energy audit in the machining center (MC) 1 located in the Manufacturing, Organization and Engineering (MOE) 3 production area. The EnMS is based on the guidelines established by the International Organization for Standardization (ISO) for the international standard ISO 50001. Consequently, actual benefits, disadvantages and methods as well as potential challenges will be examined throughout the project. Clear, direct and simple strategies will be implemented to contribute to energy savings while taking into account the profitability of all introduced measures.

ISO 50001 is based on the principle of continuous improvement represented through a Plan-Do-Check-Act (PDCA) method (KAHLENBORN, KABISCH, KLEIN, RICHTER, & SCHÜRMAMM, 2012). The present study will only focus on the “planning” phase of the PDCA cycle, and solely considers electrical energy as it will address issues such as: the formulation of energy policies for the plant; the formulation of energy objectives and targets; data collection; data analysis, among others. To assess the EE, energy performance indicators (EnPI) will be proposed, that will act as references to identify energy opportunity areas in the production process. The management is therefore able to contemplate the obtained information in the plant’s development and extension.

1.2 Justification

Due to the ongoing elevation of CO_2 concentrations in the atmosphere, caused primarily by human activities such as industrial processes, it is particularly important that companies contribute self-motivated to the reduction of their own CO_2 emissions for example through EE measures, creating environmental consciousness, and implementing sustainability in their “code of business conduct” and compliance policy. The introduction of sustainability measures often takes place through legal enforcement or requirements, or results through profit opportunities for the organization such as fiscal incentives, possible emission trading opportunities or increased economic competitiveness (KAHLENBORN et al., 2012).

In the context of climate change and sustainability, “companies should not be deterred from doing what is possible today, regardless of existent or nonexistent globally defined objectives and policies. This ensures competitiveness, because such actions correspond to a common business logic. All those companies are heading towards greater sustainability due to the enhancement of feasible measures. In cases where this dynamic does not develop by itself, governmental or intergovernmental guidelines are required, supported by possible *coalitions of like-minded* in the international arena" (Prof. Dr. Klaus Töpfer, founding director of the Institute for Advanced Sustainability Studies Potsdam) (BOSCH, 2012).

Therefore it is crucial to mention that EE measures not only contribute to the reduction of GHG emissions, but can also increase the competitiveness of an organization. The formation of an EnMS can be seen as a principle step in the identification process of opportunity areas and related capital allocation procedures (OECD, 2014).

"By implementing an EnMS to improve energy performance, companies also optimize their industrial systems and improve overall monitoring of system efficiencies. Subsequent productivity benefits for companies using an EnMS can also include enhanced production and capacity utilization, reduced resource use and pollution, and lower operation and maintenance costs, all of which result in increased value generation, and thus competitiveness, for the company." (OECD, 2014)

The elaboration of the planning phase of an EnMS according to ISO 50001 will contribute to quantify the energy consumption of the Bosch SLP plant as well as in more detail, of the elected production process. Additionally it will help with the improvement of different areas regarding energy management such as data documentation or the division of tasks and responsibilities related to that aspect. The underlying purpose is the successful replication of the applied method in other production processes in the future, to receive a more detailed result of energy consumption in the Bosch SLP plant. An established EnMS can function as an efficient tool, managing environmental as well as cost related aspects and future decision-making processes. It will also contribute to the general target of the Bosch SLP plant to generate less than 135,9 units (tons/internal activity) of relative CO_2 emissions per month. The total quantity of CO_2 generated in Bosch SLP is calculated taking into account the consumption of electricity, natural gas, liquid petroleum gas (LP gas) and fuel used for company cars (BOSCH, 2013C, 2015D). The core aspects of the justification for this thesis project are summarized as follows:

- ✓ An EnMS will contribute to the elaboration of energy policies for Bosch SLP, which have to be included in the plants compliance policy and respected in all decision-making processes.

- ✓ A detailed energy audit for the MC 1 of the MOE 3 area, as part of the planning phase for an EnMS, will help to identify main variables and data related to energy consumption of the production process.
- ✓ A detailed energy audit will help to identify energy consumption related characteristics and patterns of the MC 1 of the MOE 3 area.
- ✓ The elaboration of the planning phase of an EnMS according to ISO 50001 will function as the base of the implementation process, providing all necessary information of the initial situation of the system and will serve as the baseline for EE measures in Bosch SLP.

1.3 General objective

The general objective of this research is to elaborate the planning phase of an EnMS according to the ISO 50001 framework for Bosch SLP, exemplary performing a detailed energy audit of the MC 1 process, while providing direct and feasible strategies to improve the plant’s EE.

1.3.1 Specific objectives

In order to contribute to the achievement of the general objective, the following specific objectives have been established:

- To introduce and describe all relevant terms and concepts related to EnMS such as:
    - International norms and standards related to energy management
    - The ISO 50001 framework
    - Legal requirements related to EnMS in Mexico as well as in the European Union (EU)
- To describe Bosch SLP regarding:
    - Present management and operation functions
    - Internal business regulations regarding EnMS
    - Current environmental certifications applied in the plant
- To develop a methodology to outline the planning phase of an EnMS including:
    - Elaboration of energy policies for the Bosch SLP plant
    - Development of strategic energy objectives for the Bosch SLP plant

    - Development of operational energy targets for the Bosch SLP plant
    - Realization of a detailed energy audit for the MC 1 process
    - Identification of opportunity areas in the manufacturing process that are beneficial for energy savings
- To determine EE operations and processes:
    - Recommendations of possible implementations suitable for energy savings
    - Elaboration of an energy action plan for the Bosch SLP plant
- To review the established methodology according to its transferability

1.4 Scope and methodology of the thesis

The present section of the thesis will give a rough overview of the scope and methodological approach of this study. A more detailed approach of the research project is provided in Subchapter 2.9 after the fundamental principle of the study have been determined throughout Chapter 2. The methodology of this study was divided into various activities, including but not limited to ISO 50001 guidelines that were carried out in order to fulfill each of the objectives that have been planted. At the beginning of the study information and data was collected from a variety of reliable sources such as peer-reviewed literature for example scientific articles as well as international guidelines for EnMS requirements and implementation procedures. Some keyword in the research process included:

- Energy Management Systems
- EnMS evaluation methods
- EU legal framework on energy management
- Mexican legal framework on energy management
- ISO 50001 guidelines

Other information, e.g. already existing international as well as plant specific internal policies or requirements regarding energy management, was obtained through expert interviews with carefully selected personnel of the corporation. Since the whole research process was accompanied by a professional internship in the Bosch SLP plant some information was also obtained through personal observation and conversation with responsible staff members. The continuous presence in the plant made it possible to get a deeper impression of the day-to-day operations and process structures.

The ISO 50001 guidelines presented in Chapter 3 represent an applied procedure used as part of the methodological approach of the thesis. In this context a variety of steps were executed, e.g. the performance of an energy audit as well as the collection of information regarding production volume and energy consumption. In a further step the obtained information was analyzed and used for the development of an energy baseline (EB), EnPIs and an action plan for the implementation of an EnMS in the Bosch SLP plant.

The study is divided into six chapters with the first and present one introducing the problem statement. The focus lies on the importance of energy in the global market while later introducing EnMSs as useful tools to improve the EE of an organization. General and specific objectives of the case study are presented afterwards.

Chapter 2 presents a conceptual framework regarding management systems and their certifications in general, while putting special emphasis on EnMSs according to ISO 50001. General requirement for ISO 50001 certifications are portrayed accompanied by the description of concepts such as the PDCA-cycle. Additionally some limitations of ISO 50001 are displayed followed by a description of the current legislations regarding EE and EnMSs in the EU (Germany) and Mexico. Towards the end of the chapter, the approach of the research project is described in detail, clarifying the different perspectives and levels of application of the study.

The thesis focuses in detail on the application of ISO 50001 – planning phase in Chapter 3, explaining the different steps of preparation followed by a complete introduction of the planning phase of the international standard. In addition to the ISO 50001 guidelines, some tools and devices of energy assessment procedures such as multi-channel power meters are presented that were used during the project.

The case study is presented in Chapter 4. First introducing the Robert Bosch corporation in general while giving an overview of the company's operations. Subsequently, Mexico as a production location is introduced, displaying a variety of industrial sites located in the country. In this context, the plant in San Luis Potosi (SLP) and its production branches are presented while putting special emphasis on the environmental protection strategies and programs of Bosch SLP.

The different steps of the planning phase introduced in Chapter 3 are linked and applied to the case study of Bosch SLP in Chapter 5. Data obtained throughout the investigation project is presented and analyzed. Furthermore, documentation gaps are identified and proposals are made to add and complete missing information. Thereby it is important to mention that the methodological approach used for the study case only focuses on process-oriented not product-oriented measures.

Chapter 6 provides an overview of future steps linked to the PDCA cycle as well as on the progress of implementation in the Bosch SLP plant. The chapter seeks to amplify the discussion of EnMS and to examine the advantages and disadvantages from a different angle in order to finally conclude this study and provide recommendations for future investigation.

2 Conceptual framework

2.1 Introduction to energy management

The concept of EE is interpreted differently throughout international literature. OECD & IEA (2014) for instance present the following definition: “Energy efficiency means using less energy for the same or even increased output.” While IRREK & THOMAS (2008) elaborate more on the topic by saying: “While effectiveness refers to the degree of achievement of an activity, efficiency refers to the relationship between benefits and costs. Energy efficiency thus refers to the ratio of gained benefits and energy used. Measured here is usually not the absolute energy efficiency, but the percentage of energy savings or the absolute energy savings achieved.”

In general EE and related strategies are often seen as important and profitable concepts when reducing industrial energy consumption and CO_2 emissions. Arguments in favor of the mentioned implementations usually assume that technical modifications in the production equipment are main drivers of an increase in EE, simultaneously leading to a reduction of energy consumption (GHOSCH & BLACKHURST, 2014).

The United Nations Industrial Development Organization (UNIDO) stated that industrial EE is, especially in many developing countries, overlooked by governmental institutions, resulting from the assumption that companies will modify their energy consumption patterns as a result of external pressures such as market competition, final consumer preferences or higher energy prices. However, those external pressures cannot solely result in an increase of EE within an organization. Especially the lack of energy oriented operational practices and management structures are some of the main obstacles to overcome in the long run (MCKANE, PRICE, & DE LA RUE DU CAN, 2008). STERN (2012) mentioned that the majority of attempts to reduce and improve energy consumption in organizations have been focused on the adjustment, optimization and modification of the existing “hardware”, such as machinery, process layouts or the substitution of isolation materials, among others. Nevertheless, focusing exclusively on the improvement and replacement of existing hardware is not sufficient to improve EE noticeably. According to THOLLANDER & PALM (2013) improving the energy management of an organization can contribute to a reduction in energy consumption between 4 and 40%. In a different study TSUNG-YUNG, SHANG-LIEN, & YUNG-YIN (2012) claim that an ISO 50001 energy management system can contribute to efficiency gains of about 2-5%. Additionally, the authors mention the advantages of system optimization measures linked to the implementation of an EnMS resulting in efficiency gains up to 20-30%. Finally, they suggest that the ISO 50001 standard could potentially diminish global energy consumption by approximately 60%. Therefore, the implementation of new management tools like EnMSs can contribute significantly to the identification of opportunity areas to reduce energy consumption within an organization.

While EE is repeatedly seen as an important aspect of sustainability, some authors like Ghosch & Blackhurst (2014) and Hanley, McGregor, Swales, & Turner (2009) criticize however the contribution of EE to the reduction of the total energy demand. On a macroeconomic level, EE measures tend to decrease energy prices making energy consumption more attractive to consumers and resulting in the so called “rebound” or “backfire” effect. The mentioned concept implies, that all energy consumption savings reached through the implementation of EE measures in the industrial sector do not automatically guarantee the reduction of net energy consumption. Since cutbacks in the energy consumption per unit produced in the end allow organizations to produce more units leading to an unchanging overall total energy consumption for the company. To avoid rebound or backfire effects, consumer behavior plays a crucial role when actually preferring internationally certified companies on the market giving those certification more validity. Therefore, when trying to “reduce […] energy costs, carbon emissions, improve the reputation of [an] organization, and develop a deeper understanding of an internationally recognized energy management” (Krstinić-Nižić & Bračić, 2014) the implementation of international standards such as ISO 50001 can be helpful.

2.2 Main norms and standards for energy management around the world

Since energy management started to become an international concern in the industrial sector, due to the necessity to reduce energy consumption and GHG emissions or to save costs, several national and international frameworks and standards have been established to assist in the implementation process of energy saving measures (Hkeia, 2013).

Over the last 10 years, many countries have included energy laws into their legislation, also focusing on the aspect of EE. Usually energy laws give a legal framework with mandatory policies, regulating for instance energy savings obligations (World Energy Council, 2013). The majority of those frameworks were initially implemented in developed countries. Australia firstly established an energy management program in 1990, while the United States of America (USA) pioneered in 2000 with the adoption of a voluntary standard for energy management systems (ANSI/MSE 2000). Denmark was the first European country to develop a national norm for energy management in

2000. In 2003, 2005 and 2007 Sweden, Ireland and Spain followed among others, as can be seen in Table 1 (KAHLENBORN et al., 2012).

Table 1: History of energy management systems (HERNÁNDEZ-PINEDA, CARMONA-VÁZQUEZ, FLORES-DÍAZ, & SOSA-GRANADOS, 2014)

History of EnMS	
1970	Oil crisis. Production management and purchase of energy, energy services and energy conservation.
1988	Industries begin to develop energy efficiency programs.
1990	**Australia**: AS 3595. Energy Management Programs - A Guide for financial project evaluation.
1992	**Australia**: AS 3596. Energy Management Programs - A Guide for definition and analysis of energy and cost savings.
1995	**USA**: ANSI 739. IEEE practical recommendation for Energy Management in industrial and commercial facilities. **Canada**: Plus 1140. Guide for voluntary energy management. **China**: GB/T 15587. Guide to energy management in industrial enterprises.
2000	**USA:** ANSI/MSE 2000: 2000
2001	**Denmark**: DS 2403:2001
2003	**Sweden**: SS 627750:2003
2005	**Ireland**: I.S. 393:2005 **Holland**: Energy management system – A Guide for use
2007	**Spain**: UNE 216301:2007 **South Korea**: KSA 4000:2007 **Germany**: Energy management – Terms and definitions
2009	**South Africa**: SANS 879:2009 **China**: GB/T 23331:2009 **Europe**: EN 16001:2009
2011	International Standard ISO 50001:2011 **Mexico**: NMX-J-SAA-50001-ANCE-IMNC-2011

Consequently, many different standards, norms and voluntary guidelines exist with regard to energy management on a global scale. In general, all follow a set of requirements that have to be accomplished in order to receive a certification, containing for example the organization of documents, the elaboration of an action plan, etc. (HOLBROOK, 2009).

An organization can only receive a certification once an authorized auditor has verified that the organization has fulfilled all necessary requirements. In order to guarantee an objective, effective and correct certification process, an impartial third-party certification agency should perform the verification of the system (TSUNG-YUNG et al., 2012). The most common standard used for the certification of an EnMS is the International Organization for Standardization's draft of *ISO 50001 – Energy Management System* released in June 2011, establishing for the first time international standards for EnMSs (HERNÁNDEZ-PINEDA et al., 2014; KAHLENBORN et al., 2012).

In this context, the ISO 50001 norm can be pointed out as the most popular, certified and implemented standard since its release in 2011, and is mentioned with more detail in Subchapter 2.5.

2.3 Management Systems

Every organization, independent from its size, complexity or purpose, has some kind of management system (MS). It can be informally or formally implemented in the organization's structure, but every systematic regulation of an organization can be seen as a MS. The main purpose of any MS is the systematic completion and controllability of organizational goals in any process stage. Correctly implemented MSs contribute to the improvement and development of a strategic organizational structure in a company regarding market, clients, shareholders, society and government. The foundation of any MS lies with the definition of responsibilities, competence, operational procedures and monitoring systems to determine the completion of company goals (KAHLENBORN et al., 2012).

The first standardized approaches for MSs were developed in the 1970s as part of Quality Management (QM). In the 1980's, the first international standards for QM were published as the ISO 9000 norm series, focusing on the implementation of a Quality Management System (QMS). In the early 90's, more guidelines for specialized MSs were introduced, such as:

- British Standard BS 8800
- Occupational Health and Safety Assessment Series (OHSAS) 18001 as a MS for work safety
- Hazard analysis and critical control points approach (HACCP) for hygiene management
- Eco-Management and Audit Scheme (EMAS) and ISO 14001 for the implementation of environmental management systems
- 9100 A and 9100 B of the American Petroleum Institute for occupational safety, environmental protection and plant safety (KAHLENBORN et al., 2012)

The international standard ISO 14001 is predominantly focusing on the implementation of Environmental Management Systems (EMS) in an organization in order to improve its environmental performance (KAHLENBORN et al., 2012). EMAS was developed by the EU and exceeds the ISO 14001 norm in various aspects such as employee involvement, external communication with the public, continuous improvement of environmental performance, compliance with environmental legislation ensured by government supervision (UGA, 2015).

The standards for MSs should not be considered separately, but rather linked. Therefore the structure of the environmental management standard ISO 14001 corresponds to the structure of the quality management standard ISO 9001, and ISO 14001 simultaneously serves as the basis for EMAS. The structure of the international standard ISO 50001 for EnMSs was also developed based on that principle (HKEIA, 2013).

2.4 Energy Management and Energy Management Systems

Energy management includes all measures that are planned and implemented in order to guarantee the execution of required performances at a minimum energy input rate (DENA, 2009).

The EnMS has an influence on organizational and technical processes and behaviors to reduce the total energy consumption (including energy required for the production process) under economic aspects. It also contributes to the systematic collection of data concerning energy flows and usage as a basis for the decision-making process of investments to improve EE. A working EnMS supports the company with the compliance of energy policies and the continuous improvement of its energy performance. The formulation of an energy policy (including the strategic and operational goals as well as action plans), the planning, implementation and operation, monitoring and measuring, control and correction, internal audits and periodic reviews are all parts of an EnMS (KAHLENBORN et al., 2012). The following figure displays some positive aspects of an EnMS.

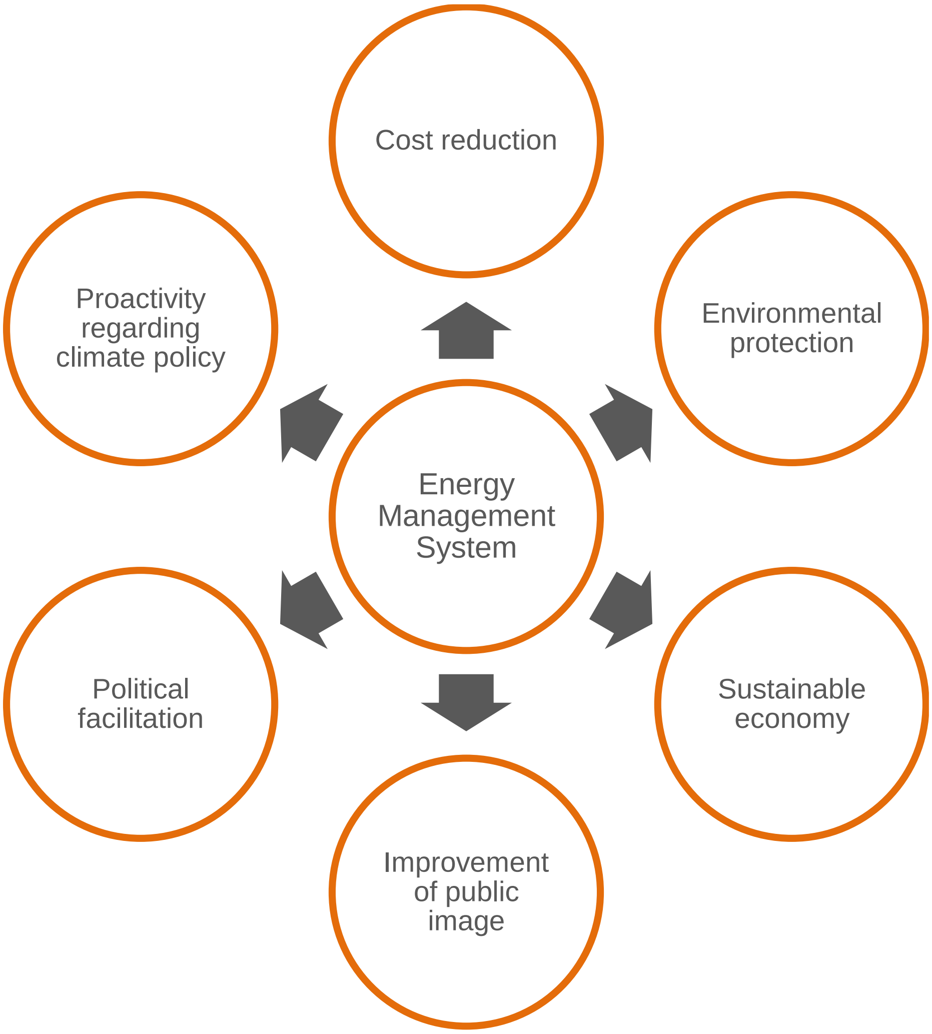


Figure 1: Energy Management Systems (own elaboration based on KAHLENBORN et al., 2012)

The implementation of an EnMS according to ISO 50001 offers additional advantages to any organization. Those advantages include:

- "Helping to achieve energy use reduction and carbon emissions in a systematic way
- Creating a clear picture of current energy use status, based on which new goals and targets can be set
- Evaluating and prioritizing the implementation of new energy efficient technologies and measures
- Providing a framework to promote energy efficiency throughout the supply chain

- Providing guidance on how to benchmark, measure, document and report corporate energy use
- Making better use of energy consuming assets, thus identifying potentials to reduce maintenance costs or expand capacity
- Demonstrating to the stakeholders that corporate commitment to comply with their best practice to protect the environment
- Fulfilling the associated regulatory requirements and responding with confidence to green trade barriers in global markets" (TÜV NORD, 2014).

2.5 ISO 50001

ISO 50001 is considered a new member of the international standards family and was developed by the ISO Projects Committee of Energy Management (ISO/PC 242). Its overall objective is to improve the energy performance and EE of an organization by introducing a standardized and process-based energy management structure. The ISO 50001 has been designed to assure a high level of compatibility among different standards, particularly with the areas of Quality and Environmental Management. Therefore common aspects already implemented in other ISO management system standards like ISO 9001 and ISO 14001 were considered in the design process (HKEIA, 2013; KAHLENBORN et al., 2012; TÜV NORD, 2014). Globally, more than 7,300 industrial sites are certified through ISO 50001 (status as of 2014) (EERE, 2014).

In the following, Table 2 gives a general overview of the differences between the standards ISO 50001, ISO 9001 and ISO 14001.

Table 2: Comparison of ISO 50001, ISO 14001 and ISO 9001 Management Systems (HKEIA, 2013; TÜV NORD, 2014)

Content	ISO 50001	ISO 14001	ISO 9001
Core concept for establishing guidelines	Based on energy consumption of the whole organization or particular production process	Based on relevant environmental aspects	Based on clients' quality requirements
Policy	Energy policy illustrates the strategy of the organization on energy management. The policy provides the frame for setting up associated	Environmental policy illustrates how the organization handles environmental matters, commitment to environmental	Meet the clients' requirements

	objectives and targets to enhance energy performance.	protection, as well as associated objectives and targets. Normally the policy will include the organizations' commitment to preventing pollution, regulatory compliance and continuous improvement.	
Strategy	Conducting energy reviews to identify significant energy use activities and set up an EB, as well as energy performance indicators Compliance to relevant regulatory requirements and setting up energy objectives, targets, and implementation plans	Compliance to relevant environmental regulatory requirements Setting up environmental objectives, targets and implementation plans	Setting up quality objectives, targets, and quality management plans
Baseline	EB is foundational to establish the system.	No such requirement	No such requirement

Since 2014, the ISO 50000 series was expanded by a variety of norms related to the implementation process of an EnMS. They were designed to give a more detailed overview of the different steps needed when implementing the requirements of an EnMS based on ISO 50001 and guides the organization to take a systematic approach in order to achieve continual improvement in energy management and energy performance (ISO, 2014). The following figure gives an overview of the ISO 50000 family, highlighting the norms related to the planning phase of an EnMS as red-marked areas.

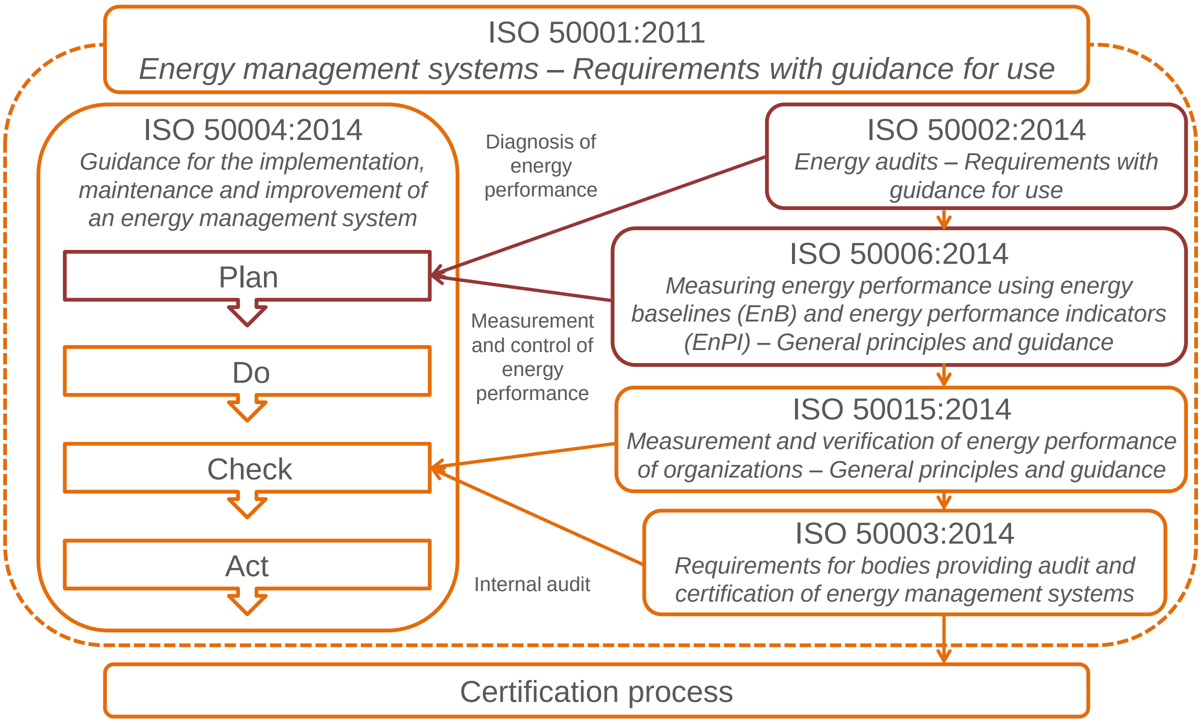


Figure 2: ISO 50000 family (modified according to HERNÁNDEZ-PINEDA et al., 2014)

An EnMS according to ISO 50001 can be implemented in companies and organizations of all industries and sizes. It can be applied independently of other management systems or integrated into existing management systems (KAHLENBORN et al., 2012).

2.6 PDCA-cycle

An EnMS according to ISO 50001 follows the PDCA-cycle (or Deming cycle, named after William Edwards Deming) also applied in other known management systems such as ISO 14001 and ISO 9001. If an organization has already implemented a management system using the PDCA method, it can easily integrate the existing structures in its energy management. The PDCA cycle provides a framework for continual improvement of processes or systems. It is a dynamic model, meaning that the results of one cycle form the basis for the next cycle. This structure allows a company to assess its current energy consumption in order to optimize and gradually decrease costs (KAHLENBORN et al., 2012).

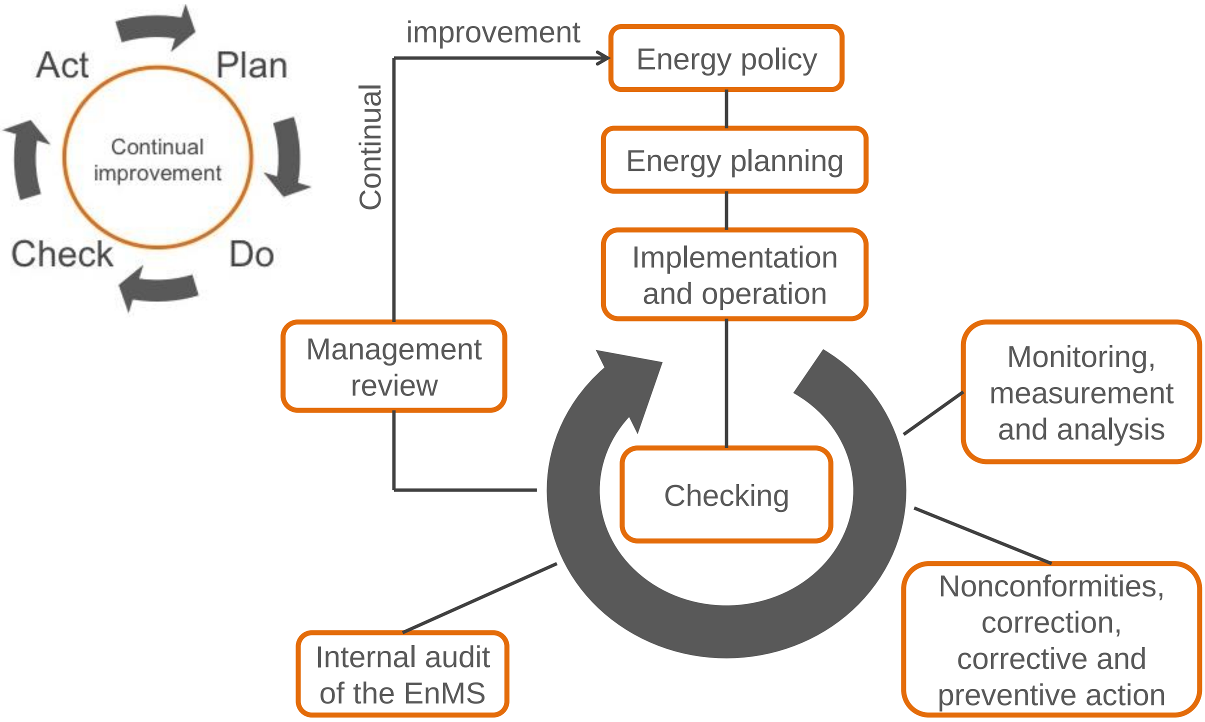


Figure 3: Model energy management system (modified according to ISO, 2011)

The individual steps of the PDCA cycle in energy management can be described according to KAHLENBORN et al. (2012) as follows:

1. Plan: Set energy saving goals, set strategy, define responsibilities and necessary measures, provide required instruments, prepare action plan.
2. Do: Introduce management structures and measures for a continuous improvement process (e.g. efficient technologies/processes).
3. Check: Verification of target achievements and the effectiveness of the EnMS; collection of new ideas via energy audits, possibly involving an external expert.
4. Act: Strategic optimization by combining the current energy data, the audit results and new findings; establishing new objectives.

The mentioned activities can be performed in parallel, and the starting point of the cycle depends on the preconditions of the organization that wants to implement the EnMS.

2.7 General requirements of ISO 50001

In order to successfully implement an EnMS the modification of current institutional energy procedures is often indispensable. Staff members familiar with the implementation of management systems (e.g. ISO 9001 or ISO 14001) can assist with the fulfillment of all requirements necessary, however, usually need a thorough training in the field of EE. External experts can bring valuable knowledge to the implementation process (Huang, 2011). The following table displays the core requirements for the certification of ISO 50001 established by the International Organization for Standardization.

Table 3: ISO 50001 requirements (Iso, 2011)

General requirements
The organization shall:
Establish, document, implement and maintain and improve an EnMS in accordance with the requirements of this International Standard;
Define and document the scope and the boundaries of its EnMS
Determine how it will meet the requirements of this international standard in order to achieve continual improvement of its energy performance and of its EnMS.
Management Responsibility
Top management shall demonstrate its commitment and support the EnMS and to continually improve its effectiveness by:
Defining, establishing, implementing, and maintaining an energy policy
Appointing a management representative and approving the formation of an energy management team
Providing the resources needed to establish, implement, maintain and improve the EnMS and resulting energy performance
Identifying the scope and boundaries to be addressed by the EnMS
Communicating the importance of energy management to those in the organization
Ensuring that energy objectives and targets are established
Ensuring that EnPIs are appropriate to the organization
Considering energy performance in long-term planning
Ensuring that results are measured and reported at determined intervals
Conducting management reviews
Top management shall appoint a management representative(s) with appropriate skills and competence, who, irrespective of other responsibilities, has the responsibility and authority to:
Ensure the EnMS is established, implemented, maintained, and continually improved in accordance with this International Standard

Identify person(s), authorized by an appropriate level of management, to work with the management representative in support of energy management activities
Report to top management on energy performance
Report to top management on the performance of the EnMS
Ensure that the planning of energy management activities is designed to support the organization's energy policy
Define and communicate responsibilities and authorities in order to facilitate effective energy management
Determine criteria and methods needed to ensure that both the operation and control of the EnMS are effective
Promote awareness of the energy policy and objectives at all levels of the organization
Energy Policy
Top management shall define the energy policy and ensure that it:
Is appropriate to the nature and scale of the organization's energy use and consumption
Includes a commitment to continual improvement in energy performance
Includes a commitment to ensure the availability of information and of necessary resources to achieve objectives and targets
Includes a commitment to comply with applicable legal requirements and with other requirements to which the organization subscribes which relate to its energy use, consumption and efficiency
Provides the framework for setting and reviewing energy objectives and targets
Supports the purchase of energy efficient products and services and design for energy performance improvement
Is documented and communicated at all levels within the organization
Is regularly reviewed, and updated as necessary
Energy Planning
Energy planning shall:
Be consistent with the energy policy and lead to activities that continually improve energy performance
Involve a review of the organization's activities which can affect energy performance
The organization shall:
Identify, implement, and have access to the applicable legal requirements and other requirements to which the organization subscribes related to its energy use, consumption and efficiency

Determine how these requirements apply to its energy use, consumption and efficiency and shall ensure that these legal requirements and other requirements to which it subscribes are considered in establishing, implementing and maintaining the EnMS
Review legal and other requirements at defined intervals
Develop, record, and maintain an energy review. The methodology and criteria used to develop the energy review shall be documented
To develop the energy review, the organization shall:
Analyze energy use and consumption based on measurement and other data
Based on the analysis of energy use and consumption, identify the areas of significant energy use
Identify, prioritize and record opportunities for improving energy performance
The organization shall:
Establish an energy baseline(s) using the information in the initial energy review, considering a data period suitable to the organization's energy use and consumption
Measure changes in energy performance against the energy baseline
Maintain an record the energy baseline
Identify Energy performance indicators appropriate for monitoring and measuring its energy performance
Record and regularly review the methodology for determining and updating the
Review and compare EnPIs to the energy baseline as appropriate
Establish, implement and maintain documented energy objectives and targets at the relevant functions, levels, processes or facilities within the organization
Establish time frames for achievement of the objectives and targets
Take into account legal requirements and other requirements, significant energy uses and opportunities to improve energy performance, as identified in the energy review
Consider its financial, operational and business conditions, technological options and the views of interested parties
Establish, implement and maintain action plans for achieving its objectives and targets
The objectives and targets shall be consistent with the energy policy
Targets shall be consistent with the objectives

Implementation and Operation
The organization shall:
Use the action plans and other outputs resulting from the planning process for implementation and operation
Identify training needs associated with the control of its significant energy uses and the operation of its EnMS
Provide training or take other actions to meet these needs
Ensure any person(s) working for, or on its behalf, are aware of: a) The importance of conformity with the energy policy, procedures and the requirements of the EnMS; b) Their roles, responsibilities and authorities in achieving the requirements of the EnMS; c) The benefits of improved energy performance; d) The impact, actual or potential, with respect to energy use and consumption, of their activities and how their activities and behavior contribute to the achievement of energy objectives and targets, and the potential consequences of departure from specified procedures
Communicate internally with regard to its energy performance and EnMS, as appropriate for the size of the organization
Establish and implement a process by which any person working for, or on behalf of, the organization can make comments or suggest improvements to the EnMS
Decide whether to communicate externally about its energy policy, EnMS and energy performance, and shall document its decision. If the decision is to communicate externally, the organization shall establish and implement a method for this external communication
Establish, implement and maintain information, in paper, electronic or any other medium, to describe the core elements of the EnMS and their interaction

Establish, implement and maintain procedure(s) to: a) approve documents for adequacy prior to issue b) periodically review and update documents as necessary; c) ensure that changes and the current revision status of documents are identified; d) ensure that relevant versions of applicable documents are available at points of use; e) ensure that documents remain legible and readily identifiable; f) ensure documents of external origin determined by the organization to be necessary for the planning and operation of the EnMS are identified and their distribution controlled; g) prevent the unintended use of obsolete documents, and suitably identify those to be retained for any purpose
Identify and plan those operations and maintenance activities which are related to its significant energy uses and that are consistent with its energy policy, objectives, targets and action plans, in order to ensure that they are carried out under specified conditions by means of the following: a) establishing and setting criteria for the effective operation and maintenance of significant energy uses, where their absence could lead to a significant deviation from effective energy performance; b) operating and maintaining facilities, processes, systems and equipment, in accordance with operational criteria; c) appropriate communication of the operational controls to personnel working for, or on behalf of, the organization
Consider energy performance improvement opportunities and operational control in the design of new, modified and renovated facilities, equipment, systems and processes that can have a significant impact on its energy performance
Incorporate the results of energy performance evaluation into the specification, design and procurement activities of relevant project
Record the results of the design activity
Inform suppliers that procurement is partly evaluated on the basis of energy performance

Establish and implement the criteria for assessing energy use, consumption and efficiency over the planned or expected operating lifetime when procuring energy using products, equipment and services which are expected to have a significant impact on the organization's energy performance
Define and document energy purchasing specifications, as applicable, for effective energy use
Checking
The organization shall:
Ensure that the key characteristics of its operations that determine energy performance are monitored, measured and analyzed at planned intervals. Key characteristics shall include at a minimum: a) significant energy uses and other outputs of the energy review; b) the relevant variables related to significant energy uses; c) EnPIs; d) the effectiveness of the action plans in achieving objectives and targets; e) evaluation of actual versus expected energy consumption
Define and implement an energy measurement plan, appropriate to the size and complexity of the organization and its monitoring and measurement equipment
Define and periodically review its measurement needs
Ensure that the equipment used in monitoring and measuring of key characteristics provides data which is accurate and repeatable
Investigate and respond to significant deviations in energy performance
Conduct internal audits at planned intervals
Develop an audit plan and schedule taking into consideration the status and importance of the processes and areas to be audited as well as the results of previous audits
Ensure objectivity and impartiality during the selection and conduction of auditors and audits
Report audit results to top management

Address actual and potential nonconformities by making corrections, and by taking corrective action and preventive action, including the following: a) reviewing nonconformities or potential nonconformities; b) determining the causes of nonconformities or potential nonconformities; c) evaluating the need for action to ensure that nonconformities do not occur or recur; d) determining and implementing the appropriate action needed; e) maintaining records of corrective actions and preventive actions; f) reviewing the effectiveness of the corrective action or preventive action taken
Establish and maintain records, as necessary, to demonstrate conformity to the requirements of its EnMS and of this International Standard, and the energy performance results achieved
Define and implement controls for the identification, retrieval and retention of records
Management review
Top-Management shall:
Review the organization’s EnMS to ensure its continuing suitability, adequacy and effectiveness at planned intervals
Inputs to the management review shall include: a) follow-up actions from previous management reviews; b) review of the energy policy; c) review of energy performance and related EnPIs; d) results of the evaluation of compliance with legal requirements and changes in legal requirements and other requirements to which the organization subscribes; e) the extent to which the energy objectives and targets have been met; f) EnMS audit results g) the status of corrective actions and preventive actions; h) projected energy performance for the following period; i) recommendations for improvement

> Outputs from the management review shall include any decisions or actions related to:
>
> a) changes in the energy performance of the organization;
>
> b) changes to the energy policy;
>
> c) changes to the EnPIs;
>
> d) changes to objectives, targets or other elements of the EnMS, consistent with the organization's commitment to continual improvement;
>
> e) changes to allocation of resources

The next sections (2.7.1 & 2.7.2) will give an overview of legal requirements related to EnMS in two different parts of the world in order to contrast opposing legal policies. Mexico was chosen due to its applicability in the Bosch SLP plant and its rather vague legislation concerning EnMS. The EU, especially Germany, was chosen due to its connection with the corporation as a whole, since the Robert Bosch GmbH is a German company, but also to show a more advanced legislation regarding EnMS.

2.7.1 Legal requirements Mexico

Mexico has set ambitious goals, wanting to reduce GHG emissions by 30% until 2020 compared to 2006 (SEMARNAT & INE, 2010). After the transport sector, a reduction of energy consumption in the industrial sector presents one of the greatest opportunity areas for the reduction of GHG emissions. The efficient use of energy resources as well as the implementation of energy savings measures can contribute enormously to the achievement of the mentioned goals (HERNÁNDEZ-PINEDA et al., 2014).

To meet the set objective, the Mexican government has established a mandatory series of policy instruments including the formulation of regulations through Official Mexican Norms (NOM for its abbreviation in Spanish). NOMs are mandatory technical regulations, valid throughout Mexico and represent the basis of the country's EE policy. NOMs in the context of EE assure the entrance of products, equipment and systems with lower energy consumption into the market, and thereby shall contribute to an increase in EE. Today, Mexico counts with 27 NOMs approved by the National Commission for Efficient Energy Use (CONUEE for its abbreviation in Spanish), covering a broad spectrum of products, equipment and systems (CONUEE, 2013).

Despite the existing NOMs in the field of EE, Mexico does not count with existing mandatory regulations regarding EnMSs or energy audits (HERNÁNDEZ-PINEDA et al., 2014). Part V, chapter I of the Law of Sustainable Energy Use (LASE for its abbreviation in Spanish) states in article 26: “Individuals may voluntarily, through the certification of processes, products and services, conduct a methodological review of its operations regarding the incorporation of EE as well as its compliance with international regulations and parameters in order to define preventives and correctives necessary to optimize energy performance.” (PROFECO, 2008)

Therefore every organization can use ISO 50001 voluntarily as a tool to support the implementation of the LASE, however, is not by law obliged to do so (ACOLTZI-ACOLTZI & PÉREZ-REBOLLEDO, 2011).

2.7.2 Legal requirements European Union (Germany)

Germany, together with 27 European partners, agreed to the importance of EE and determined to reduce their primary energy consumption by 20% until 2020 and 50% by 2050, compared to 2008 (KAHLENBORN et al., 2012). At European level, several acts have been adopted in recent years in order to increase EE. In 2012 the EU Commission approved a new Energy Efficiency Directive (2012/27/EU), which entered into force on December 4th of the same year. The Energy Efficiency Directive foresees a number of measures that must be implemented by the member states. Article 8, paragraph 4-7, states that all enterprises (with exception of small and medium-sized enterprises (SMEs)) located in the EU, have the obligation to perform an energy audit. On national level in Germany, the 2010 established law on energy services and other energy efficiency measures (EDL-G for its abbreviation in German) was amended in 2015 as a result of the EU Energy Efficiency Directive, demanding an energy audit for all enterprises (with exception of SMEs) at least every four years as of December 2015. Consequently, organizations will be asked randomly, after a reasonable period of time, to provide evidence that an energy audit has been carried out, or that the organization is exempted from this obligation. Otherwise a fine of up to 50,000 Euro will have to be paid (BAFA, 2015).

The energy audit has to correspond to the requirements of DIN EN 16247-1 (status as of October 2012), and is a prerequisite for the granting of fiscal advantages in Germany (DENA, 2015). According to Article 8, paragraph 1 EDL-G, companies can be exempted from the obligation of performing an energy audit when at the prevailing time either an EnMS according to DIN EN ISO 50001, or an EMS in accordance with the regulation (EG) Nr.1221/2009 of the European Parliament and of the council (EMAS), has been implemented (BAFA, 2015).

2.8 Limitations of ISO 50001

One of the biggest barriers for many organizations is the financial investment related to the implementation of an EnMS. Costs can be generated through external consultants, acquisition of human resources within the organization as well as the acquisition of necessary software and hardware. The deficiency of practical experience can also be considered as a limiting factor for the implementation process of ISO 50001 (MAJERNÍK, BOSÁK, STOFOVÁ, & SZARYSZOVÁ, 2015).

It could be rather difficult to independently self-assess an organization’s EE without enough previous experience in the field of EnMSs. The document issued by the International Organization of Standardization “ISO 50001:2011 Energy management systems – Requirements with guidance for use” provides some important guidelines, however could be insufficient due to its partially unclear and unspecific formulation of the actual procedure (see Table 3).

JOVANOVIĆ & FILIPOVIĆ (2016) argue that although many organizations, especially SMEs, are committed to energy management, aspects such as market pressures or limited financial resources do not allow new investments and limit innovative implementations. Furthermore they discuss the fact that the ISO 50001 standard is solely anticipated for certification, which could lead to a stagnancy in the enhancement of EE. This aspect is however rather a limitation of the organizational system in general and applies for many different certification processes and not exclusively for the ISO 50001 standard.

The implementation process of an EnMS often requires to increase the workload of the current staff or creating new job positions, especially when the organization does not count with another already existing ISO system (REZAEI, CELIK, & BAALOUSHA, 2011).

However, it is crucial to mention, that due to the short history of ISO 50001 more shortcomings and limitations in the implementation process could be identified in the future (MAŇKO & KOŠÍKOVÁ, 2012).

2.9 Detailed approach of research project

After the complete description of all basic principles relevant to the study in the previous subchapters, the current section seeks to clarify the case-specific approach of the research project. The planning stage of an EnMS according to ISO 50001 requires a variety of tasks that have to be fulfilled in order to proceed with the next steps of the PDCA cycle. For the purpose of this study those tasks were evaluated on three different levels: company level, plant level and process level. It is important to mention that not all tasks could be executed on all levels due to the missing applicability. The tasks that could be realized in the implementation process are color-marked according to the level of application as can be seen in Figure 4. Since this study only focuses on the planning phase, the other phases are not further elaborated and marked as *not applicable* (n/a), however, have to be displayed in order to demonstrate the process of continual improvement. Detailed descriptions of the different steps related to the planning phase are presented in Chapter 3.

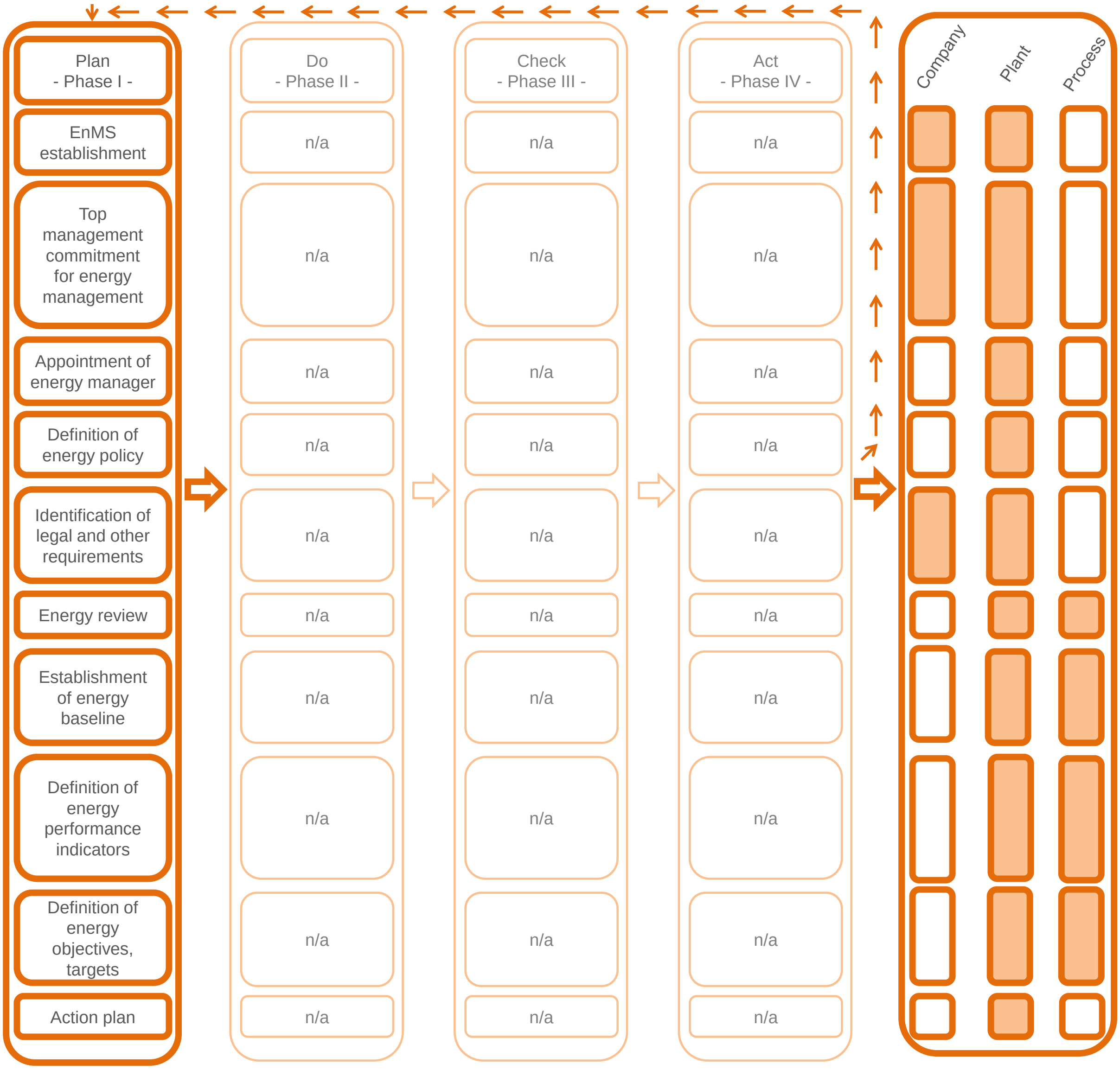


Figure 4: ISO 50001 process model based on PDCA cycle demonstrating the different level of application (modified according to JOVANOVIĆ & FILIPOVIĆ, 2016)

3 Application of ISO 50001 (planning phase)

As part of the methodological approach of this study this chapter will, with greater detail, elaborate on the standard procedures required for the planning phase of an EnMS according to ISO 50001. Figure 5 gives a general summary over the different steps used in the method.

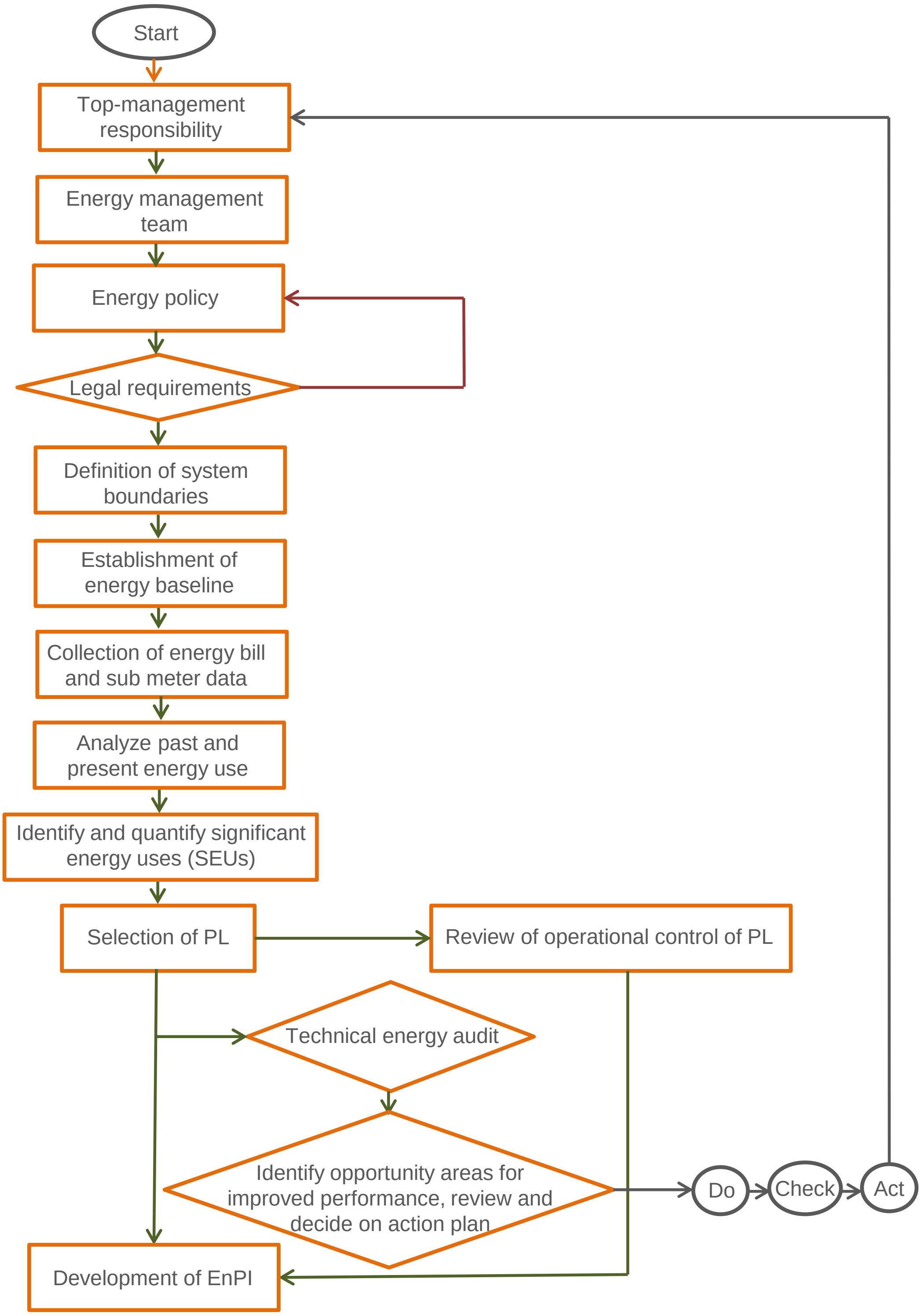


Figure 5: Methodology flow chart (own elaboration)

3.1 Preparation of PDCA cycle

3.1.1 Definition of scope and boundaries of the system

In the preparation phase, prior to the planning phase, it is important to identify all requirements necessary for the implementation of an EnMS. In order to implement an EnMS successfully it is essential to previously define the scope and boundaries of the system that will be analyzed (AFKHAMI, AKBARIAN, BEHESHTI, KAKAEE, & SHABANI, 2015). "The scope refers to the extent of activities, facilities and decisions that the organization addresses through an EnMS, which can include several boundaries. The boundaries are defined as physical or site limits and/or organizational limits as defined by the organization that could be a process, a group of processes, a site, an entire organization and multiple sites under the control of an organization." (TÜV NORD, 2014)

3.1.2 Management responsibility

> *The ISO 50001 standard says: "It requires the top management to demonstrate its commitment to support and continually improve the effectiveness of the EnMS." (Item 4.2.1)* (CEN/CENELEC, 2011)

Following the definition of system boundaries, top management (TM) commitment becomes even more important, leading the organization for example to more energy oriented operations or defining the company's energy policy.

The main task of the TM is to ensure the long-term sustainable implementation of an EnMS. For the successful achievement of this task it has to provide all required resources for the implementation, maintenance and continuous improvement of the management system. Additionally, the TM has to define an energy policy as well as related strategic and operational goals, which is seen as the basis for an EnMS in an organization. Furthermore, EnPIs have to be developed by the TM in order to be able to review established objectives and the overall functioning of the system. Furthermore, an energy management officer (EMO), and, if necessary, an associated energy management team has to be appointed. It is responsible for the provision of all information that is necessary for a functioning EnMS and has to conduct an annual evaluation of the EnMS as part of a management review (BRANDL & KANZIAN, 2013).

3.1.3 Energy management officer

> *The ISO 50001 standard says: "It requires the top management to appoint a management representative(s) to promote awareness and oversee the implementation of the EnMS." (Item 4.2.2)* (CEN/CENELEC, 2011)

The candidate selected by the TM to function as the organization's EMO has to support the TM in the operational implementation of the EnMS. The EMO must ensure that the system is established, implemented, maintained and continuously improved. One of the EMO's responsibilities includes, among other aspects, to communicate the company's energy performance as well as all issues concerning the EnMS to the TM. Furthermore, the EMO has to propose energy-related improvement options and create awareness of the energy policy and developed energy targets throughout the company. All responsibilities can be documented in the EMO's job descriptions. The EMO can be incorporated, if existing, in the environmental department of a company.

Especially in larger enterprises, the EMO has to be supported by an energy management team. It is useful, however, to incorporate employees from a variety of departments such as purchasing, maintenance, production, human resources and accounting in the energy team. This simplifies the implementation of the system at all levels and in all areas across the enterprise, as each of the mentioned departments has a direct or indirect impact on the overall energy consumption. Furthermore, each member of the energy management team, should be interested in the topic of EE in order to transmit the importance of the issue across the organization (LIEBACK, BUSER, GNEBNER, BEHRENDT & FELKER, 2016).

3.1.4 Energy policy

> *The ISO 50001 standard says: "It requires the organization to define an energy policy to state its commitment for achieving energy performance improvement." (Item 4.3)* (CEN/CENELEC, 2011)

An important aspect of the implementation and improvement of an EnMS is the formulation of an energy policy, always taking into account the scope and boundaries of the system. The energy policy serves as a written documentation where all objectives and targets are expressed. It specifies a framework for energy management to improve the energy performance of an organization. The document is the first step in a structured energy management process. The energy policy defines the energy-related guidelines, principles of action and long-term overall goals of a company. Based on the policy, the effectiveness of an organization’s energy management can be measured (KAHLENBORN et al., 2012; TÜV NORD, 2014).

According to UNIDO (2013), the energy policy of an organization has to include the following aspects:

- “Commitment to continual improvement of energy performance through the development and achievement of relevant objectives and targets.
- Commitment to provide the necessary resources to achieve its energy objectives and targets.
- Commitment to develop the necessary measures to demonstrate performance improvement.
- Commitment to comply with all legal and other requirements that apply to its energy using activities.
- Support for the purchase of energy efficient products and services when economically feasible.”

To be valid, the TM should approve and sign the energy policy in order to underline the organization’s commitment to the EnMS. It is important to update and review the policy on a regular basis (e.g. annually) to confirm its accuracy. Furthermore all changes and adaptations have to be made accessible for the employees.

3.2 Energy planning

The planning phase of ISO 50001 requests the documentation of all legal as well as company internal requirements, and their compliance related to the development of an EnMS. Furthermore, as part of the ISO 50001 implementation process, a review of the company’s energy performance is required. Therefore, an EB has to be established as a reference value. EnPIs must be defined in order to be able to measure the organization’s energy consumption as well as to link them with other factors (e.g. production volume). Based on the defined energy policy, strategic and operational objectives have to derive, and appropriate measures have to be set and implemented in the company.

Figure 6 shows general concepts of the energy planning process according to ISO 50001 divided into data collection, the auditing process as well as the outputs of the planning phase that can be used in the following stages of the PDCA-cycle.

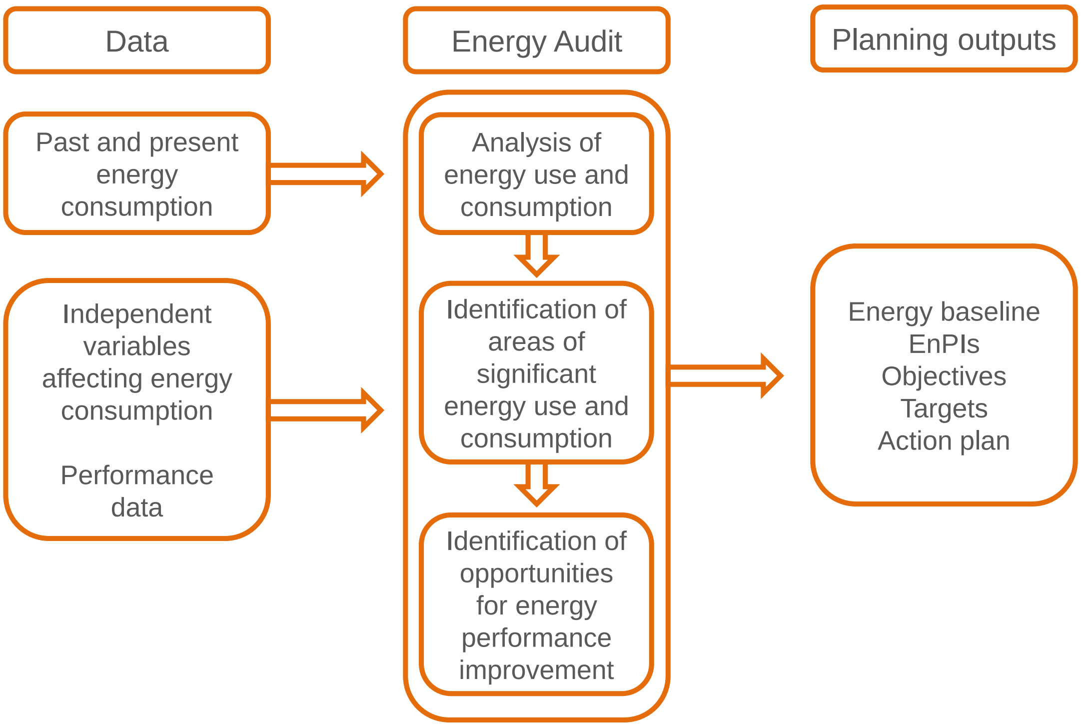


Figure 6: Energy auditing and planning process (ISO, 2011)

3.2.1 Legal and other requirements

> *The ISO 50001 standard says: "It requires the organization to identify and have access to the applicable legal and other requirements in relation to its energy uses, consumption and efficiency to which it subscribes." (Item 4.2.2)* (CEN/CENELEC, 2011)

The ISO 50001 standard demands a record of all legal requirements related to energy use, consumption and efficiency to guarantee its compliance with international, national, regional and local governmental legislations. Specific measures and responsible parties have to be defined to secure the implementation of all legal regulations in the organization's structure. Besides legal requirements, other requirements such as internal business regulations or costumer requirements as well as voluntary programs or public commitments of the organization or its parent organization have to be reviewed. The creation of a legal energy register can thereby contribute to a structured overview and examination of the applicable requirements (BRANDL & KANZIAN, 2013; TÜV NORD, 2014).

TÜV NORD (2014) recommends that the following aspects should be addressed in order to ensure the fulfillment of all legal and other requirements in the energy planning process:

- Identification of all relevant legal and other requirements
- Securing of the organization's compliance with relevant requirements
- Verification that required knowledge is transmitted to key staff members in order to be able to administrate relevant legal and other requirements
- Verification that all applicable information regarding legal and other requirements is properly communicated to other staff members
- Verification that all information regarding legal and other requirements are up-to-date

All relevant legal and other requirements have to be reviewed periodically in order to verify their timeliness and adjust operations if needed (BRANDL & KANZIAN, 2013).

3.2.2 Energy review

> *The ISO 50001 standard says: "It requires the organization to develop record and maintain an energy review as well as document the methodology and criteria used to develop the review." (Item 4.4.3)* (CEN/CENELEC, 2011)

In order to perform an energy review, an actual state analysis of the organization's energy consumption has to be conducted. In practice, this means that the organization must be clear about all energy flows within the selected system. In this context, all energy consumption data and purposes have to be documented. Usually a variety of different energy sources can be identified. Especially in large and complex systems, the number and diversity of energy inputs can be quite large. However, ISO 50001 does not require the examination of all energy inputs with the same priority, but rather seeks the possibility to distinguish between essential (primary) and non-essential (secondary) energy inputs and consumption. This is to ensure that an organization can focus on the measures that promise the greatest success during the implementation of an EnMS. The amount of energy used is usually considered as the most important selection criterion (GIRBIG, GRASER, JANSON-MUNDEL, SCHUBERTH & SEIFERT, 2016). The energy review should help to define a company's energy performance by identifying opportunity areas. It is also beneficial in the development process of the EB and EnPIs (TÜV NORD, 2014).

3.2.2.1 Top-down and bottom-up analysis

As a first step of the energy review, a top-down analysis should be carried out to identify potential energy savings opportunities in the organization. During that process, an attempt is made to represent the entire company as a preferably real model. Thereby, the entire enterprise or a single site can be considered holistically, followed by a more detailed analysis of the production. This leads to an identification of the main consumers of energy and potential energy savings can be estimated.

In a next step, a bottom-up analysis of the previously identified main energy consumers has to be conducted. During this stage all individual manufacturing processes, procedures and machinery and equipment (MAE) are considered in more detail in order to exploit all the potential through targeted measures (MATSILIZA, MUROVE & GRON, 2004).

3.2.2.2 Identification of main energy consumers

The main objective of a top-down analysis is to identify the principal energy consumers, and to obtain an initial assessment of optimization potentials. The classification of the main energy consumers can vary substantially depending on the organization. The most common form of representation is the division into consumer and consumer groups. Hereby main consumer groups can be identified such as lighting systems or production processes, but also individual energy consumers such as production machines. Some companies represent their production facilities each as a main energy consumer. However, this method is not very common, as its classification is rather superficial and detailed analyses are difficult to obtain.

A classic method used for a top-down analysis is the establishment of a load profile to identify individual main consumers of energy. It is used to get a rough idea of the main consumers in an organization. Furthermore, important aspects of energy consumption, such as the shutdown periods of MAE in non-productive hours as well as the peak load can be analyzed (MATSILIZA et al., 2004).

3.2.2.3 Collection of energy consumption data

The basis for an improvement in EE and the identification of energy savings opportunities forms the systematic collection and analysis of consumption data in the energy review. Energy consumption and demand can be determined through different methods such as the revision of energy bills, the installation of sub-meters, power quality assessments or energy estimations and can be illustrated through a power demand profile (KAHLENBORN et al., 2012).

3.2.2.3.1 Power demand profile

A power demand profile serves as a useful tool to depict the power consumed over a certain timeframe and the variation in the demand, e.g. for facilities, buildings or individual consumers of electricity. Its main function is to present detailed data of an organization's energy consumption, or of individually metered sections of an organization. It can be described as the "electrical fingerprint" of a company. According to MATSILIZA et al. (2004) and TÜV NORD (2014) there are several ways of creating power demand profiles such as:

- Analysis of energy bills
- Periodic utility-meter readings
- Recording clip-on ammeter measurements
- Basic recording power meter
- Multi-channel recording power meters
- A facility energy management or Supervisory Control and Data Acquisition (SCADA) system
- A dedicated monitoring system

The simplest and usually least expensive way includes the collection of utility-meter data on a monthly, daily or hourly basis, if possible even more frequently. A monthly demand profile can be easily obtained by recording the amount documented on the utility bill. More frequent data can usually also be supplied by the responsible energy provider. Multi-channel recorders on the other hand are rather expensive and difficult in its usage, however, provide a variety of information including data of real power demand and power quality. It is crucial to perform the data collection during typical operating hours in order to be able to identify the highest demands (MATSILIZA et al., 2004).

Some important information that can be obtained through a power demand profile are demonstrated in the following table:

Table 4: Information obtained from demand profile (MATSILIZA et al., 2004)

Information	Description
Peak demand	The time, magnitude and duration of the peak demand period or periods may be determined. Peak demand can be understood as the greatest of all demands that have occurred during a specified period of time.

Night load	The demand present at night (or during unoccupied hours) is clearly identified.
Start-up	The effect of operation start-up(s) upon demand and the peak demand may be determined.
Shut-down	The amount of load turned off at shut-down may be identified. This should equal the start-up increment.
Weather effects	The effect of weather conditions upon the demand for electricity can be identified from day to night (with changing temperature), and from season to season by comparing demand profiles in each season.
Loads that cycle	The duty cycle of many loads can usually be seen on the demand profile. This can be compared to what is expected.
Interactions	Interactions between systems may be evident – for example, the increased demand for electric heat when ventilation dampers are opened.
Occupancy effects	Often the occupancy schedule for a facility is reflected in the demand profile; if it is not, this could identify control problems.
Problem areas	A short-cycling compressor is usually easy to spot from the demand profile.

In the following section the previously mentioned demand profiling methods are explained in greater detail.

3.2.2.3.2 Analysis of energy-utility bills

Companies usually consume a variety of energy types in their day-to-day operation such as electrical energy, natural gas, LP gas or gasoline among others. For the proper documentation of an organization’s energy consumption, all significant energy bills should be registered. The information obtained form a substantive part in the identification of the total energy consumption (TÜV NORD, 2014).

3.2.2.3.3 Periodic meter readings

Periodic meter readings are usually conducted on an hourly basis and require installed meters available for readings. Being a rather simple method, it shows great advantages in its cost efficiency. However, some negative aspects include limitations in time resolution (meaning that data between readings has to be estimated leading to a greater inaccuracy) as well as labor intensity (MATSILIZA et al., 2004).

3.2.2.3.4 Recording clip-on ammeter

Single- or three-phase ammeters can be connected to a recording instrument in order to achieve the regular documentation of power demand data. It is usually connected to an output plug on the clip-on ammeter as can be seen in Figure 7.

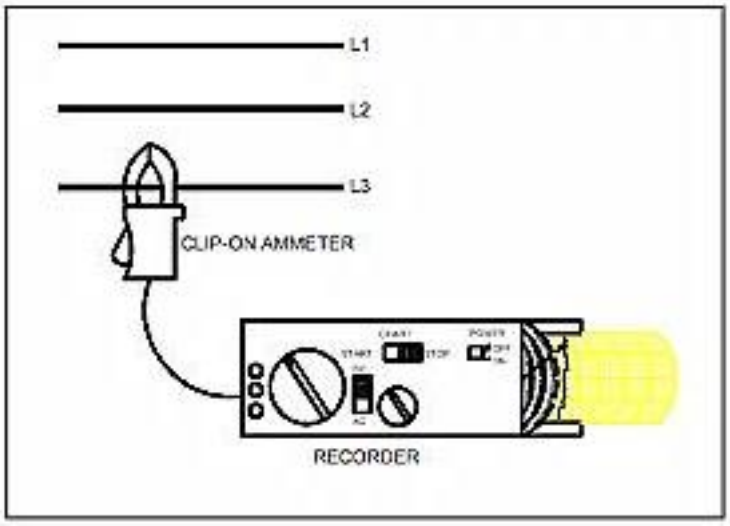


Figure 7: Recording ammeter set-up for single phase measurements (MATSILIZA et al., 2004)

The instruments can be attached to specific MAE as well as to previously defined strategic measuring points such as the point of common coupling (service conductor). In a further step, the obtained data has to be put into correlation with the system voltage (V) and power factor (PF) in order to be able to approximate the power demand (MATSILIZA et al., 2004).

Table 5: Installation procedure of recording clip-on ammeter (MATSILIZA et al., 2004)

Installation procedure	
Step I	• Acquire a recording ammeter that is suitable for the installation on the organization’s service conductor • The help of a certified electrician in the selection and installation process of the device is essential to guarantee a save execution • Three-phase ammeters are recommended for three-phase served power installations
Step II	• To obtain representative results the selection of a typical operation period is crucial • The recording ammeter has to be connected in order to measure the voltage and power factor
Step III	• Disconnect the recording ammeter

	• Collect the data in order to create a demand profile on a paper strip chart or through an appropriate software
Step IV	• Convert the obtained data of the current displayed in the demand profile to kVA or kW according to the circumstances: ➢ For kW and single phase: *kW = Amps × Volts × PF ÷ 1000* ➢ For kW and three phase: *kW = Amps × Volts × PF × 1,73 ÷ 1000* ➢ For kVA and three phase: *kVA = Amps × Volts × 1,73 ÷ 1000*

3.2.2.3.5 Basic and multi-channel recording power meters

Basic and multi-channel recording power meters are nearly similar methods with the exception that the basic method only records data such as kilowatts (kW) or kilovolt ampere (kVA), while the multi-channel recorder is able to measure a greater variety of values (e.g. kW, kVA, phase current, voltage, overall power factor, apparent power (S) etc.).

The recording power meters collect data of current and voltage instantaneously using up to three phases. Subsequently they calculate the corresponding values for kW, kVA and power factor. The obtained data can often be stored on the device's memory card. A common set-up of the mentioned devices is shown in the following figure:

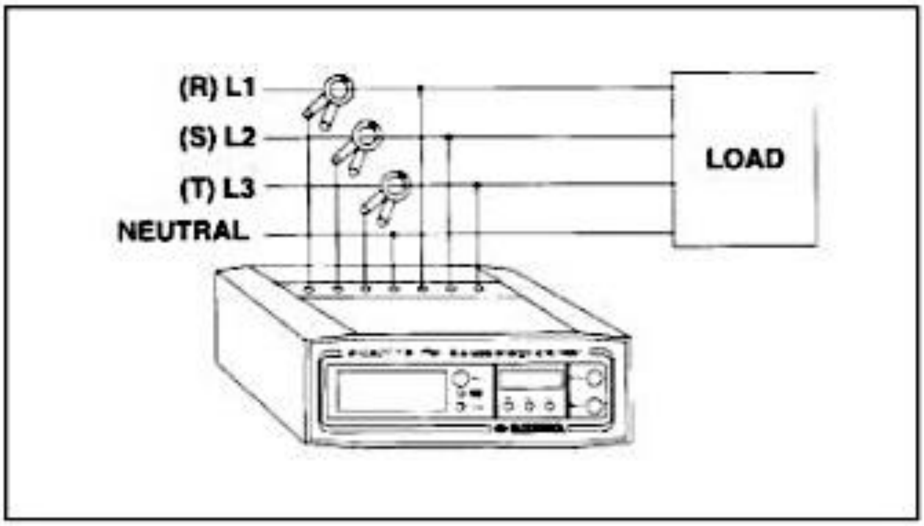


Figure 8: Recording multi-channel power meter for three phase measurements (Matsiliza et al., 2004)

Before installing the recording power meter it is recommended to thoroughly act upon the instructions displayed in the manual to avoid any risks. The following table presents some steps of the general installation process.

Table 6: Installation procedure of basic and multi-channel recording power meters (MATSILIZA et al., 2004)

Installation procedure	
Step I	• Acquire a basic or multi-channel recording power meter that is suitable for the installation on the organization's service conductor • The help of a certified electrician in the selection and installation process of the device is essential to guarantee a save execution • Three-phase meters are recommended for three-phase served power installations • It is important to affirm that the highest power value measured does not pass the estimated peak
Step II	• Choose a representative 24-hour measuring period • Connect the meter for the chosen period
Step III	• Disconnect the recording power meter • Collect the data in order to create a demand profile on a paper strip chart or through an appropriate software

When analyzing established demand profiles it is important to consider the different measuring frequency of the recording power meter and the ammeter in comparison with utility meter measurements. While the power meter is able to measure a high number at a great velocity of values per minute, utility meters usually display an average value of the power demand registered over a 15 minute timeframe (MATSILIZA et al., 2004).

3.2.3 Energy baseline (EB)

> *The ISO 50001 standard says: "It requires the organization to establish an energy baseline(s) for the measurement of the energy performance." (Item 4.4.4)*
> (CEN/CENELEC, 2011)

EBs primarily imply the documentation of energy consumption data in order to measure and demonstrate energy performance improvements and simultaneously evaluate EE development. Usually it is based on a determined timeframe of a one-year period, but can vary depending on specific circumstances of the organization (BMLFUW, 2014). The EB methodology has to be chosen carefully to decrease distortions that can otherwise appear due to variations in weather conditions, production mix and other variables affecting energy consumption (NEEA, 2013). According to PURCEL & JIMÉNEZ (2013) an EB has to include the following aspects:

- “Historic energy consumption over a sufficient period of time (minimum one year) and with sufficient resolution (minimum monthly) to identify variations in consumption
- Inventory of energy uses and an estimated breakdown in energy consumption according to use (e.g. lighting, heating, office equipment, servers etc.)
- Independent and fixed variables affecting energy consumption and the relevant values (e.g. degree days for heating or cooling, floor area for lighting, building opening hours, metering period length etc.). This data should be measured at the same time as, and correspond to, the energy consumption data.”

ISO 50001 does not establish specific requirements for the EB. Therefore all parameters have to be selected by the organization itself.

3.2.4 Energy Performance Indicators (EnPIs)

> *The ISO 50001 standard says: “It requires the organization to identify appropriate energy performance indicators to monitor and measure its energy performance.” (Item 4.4.5)*
> (CEN/CENELEC, 2011)

According to ISO (2011) the concept of energy performance itself includes factors such as energy use, EE, energy consumption and energy intensity, among others. In order to monitor and measure energy performance and consumption it is important to define suitable EnPIs. EnPIs are quantitative and therefore measurable values for the energy performance of an organization and can be used by the management to gauge the effectiveness of implemented EE measures. They can vary from simple parameters and ratios to complex models (TÜV NORD, 2014). ISO 50001 does not impose already existing EnPIs, therefore every company is able to choose and identify appropriate EnPIs depending on its business operations in order to assess and evaluate its energy performance.

Some typical examples of EnPIs are:

- Total energy consumption [kWh]
- Energy consumption per energy source [kWh]
- Energy consumption in relation to production volume [kWh / total production volume]
- Energy consumption per manufactured unit of production [kWh / produced pieces]
- Total energy cost [€]

- Energy costs per produced unit of output [€ / pieces produced]
- Share of renewables in total energy consumption [%]
- Amount of carbon dioxide emitted by energy generation sources [ppm] (KAHLENBORN et al., 2012; NEEA, 2013)

It is important to regularly review, document and update existent EnPIs to guarantee their significance as well as to compare them to the previously defined EB (KAHLENBORN et al., 2012). To improve its energy performance a company can select from a large variety of energy performance measures such as the reduction of peak demand, the redirection of excess energy or operational improvements of systems, processes or equipment (ISO, 2011).

3.2.5 Energy objectives and targets

> *The ISO 50001 standard says: "It requires the organization to establish, implement and maintain documented energy objectives, targets and action plans specified outcome or achievement defined to meet its energy policy related to improved energy performance." (Item 4.4.6)* (CEN/CENELEC, 2011)

After establishing the EB, it is important to develop long-term (strategic) objectives in accordance with the organization's energy policy and subsequently (operational) targets to be reached in a shorter time period as well as an action plan. Objectives, targets and action plan are closely linked during the implementation process of an EnMS. Therefore Figure 9 shows the differences between the mentioned aspects as well as their specific characteristics and linkages to each other.

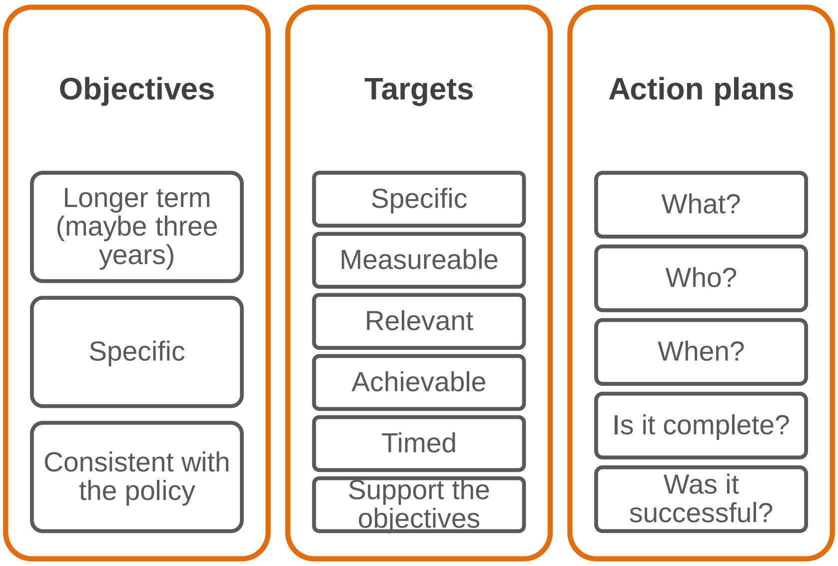
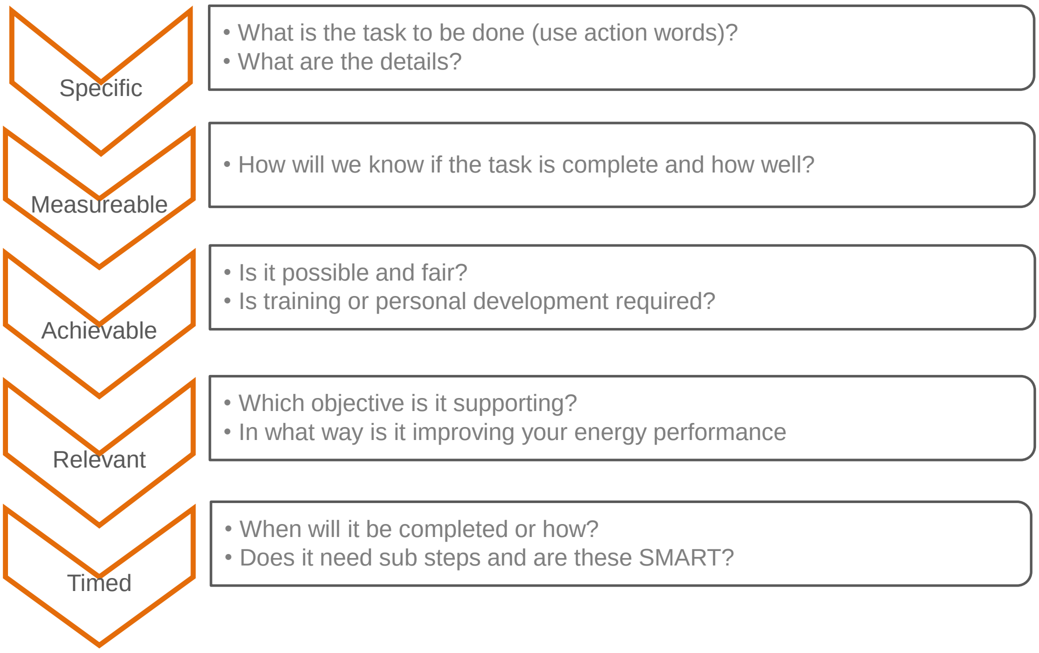


Figure 9: Relationship between objectives, targets and action plan (UNIDO, 2013)

During the development of objectives and targets it is important to follow the "S.M.A.R.T." principle, explained as follows:



Specific
- What is the task to be done (use action words)?
- What are the details?

Measureable
- How will we know if the task is complete and how well?

Achievable
- Is it possible and fair?
- Is training or personal development required?

Relevant
- Which objective is it supporting?
- In what way is it improving your energy performance

Timed
- When will it be completed or how?
- Does it need sub steps and are these SMART?

Figure 10: S.M.A.R.T. objectives and targets (UNIDO, 2013)

3.2.5.1 (Strategic) objectives

During the development stage of strategic objectives, it is important to take into account previous steps of the planning process such as drivers of energy consumption. Objectives are usually established for a longer time period and therefore are less precise than targets. They should be set for all parameters influencing energy consumption in an organization, however, always taking into consideration their measurability. On the one hand, objectives should be ambitious, while on the other also realistic since they have to be able to be reached in the provided timeframe. The consideration of legal and other requirements is crucial in the implementation process of strategic objectives as well as operational targets (KAHLENBORN et al., 2012).

3.2.5.2 (Operational) targets

Targets are derived from objectives to support their long-term implementation. Therefore each objective usually has various targets assigned to it. Targets are set to be realized in a short to medium-term timeframe. They mostly relate to individual responsibilities or departments (EBEL, 2003).

In general the formulation of objectives and targets can be described by the following figure:

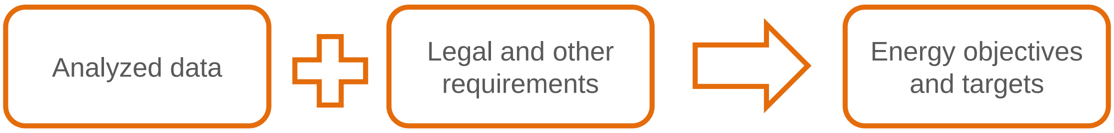


Figure 11: Formulation of energy targets and objectives (modified according to Kahlenborn et al., 2012)

Therefore a typical example that shows the difference between a strategic objective and an operational target is provided by TÜV Nord (2014) and could look as follows:

Strategic objective	Reduce overall electricity consumption by 10%
Operational target	Reduce electricity consumption in production by 15% and in warehouse by 5% by December 2014

3.2.6 Action plans

Following the definition of objectives and targets, an action plan has to be developed presenting concrete measures of how the established goals can be reached. The action plan forms the basis of all actions related to energy saving measures, not only focusing on technical but also on organizational adjustments. It includes specific activities necessary to improve a company's energy performance (Unido, 2013). All different steps described so far should be documented in the action plan and updated on a regular basis in order to control and guarantee the successful implementation of an EnMS. Specific measures must be assigned to each objective or target including staff responsibilities, deadlines and resources necessary for the implementation (Kahlenborn et al., 2012).

If objectives and targets are supposed to be S.M.A.R.T. action plans should be S.M.A.R.T.E.R. additionally including the aspects of Evaluation and Reassessment. As a result, the confirmation of all actual savings after the action plan period is necessary as well as the review of additional energy saving opportunities (Unido, 2013). In order to develop a valid action plan the following principles, amongst others, should be prioritized:

- Compliance with all legal requirements
- Investment cost
- Investment risk
- Amortization period
- Integration of actions that raise the staff's awareness regarding the EnMS
- Technical feasibility
- Stakeholder approval (Kahlenborn et al., 2012; Unido, 2013)

A time frame (usually a one-year period) must be established to be able to verify the compliance with the defined objectives and targets. A summary of the action plan should also be part of the final energy report (KAHLENBORN et al., 2012).

4 Industrial case study description

The previously described methods were applied to the Bosch SLP plant in Mexico. To get a brighter picture of the company as a whole, its business structures and internal policies among others, the following section will give a short overview of the Robert Bosch GmbH. First introducing the international company in general, while later describing the Bosch SLP plant as the case study of this thesis.

4.1 Introduction of the company – Robert Bosch GmbH

The Robert Bosch GmbH (short Bosch) is a German multinational engineering and electronics company. It was founded in 1886 in Stuttgart, Germany, by Robert Bosch, who opened a workshop for precision and electric engineering (Bosch, 2015h).

Nowadays Bosch is one of the worldwide leading automotive electronic and mechatronics component suppliers. All products and services fabricated and provided by the company can be identified by the logo in Figure 12.

BOSCH

Figure 12: Robert Bosch GmbH Logo (Bosch, 2014a)

The enterprise is structured in four core sectors, including **mobility solutions** (e.g. diesel systems, chassis systems control, electrical drives, starter motors and generators, car multimedia, gasoline systems, automotive electronics or automotive steering), **industrial technology** (e.g. drive and control technology or packaging technology), **consumer goods** (e.g. power tools or household appliances) as well as **energy and building technology** (e.g. security systems, thermotechnology or solar energy) (Bosch, 2015g). The following image shows the percentage of each core sector regarding the total annual turnover of the company.

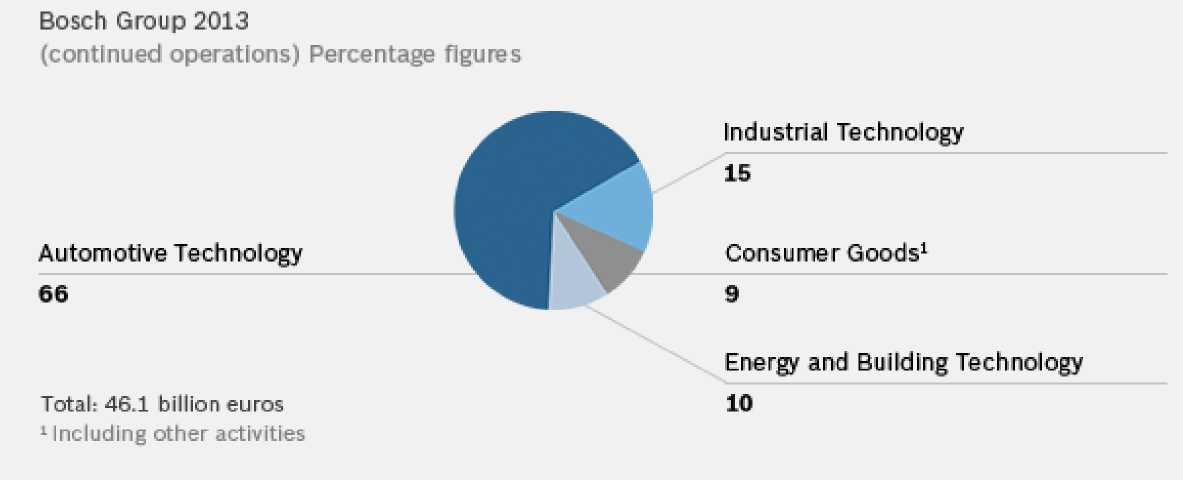


Figure 13: Sectorial percentage regarding the core sectors of the company (BOSCH, 2013D)

With more than 290.000 employees around the world, the Robert Bosch GmbH is present in 50 countries with around 260 industrial locations. In 2014, the annual turnover of the company amounted to 48,9 Billion Euro (BOSCH, 2014A). Especially the companies' particular ownership structure makes it possible to invest in long-term projects to protect its future and ensure entrepreneurial freedom. The Robert Bosch Stiftung GmbH, a charitable foundation, holds 92% of the share capital. The Robert Bosch Industrietreuhand KG, an industrial trust, holds the majority of voting rights. The entrepreneurial ownership functions are carried out by the trust. The remaining shares are held by the Bosch family and by the Robert Bosch GmbH (BOSCH, 2013A).

4.2 Environmental protection – Robert Bosch GmbH

The Bosch corporation has set the goal to minimize the environmental impact of their activities in the product development as well as in manufacturing and to constantly improve environmental protection (BOSCH, 2016C). On the company's homepage it says: "Bosch has always given top priority to being conversant with legal requirements and complying with or even exceeding these requirements, as demonstrated in particular by our code of business conduct" (BOSCH, 2016A). According to the Bosch principles of environmental protection, each part of the company should act upon the following guidelines:

Table 7: Principles of work safety and environmental protection Robert Bosch GmbH (BOSCH, 2015C)

Products: *Development and manufacturing of products has to be safe, eco-friendly, and economical. The products enhance people's safety and reduce burdens to the environment, also during their subsequent recycling and disposal*

Processes: *Processes are designed to ensure that people's health and safety have priority and that effects on the environment are kept to a minimum.*

Sustainability: *All actions must accord with the economy, the ecology, and the responsibility that is taken for the community at large, also with a view to future generations. For this reason, respect for people's health and safety, for an economic use of resources, and for a natural and clean environment are basic principles of the business policy.*

Responsibility: *It is the task of all associates to help prevent the endangering of people and the environment, as well as to maintain strict compliance with all laws and regulations pertaining to work safety and the protection of people's health and the environment. It is a leadership task to recognize such danger, to evaluate them, and to undertake appropriate actions.*

Continuous improvement: *Processes and behavior is reviewed on a regular basis, just as their effects on people and on the environment. This is how weak points and potential for improvement are identified and the effectiveness of work safety and protection of people's health and the environment is ensured*

The master thesis will incorporate the mentioned principles of environmental protection, however, only focusing on the issues of processes, sustainability, responsibility and continuous improvement. Products will be left out in this research project since it does not correspond with the overall objective of this study. Nevertheless it has to be stated that the Robert Bosch GmbH as a company sets these statements. The plant in SLP has adapted those environmental principles to fit their capacities, production activities, workers extension and other factors that may have been considered while developing and implementing their respective environmental guidelines (see Subchapter 4.3).

Additionally the Robert Bosch GmbH has taken the decision to define climate protection as a corporate goal, integrating CO_2 reduction programs in different production locations around the world. CO_2 management strategies are based on the following scopes of the Greenhouse Gas Protocol:

- Scope 1: All direct CO_2 emissions from stationary combustion (e.g. heating, generators) and mobile combustion (e.g. company-owned vehicles)
- Scope 2: All indirect CO_2 emissions (purchased electricity, district heating, cooling, steam)

All other indirect emissions resulting from the company´s operations, but not from company owned sources, fall under scope 3 (e.g. production of material, external logistics) and do not apply to the reduction target (BOSCH, 2009). For the implementation of an EnMS, the present study will focus on energy sources included in scope 1 as well as scope 2. A successful EnMS can contribute to the reduction of CO_2 emissions through a more efficient use of energy sources.

4.3 Robert Bosch Mexico

Bosch began its operations in Mexico in 1955 by providing the local market with imported parts used in the automotive sector, and began local production of these components in Toluca in 1966 (BOSCH, 2005). Nowadays Mexico counts with over 5.000 associates, 10.000 employees and an annual turnover of about 853 Million Euro (status as of 2013) (BOSCH, 2005, 2013B). The following figure shows all industrial sides located in Mexico.

Figure 14: Robert Bosch GmbH industrial sites in Mexico (Bosch, 2015i)

4.3.1 Industrial plant in San Luis Potosi, Mexico

Name: Robert Bosch Automotive Systems S.A. de C.V.

Plant address: Eje Centro Sahop 245. Zona Industrial, 78395 San Luis Potosi, Mexico

The industrial plant in SLP is part of the mobility-solutions branch of the company, and engages in the manufacturing and production of components for gasoline system, chassis systems, wheel speed sensors and ignition coils for the automotive industry since 1996 (see Figure 17). The plant was formally owned by the Allied Signal hydraulics systems division but in 2011 the company finally changed the name of the plant to Robert Bosch Automotive Systems S.A. de C.V.. Bosch SLP currently covers a ground area of 19.370 m^2. By the end of 2016 this area will increase by adding 4000 m^2 of office space, a 9.300 m^2 logistic center including warehouse and sample areas, additional manufacturing areas, offices and technical floors (6.400 m^2), facilities of 2.700 m^2 including warehouses, chemical rooms, scrap areas and fire pump house treatments), a new guardhouse (50m^2), laboratory areas (4.350 m^2) as well as a canteen and training center (2.700 m^2). After the completion of the new installations, Bosch SLP will cover a surface area of 48.870 m^2 (G. Zamarron-Rios, personal communication, July 1st, 2016).

The plant distributes its products to customers such as Ford, Honda, Fiat, Nissan, Toyota, Volkswagen or General Motors to countries all over the world like the USA, Mexico, Canada, Brazil, Spain, Turkey, China, South Korea and Taiwan (see Figure 15 & Figure 16) (BOSCH, 2015I).

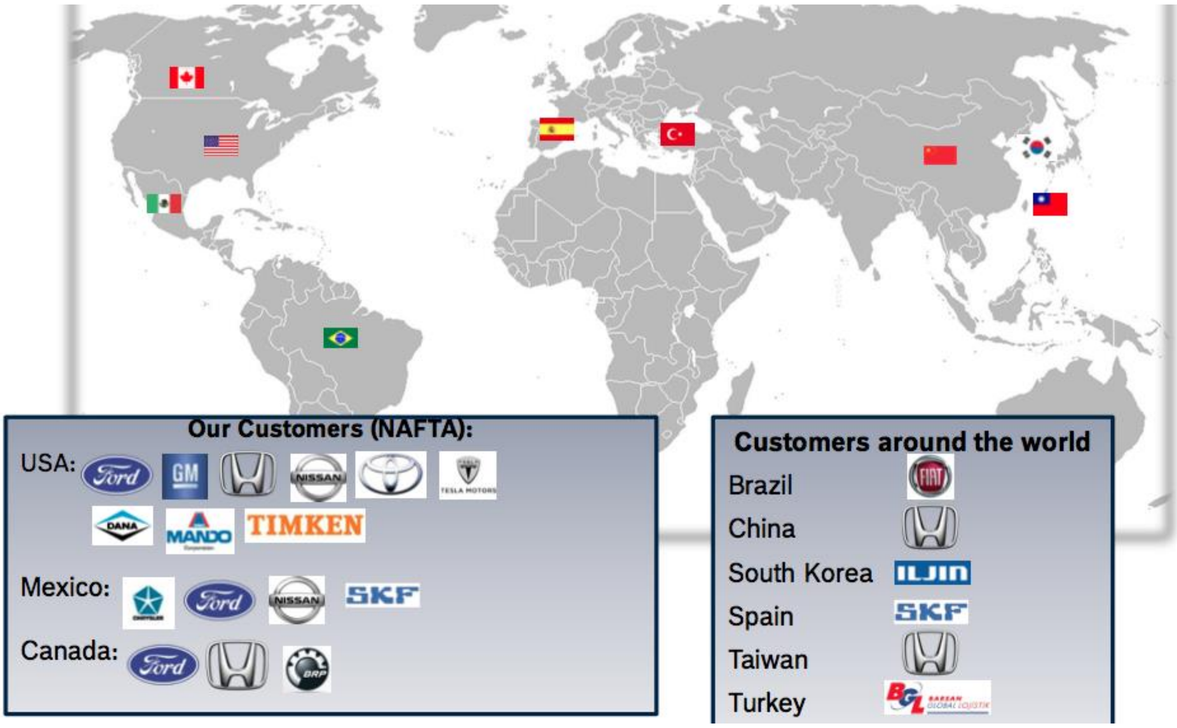


Figure 15: Bosch SLP international customers for the Chassis Systems Control division (BOSCH, 2015I)

Figure 16: Bosch SLP international customers for the Gasoline Systems division (BOSCH, 2015I)

The following figure displays the variety of products manufactured in Bosch SLP:

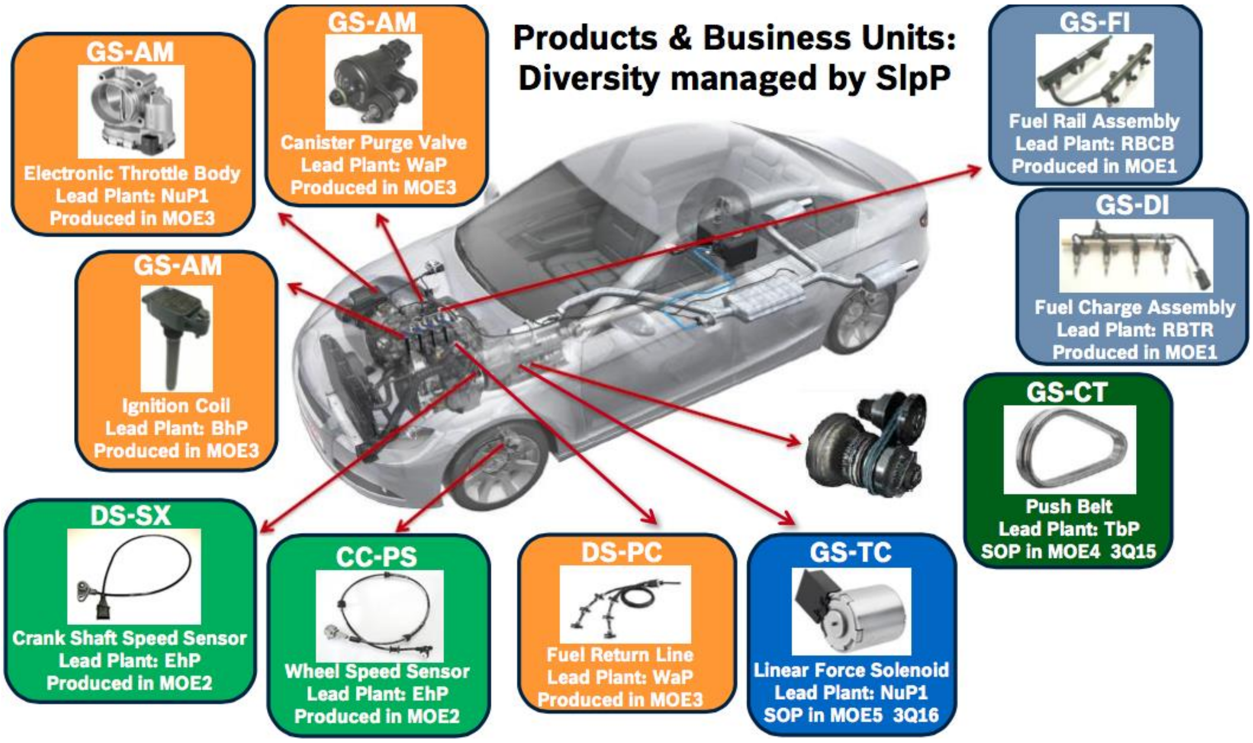


Figure 17: Products and Business Units Bosch SLP (BOSCH, 2015I)

The plant counts with around 1.400 employees: 1.132 employees work directly in the production process with a working schedule divided into three shifts, each 8 hours, while 268 employees are working in the office area (BOSCH, 2015I).

4.3.2 Environmental protection – Bosch SLP

To contribute to the reduction of CO_2 emissions in the industry, Bosch SLP is investing in energy saving measures, especially energy obtained from fossil fuel sources. The whole CO_2 profile of the plant is generated through the consumption of electrical energy, natural gas, LP gas as well as fuel used for company cars. As part of the CO_2 reduction program, energy consumed in the assembly process as well as in other parts of the plant will be analyzed and reduction measures will be implemented in the plant's future development (BOSCH, 2013C). Some actions already enforced in Bosch SLP are the following:

- Shut down of MAE in non-working hours in all production areas
- Detect/correct air pneumatic leaks (MAE and installations in all production areas)
- Partial utilization of renewable energy sources (Eolic generation project)

- Replace old Heating, Ventilation and Air Conditioning (HVAC for its abbreviation in English) units by new generation equipment
- Increase use of LED lamps in production and office areas (BOSCH, 2015E)

However, since the Bosch SLP plant accounts for more potentials regarding EE improvements and simultaneously CO_2 reduction, the implementation of an EnMS can greatly contribute to systematically document, organize and expand energy saving measures throughout the plant.

In previous years, Bosch SLP performed various auditing procedures in order to obtain certifications in the field of environmental management, providing a good basis for the implementation of an EnMS according to ISO 50001. The company joined the National Environmental Audit Program offered by the Federal Attorney for Environmental Protection (PROFEPA for its abbreviation in Spanish) in order to improve its environmental performance and compliance with the federal environmental legislation. PROFEPA issued the *Clean Industry Certificate* (certificado de industria limpia) to the Organization on August 7th, 2002, renewing it every two years.

According to the activities of the company and in accordance with the provisions of Article 111bis of the General Law of Ecological Balance and Environmental Protection (LGEEPA for its abbreviation in Spanish) the production process does neither conduct heat treatment nor casting processes using fossil fuels. There are no direct GHG emissions generated in the production process and released into the atmosphere. According to the regulation of LGEEPA in Article 17a, paragraph E) Section VII, the Company is not occupying any fixed source of federal jurisdiction. For the same reason it is worth mentioning that the company does not require operating permits issued by the Secretariat of Ecology and Environmental Management of SLP (SEGAM for its abbreviation in Spanish) or the municipality of SLP, as stated in article 76 of the Environmental Law of the State of SLP, because the plant installations do not exhibit any fixed emission sources polluting local jurisdiction (PROFEPA, 2014).

Furthermore, Bosch SLP counts with a properly implemented EMS based on the international standard ISO 14001: 2004, and is officially certified since 2001. The last renovation process was performed on the 17th of October 2013, and is valid until November 2016. The EMS has helped implement procedures and policies of environmental management in order to comply with national regulations on environmental matters.

Table 8: Environmental Policy Bosch SLP (BOSCH, 2013C)

Environmental Management System – ISO 14001

Environmental Policy

In Robert Bosch Mexico Automotive Systems S.A. de C.V., dedicated to the production of components for gasoline systems as well as velocity sensors for the automotive industry, we are committed to:

- Prevent pollution as well as occupational injuries and illnesses
- Continuously improve our processes, through the establishment of objectives and goals
- Comply with all applicable legal requirements as well as with the internal norm Bosch N93*

Sustainability and prevention of occupational diseases and injuries is EVERYONE's responsibility.

*Bosch norm for all aspects related to health, safety and environment

The main environmental objectives and goals are the following:

Objective	Goal
Reduce CO_2 generation	Generation ≤ 135,9 units of relative CO_2 per month
Reduce generation of non-hazardous waste	5% in comparison to the previous year

Principles of action:

- Compliance with federal, state and local regulations applicable to the company
- Realization of all activities in accordance with the principles of Safety, Health and Environment
- Compliance with our objectives and goals
- Continuous improvement of our procedures and programs to reduce the impact of our processes on the environment
- Prevention of injuries and illnesses
- Use of clean technologies and production equipment that minimize the impact on the environment and the use of nonrenewable resources
- Establishment of safety conditions in processes that use chemical substances to protect employees from major accidents and prevent damages to plant

installations

- To promote education in the areas of safety, health and environment for all employees in order to prevent injuries and illnesses as well as to preserve natural resources and the ecological environment

Additionally to the environmental certifications Bosch SLP is also certified through ISO/TS 16949 for Quality Management which is based on ISO 9001, however, specifically designed for the automobile industry (BOSCH, 2014B).

5 Research results of ISO 50001 – planning phase

The following section will take the steps of ISO 50001 – planning phase presented in Chapter 3, and depict their results implemented in the Bosch SLP plant in Mexico. As has been explained in Subchapter 2.9, the implementation process takes place on various levels. This means for the case study that the steps of the planning phase are executed on one or more of the following levels: Bosch international, Bosch SLP and MC 1 as can be seen in Figure 18.

In order to obtain actual long-term results of energy savings it is necessary for the Bosch SLP plant to continue independently with the PDCA cycle and the implementation process of an EnMS according to ISO 50001. For that reason the next stages of the PDCA cycle are illustrated in the figure below, however not addressed as part of the study.

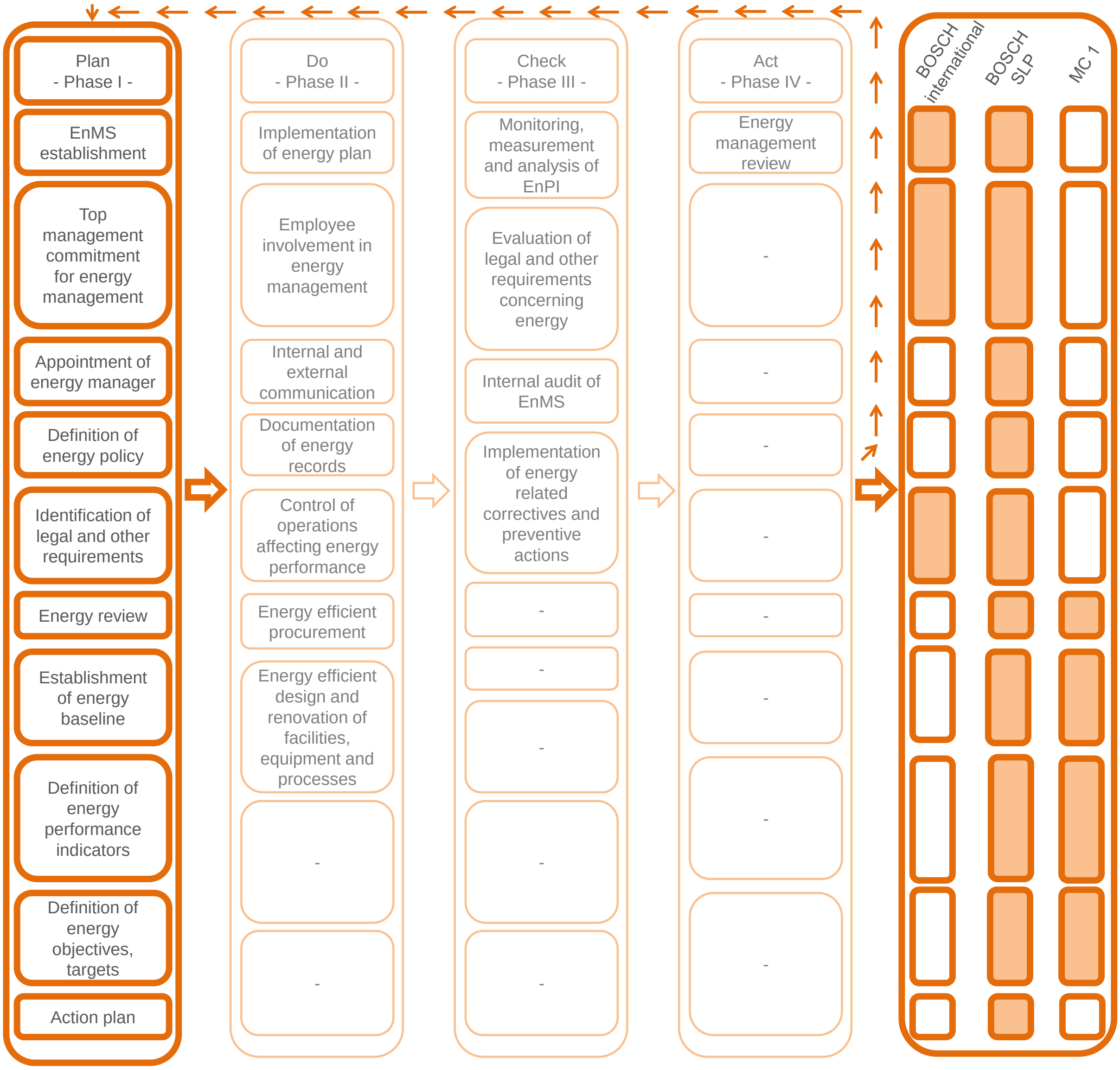


Figure 18: **ISO 50001 process model based on PDCA cycle demonstrating the different level of application** (modified according to JOVANOVIĆ & FILIPOVIĆ, 2016)

5.1 Preparation Bosch SLP

5.1.1 Definition of scope and boundaries Bosch SLP

This research study considers three different levels as has been explained in the previous section, however a greater focus is put on the levels Bosch SLP and MC 1, also considered as the prior-ranking boundaries of this study. All steps of the planning phase are examined on the Bosch SLP level, however only some are assessed on the MC 1 process level. The smaller scale was additionally chosen for the steps: Energy review, energy baseline, energy performance indicators, definition of objectives and targets, to demonstrate the ISO 50001 – planning phase procedure in more detail. The production line (PL) chosen as an example was the MC 1 in the production area MOE 3, highlighted with a red line in Figure 19. It was identified as one of the oldest PL with highest energy consumption in the plant, which can increase the identification of opportunity areas.

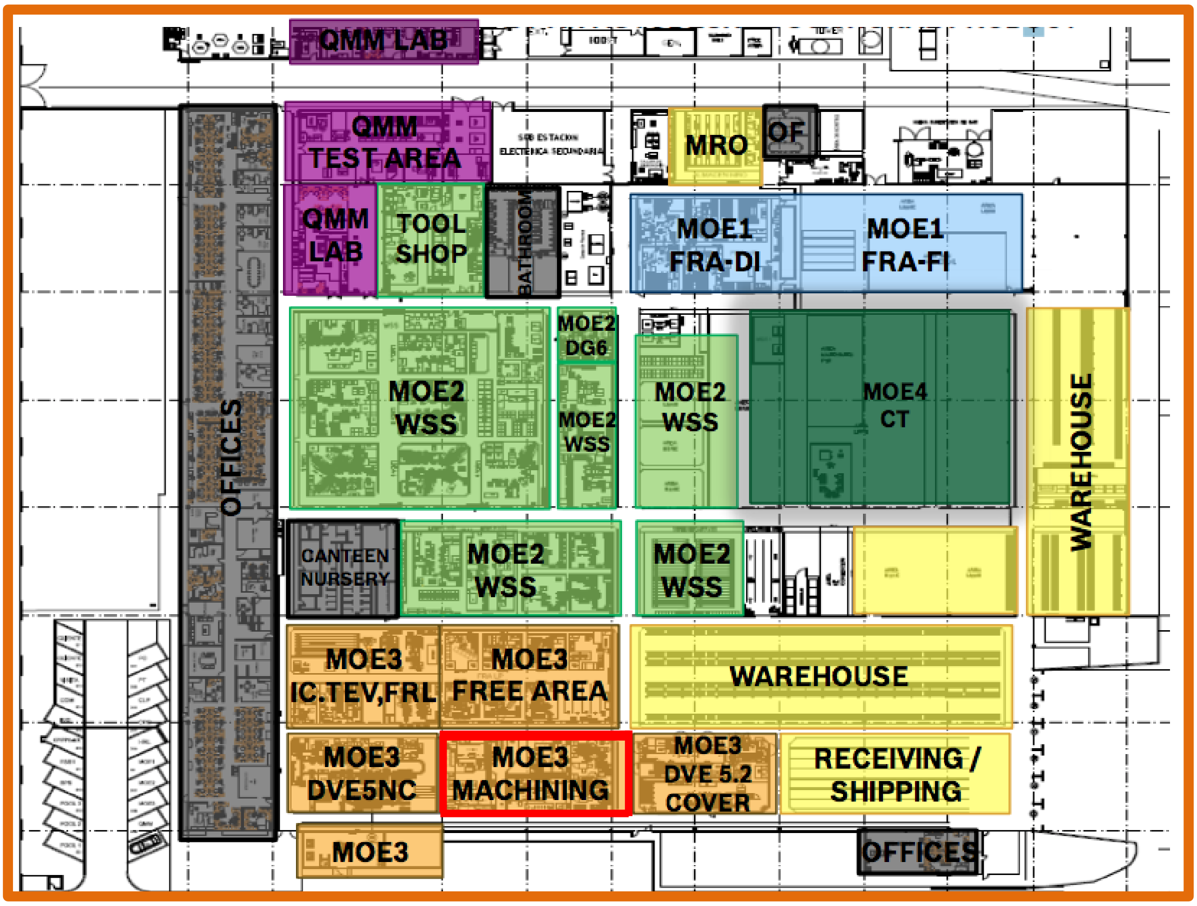


Figure 19: Bosch SLP plant outline (BOSCH SLP is highlighted with orange; MC 1 is highlighted with a red line) (Bosch, 2015i)

The MC 1 is responsible for the roughing process of the electronic throttle body, milling and polishing the superficial part of the body housing. BOSCH (2015E) further clarifies that: “The throttle body is an essential part of the inlet air stream of a modern gasoline engine. In combination with the electronic throttle control system, the throttle body assembly is designed to control the amount of fresh air entering the engine.”

A series of figures demonstrating the process are shown as follows:

Figure 20: Hüller Hille Specht Z500 machining center (own image)

Figure 21: Hüller Hille Specht Z500 pallet/rotary table (own image)

Figure 22: Electronic throttle body before roughing process (own image)

Figure 23: Electronic throttle body after roughing process (own image)

5.1.2 Management responsibility Bosch SLP

TM commitment is a key factor in the implementation process of an EnMS. Resources and personnel have to be allocated to energy management and all executive decisions have to be made taking into account the energy aspect, among others. The Bosch SLP plant, at the present stage, has not yet committed to the official implementation of an EnMS to support EE and energy savings measures. However, as part of the CO_2 reduction program, some steps have already been made towards a more energy oriented plant operation as has been mentioned in Subchapter 4.3.

5.1.3 Energy management officer Bosch SLP

The nomination of an EMO as well as responsible members for the energy management team, so called energy representatives (ER), is an important step in the implementation process of an EnMS. Regular meeting between the members should be held based on need, however, at least once every business quarter. At least annually the TM should be involved in the meetings to assure their participation in energy related projects. An organizational chart for the Bosch SLP plant could look as follows:

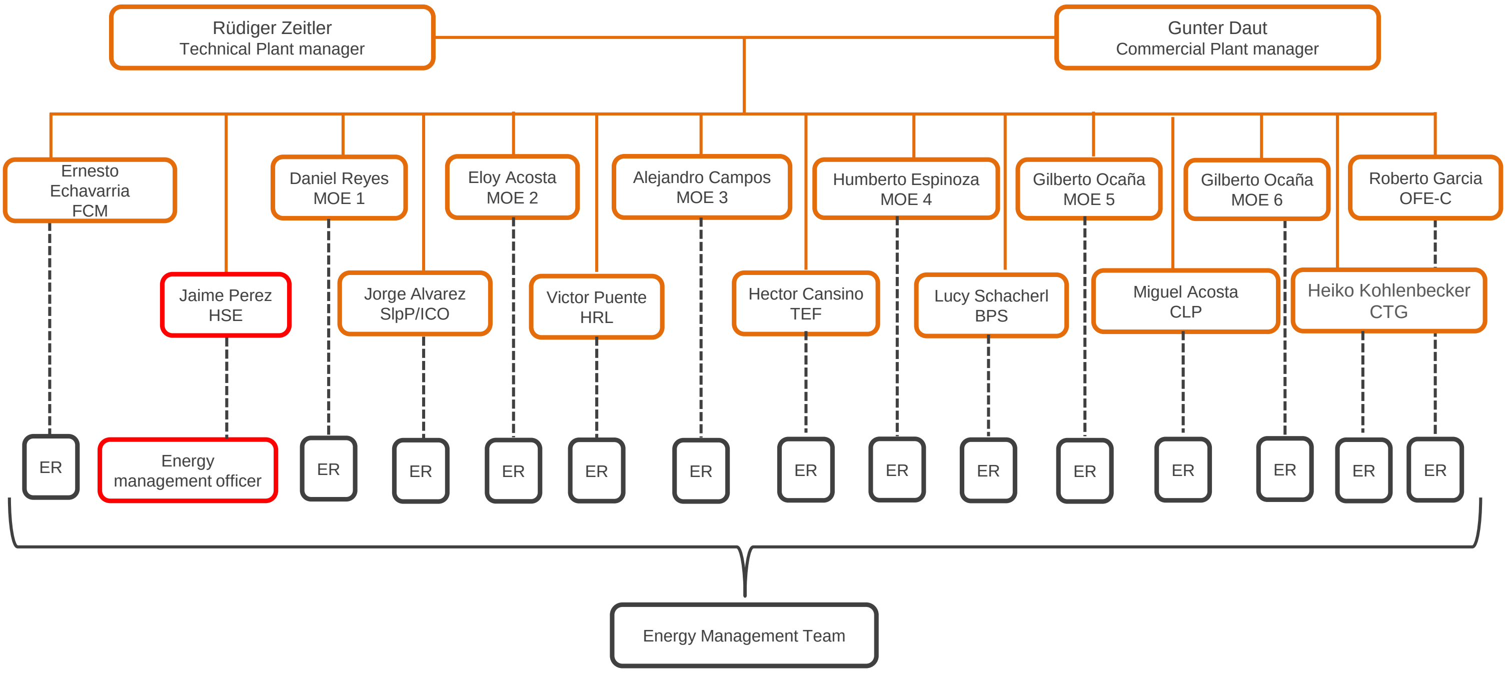


Figure 24: Organization chart Bosch SLP (own elaboration)

The chart gives an overview of the different business departments that form part of the Bosch SLP plant. On the first level the TM is represented through the technical plant manager as well as the commercial plant manager. The following level consists of the different departments represented through their responsible department managers or directors. The ideal scenario would include at least one representative from each department forming part of the energy management team. The department of Health, Security and Environment (HSE) (highlighted red in the figure above) would be a good option to provide the EMO since they are already familiar with the implementation of other management systems such as ISO 14001 and ISO/TS 16949.

5.1.4 Energy policy Bosch SLP

The formulation of an energy policy, through the TM in collaboration with the energy management team, is one of the first steps in the implementation process of an EnMS. The Bosch SLP plant has, at present time, not included an energy policy into their management structures. However, a possible energy policy for the plant could look as follows:

Table 9: Energy policy for Bosch SLP (modified according to Bosch, 2015a; TÜV Nord, 2014)

Energy Policy Robert Bosch Automotive Systems S.A. de C.V. San Luis Potosi

- Robert Bosch Automotive Systems S.A. de C.V. in San Luis Potosi will contribute through a careful use of resources and energy to the reduction of environmental impacts.
- The compliance with all applicable legal and other requirements related to energy management will be a top priority.
- The availability of information and resources necessary to meet all established objectives and targets shall be secured.
- The environment should be relieved sustainably through continuous development and improvement of production methods and supply engineering.
- Energy consumption should be reduced in the long term through the implementation of energy savings measures; energy efficiency should be increased in a process of continuous improvement.
- These objectives will also be pursued in the energy-conscious procurement of raw materials and supplies, equipment and services.
- Energy saving awareness should be communicated to all staff members.

Rüdiger Zeitler **Technical Plant Management**	**Gunter Daut** **Commercial Plant Management**	**To be nominated** **Energy Management Officer**

5.2 Energy planning Bosch SLP

The following subchapter display the results obtained through the implementation process of the ISO 50001 planning phase in the Bosch SLP plant.

5.2.1 Legal and other requirements Bosch SLP

As has been mentioned in Subchapter 3.2.1, ISO 50001 requires the completion with all relevant legal and other requirements and suggests the development of a legal energy register to facilitate the documentation process. The Bosch SLP plant is currently not facing any laws, regulations or requirements regarding the implementation of an EnMS (see Subchapter 2.6.1). However, a potential energy register for Bosch SLP could look as presented in Table 10. Any legal changes should be documented considering the aspects presented below including all energy related regulations, measures and responsible staff members.

Table 10: Legal energy register Bosch SLP (modified according to BMLFUW & AEA, 2014)

<table>
<tr><th colspan="6">Legal energy register of Robert Bosch Automotive Systems S.A. de C.V.</th></tr>
<tr><td colspan="6">Regularly updated by: <i>insert responsible staff member</i>
Date of most recent update: <i>insert date</i>
Date of next update: <i>insert date</i></td></tr>
<tr><td>Law, regulation or requirement</td><td>Issue date</td><td>Brief content description</td><td>Processes/ equipment affected by law, regulation or requirement</td><td>Required measures</td><td>Staff member responsible for compliance of law, regulation or requirement</td></tr>
<tr><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td><td>…</td></tr>
</table>

Since Bosch SLP already counts with certified ISO/TS 16949 and ISO 14001 management systems, the plant could expand the previously designed legal register adding energy-related elements according to ISO 50001.

5.2.2 Energy review Bosch SLP

As part of the ISO 50001 planning phase, an energy review was conducted in the Bosch SLP plant that was recorded and should be maintained in the future. As a first step all relevant primary energy resources were identified for the Bosch SLP plant:

- Electricity
- Natural gas
- LP gas
- Gasoline used for management cars and car pool

The conversion of primary energy resources into secondary resources occur in some production processes of the plant and are listed as follows:

- Compressed air
- Heat
- Cooling energy

After analyzing the energy resources used in Bosch SLP, it was observed, that the main energy source is electrical energy. The following table shows the total energy consumption and cost for the year of 2015.

Table 11: Bosch SLP plant electrical energy review 2015

Bosch SLP Electricity 2015	
Total energy consumption (kWh)	11.880.213
Total energy cost (Pesos)	13.573.269

Following the identification of electricity as the main energy resource of the plant, a decision was made to concentrate energy savings measures, at least in the starting stage, on electrical energy in order to obtain more relevant results.

As part of a top-down analysis of the plant it is important to identify MAE with the highest energy consumption. In general the following types of equipment can be distinguished in an enterprise, which also applies for the Bosch SLP plant:

- **Production equipment:** MAE which are directly required for the production process (e.g. machining equipment, welding equipment, molding machines)
- **Auxiliary equipment:** MAE needed for the production, however, is not used in the production process itself (e.g. air-cleaning systems, cooling and lubricating systems or cranes)
- **Energy-conversion systems:** Used to provide secondary resources (e.g. compressors for compressed air generation or chiller systems)
- **Building technology:** (e.g. lighting, building ventilation, server)

In the case of Bosch SLP, MAE with highest energy consumption was identified through the collaboration of plant personnel as well as through the documentation of information plates attached to all MAE. An example for the MC 1 process can be observed in the following figure.

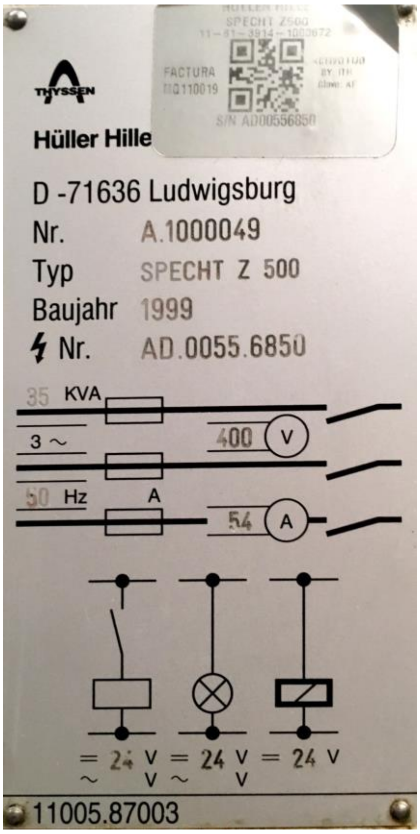


Figure 25: Information plate Hüller Hille Specht Z500 Bosch SLP (own image)

Some of the highest energy consumers found in the Bosch SLP plant include the following MAE:

- Molding machines
- Machining center
- Compressors
- Chillers
- X-ray machines
- Thermo shock chambers
- Climatic chambers
- Computer numeric control (CNC) machines
- Vacuum pumps
- Shaker

In order to increase EE and reduce overall energy consumption of the plant, the mentioned high-energy consumers need to be monitored with respect to their energy usage during operating hours. The question of *how* will be answered as part of the action plan in Subchapter 5.2.7.

5.2.3 Collection of energy consumption data Bosch SLP

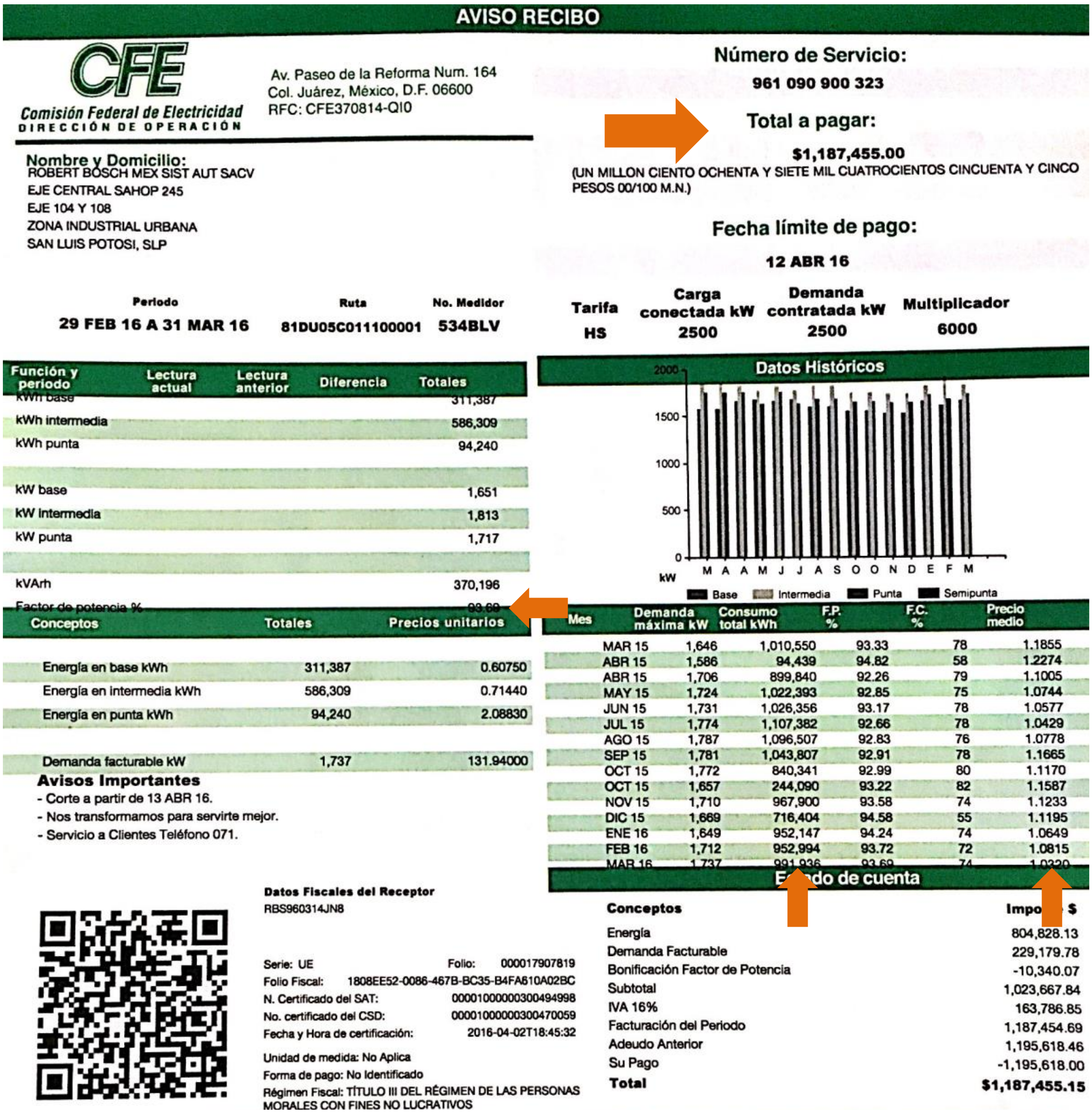
For the purpose of this thesis, the collection of energy consumption data for Bosch SLP was performed on different levels. As can be seen in Figure 18, the plant level as well as the process level were included in the data collection of the energy review. Furthermore, the devices and techniques used in the thesis project were a utility-bill analysis (plant level) as well as a multi-channel recording power-meter analysis (process level).

Plant level

For the data collection on plant level, all energy-utility bills over a time period of two years (March 2014 until March 2016) were gathered and documented. Important information that derive from the utility bills include:

- Total monthly energy consumption (kWh)
- Total monthly energy cost (Mexican pesos)
- Average monthly energy rate (Mexican pesos)
- Power Factor

An example of an energy-utility bill for Bosch SLP is pictured in the following figure:



AVISO RECIBO

CFE
Comisión Federal de Electricidad
DIRECCIÓN DE OPERACIÓN

Av. Paseo de la Reforma Num. 164
Col. Juárez, México, D.F. 06600
RFC: CFE370814-QI0

Nombre y Domicilio:
ROBERT BOSCH MEX SIST AUT SACV
EJE CENTRAL SAHOP 245
EJE 104 Y 108
ZONA INDUSTRIAL URBANA
SAN LUIS POTOSI, SLP

Número de Servicio:
961 090 900 323

Total a pagar:
$1,187,455.00
(UN MILLON CIENTO OCHENTA Y SIETE MIL CUATROCIENTOS CINCUENTA Y CINCO PESOS 00/100 M.N.)

Fecha límite de pago:
12 ABR 16

Periodo	Ruta	No. Medidor
29 FEB 16 A 31 MAR 16	81DU05C011100001	534BLV

Tarifa	Carga conectada kW	Demanda contratada kW	Multiplicador
HS	2500	2500	6000

Función y periodo	Lectura actual	Lectura anterior	Diferencia	Totales
kWh base				311,387
kWh intermedia				586,309
kWh punta				94,240
kW base				1,651
kW intermedia				1,813
kW punta				1,717
kVArh				370,196
Factor de potencia %				93.69

Conceptos	Totales	Precios unitarios
Energía en base kWh	311,387	0.60750
Energía en intermedia kWh	586,309	0.71440
Energía en punta kWh	94,240	2.08830
Demanda facturable kW	1,737	131.94000

Avisos Importantes
- Corte a partir de 13 ABR 16.
- Nos transformamos para servirte mejor.
- Servicio a Clientes Teléfono 071.

Datos Históricos

Mes	Demanda máxima kW	Consumo total kWh	F.P. %	F.C. %	Precio medio
MAR 15	1,646	1,010,550	93.33	78	1.1855
ABR 15	1,586	94,439	94.82	58	1.2274
ABR 15	1,706	899,840	92.26	79	1.1005
MAY 15	1,724	1,022,393	92.85	75	1.0744
JUN 15	1,731	1,026,356	93.17	78	1.0577
JUL 15	1,774	1,107,382	92.66	78	1.0429
AGO 15	1,787	1,096,507	92.83	76	1.0778
SEP 15	1,781	1,043,807	92.91	78	1.1665
OCT 15	1,772	840,341	92.99	80	1.1170
OCT 15	1,657	244,090	93.22	82	1.1587
NOV 15	1,710	967,900	93.58	74	1.1233
DIC 15	1,669	716,404	94.58	55	1.1195
ENE 16	1,649	952,147	94.24	74	1.0649
FEB 16	1,712	952,994	93.72	72	1.0815
MAR 16	1,737	991,936	93.69	74	1.0320

E do de cuenta

Conceptos	Impo $
Energía	804,828.13
Demanda Facturable	229,179.78
Bonificación Factor de Potencia	-10,340.07
Subtotal	1,023,667.84
IVA 16%	163,786.85
Facturación del Periodo	1,187,454.69
Adeudo Anterior	1,195,618.46
Su Pago	-1,195,618.00
Total	**$1,187,455.15**

Datos Fiscales del Receptor
RBS960314JN8

Serie: UE Folio: 000017907819
Folio Fiscal: 1808EE52-0086-467B-BC35-B4FA610A02BC
N. Certificado del SAT: 00001000000300494998
No. certificado del CSD: 00001000000300470059
Fecha y Hora de certificación: 2016-04-02T18:45:32

Unidad de medida: No Aplica
Forma de pago: No Identificado
Régimen Fiscal: TÍTULO III DEL RÉGIMEN DE LAS PERSONAS MORALES CON FINES NO LUCRATIVOS

Figure 26: Energy utility bill Bosch SLP (provided by Bosch SLP)

An energy demand profile put into correlation with the total energy cost for the same time period can be seen in Figure 27. It can be observed that both graphs are directly proportional to each other. Meaning that when the energy consumption decreases, the energy cost also decreases. An anomaly can be detected between the month of September and October 2015, when energy costs are slightly unproportional in relation to the energy consumption.

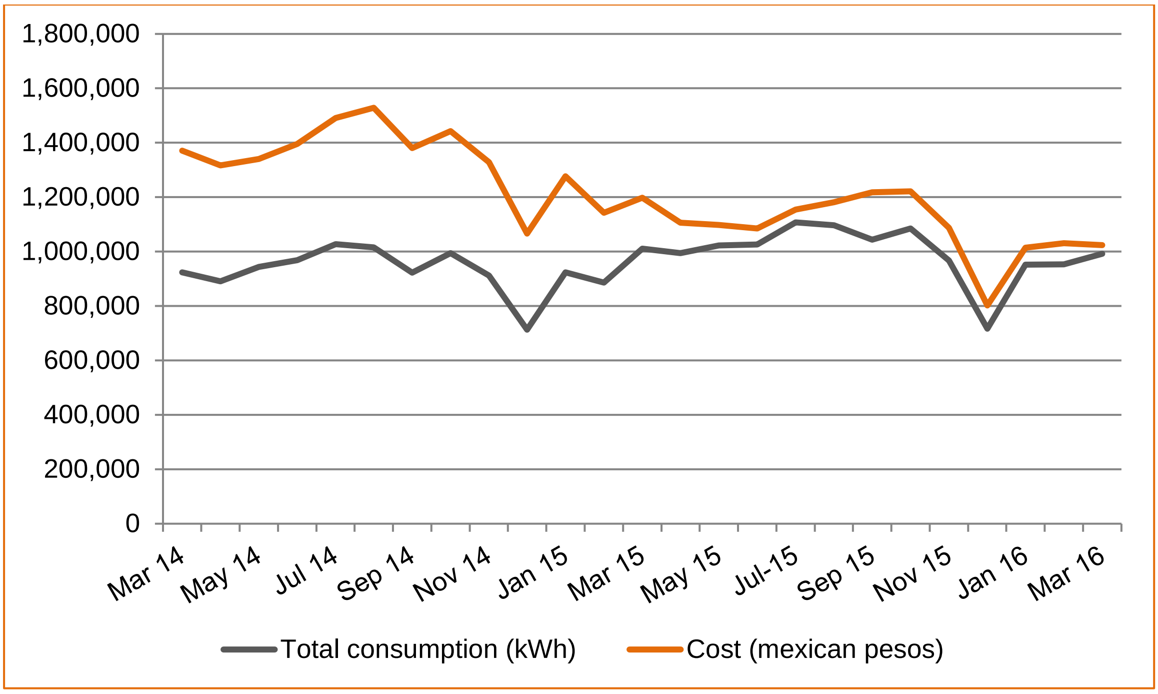


Figure 27: Demand profile of total monthly energy consumption in correlation to cost (own elaboration)

After the identification and analysis of all main energy sources and consumers of energy, an energy review continues with the detection of potential measures and savings of individual systems and machines executed during a bottom-up analysis.

Process level

In order to be able to perform a more detailed analysis of the energy consumption on process level, an energy audit was performed for the MC 1 process using a multi-channel recording power meter. The meter used was the Dranetz power guide 4400 and is presented in the following figure.

Figure 28: Dranetz power guide 4400 (own image)

The installation of the measuring equipment involved a series of steps detailed as follows:

I. Selection of the MAE used for the measuring procedure
II. Check availability of selected MAE
III. Identification of the MAE's electric board (connection points for current and voltage)
IV. Verify and assure the free access to all connection points
V. Turn on multi-channel recording power meter
VI. Connect voltage measuring cables (Figure 29 a))
VII. Connect current probes (Figure 29 b))
VIII. Verify the correct connection of the sequence of the phases to the multi-channel recording power meter
IX. Set the device to obtain the data necessary for the analysis
X. Leave device connected for the time required to obtain a representative data set
XI. Perform regular check-ups to verify the correct operation of the device
XII. Disconnect the device after the measuring period is over
XIII. Extract data from device
XIV. Process data in Dran View 6 software
XV. Analyze data set
XVI. Manipulate data to obtain relevant information for the required study case

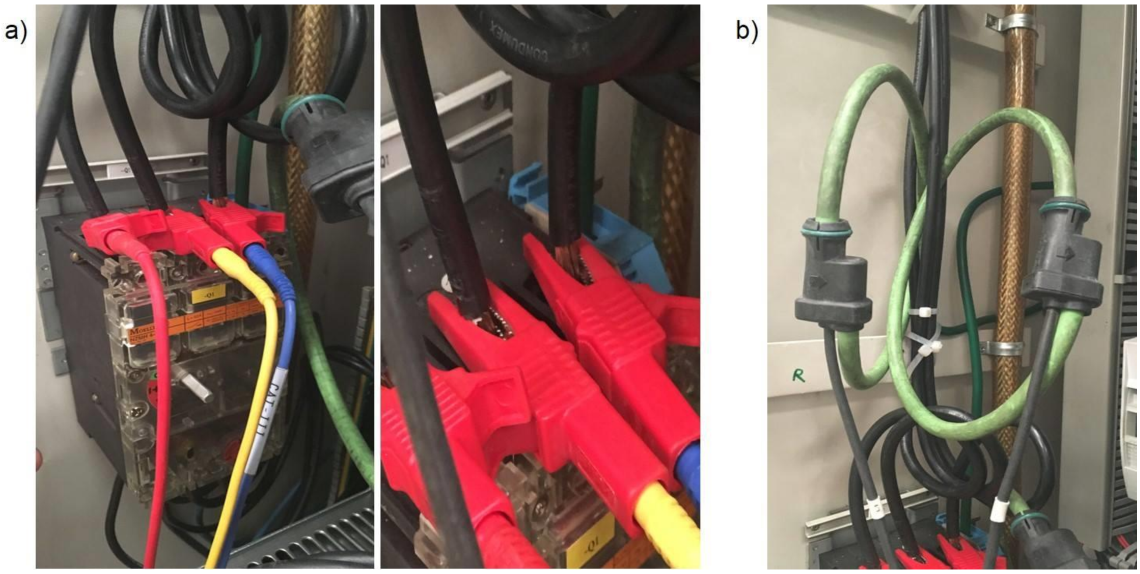


Figure 29: Connection of Dranetz power guide
a) Voltage measuring clamps b) Current probes (own image)

During the installation procedure in Bosch SLP, some obstacles had to be overcome. In order to be able to measure the voltage of the MC 1 process, some cable protectors had to be shortened to expose the wires and to connect the voltage measuring cables adequately. The measuring period for the MC 1 process was set from April 16th 2016 until April 22nd 2016. During that time period a set of variables were measured, however, the most significant ones for this study include:

- *Total average active power* (average rate at which work is done; watt; P=V*I*cos θ)
- *Total power factor* (ratio of the active power that is used to do work and the apparent power that is supplied to the circuit; PF=P/S)
- *Total average energy* (average power integrated over time; kWh) (DRANETZ, 2005)

The gathered data was then transferred to an excel sheet and works as a basis for the EB as will be explained in the following section. A demand profile displaying *Total average active power per minute* for the MC 1 process during the time period mentioned above can be observed in Figure 30.

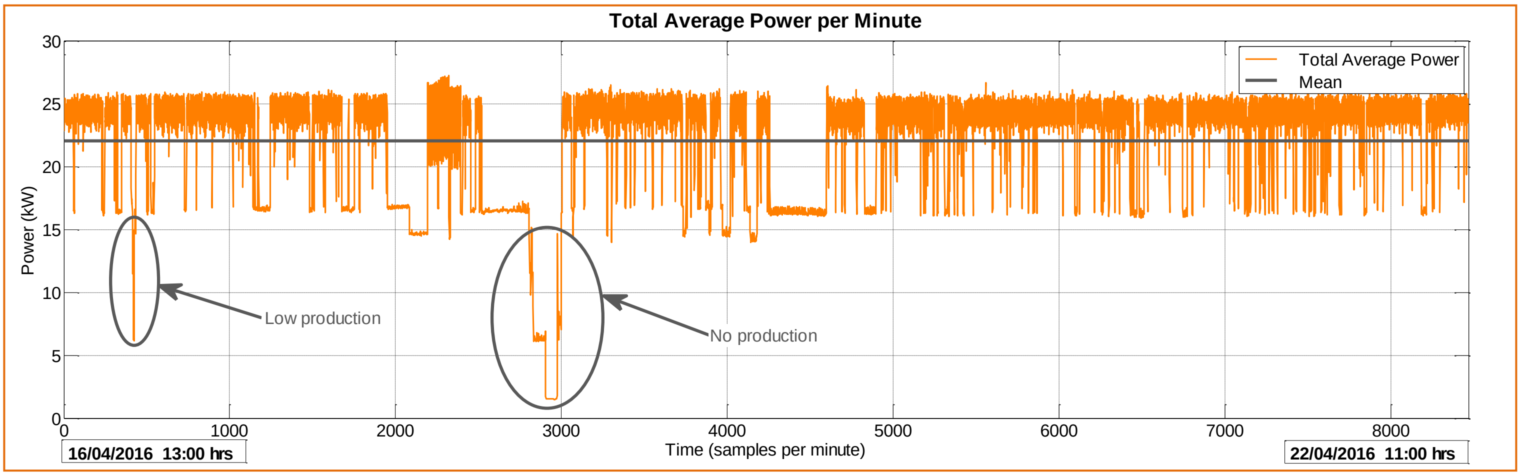


Figure 30: Power demand profile for the MC 1 production line in Bosch SLP (own elaboration)

Two drops in the demand curve attract some attention in the relatively even distribution. The first and lighter drop can be associated with a decrease in the production volume leading to a decrease in power demand. The second, steeper drop on the other hand is related to a total production stop, decreasing the power demand to almost 1 kW.

5.2.4 Energy baseline Bosch SLP

The data obtained through the collection of energy-utility bills and multi-channel power measurements, explained in the previous section, serves as a basis for the elaboration of an EB. Therefore the data has to be documented in the mentioned EB in order to acquire the current status of the plant's energy data. It is important to make a distinction, as has been made in previous sections of this thesis, between plant level and process level. In the case of an EB it should even be considered to create another level – an area or section level. In order to be able to identify and eliminate or decrease inefficiencies, the documentation of all main energy consumers whether it is a single PL or a whole production area can be helpful to subsequently be able to take relevant measures on a smaller scale. To find out whether EE measures that will later be proposed in the action plan are successful, the EB should contain all relevant and accessible hard data available for the plant.

Starting this research, only data on plant level was available, however was not documented as it could count as an EB suggested by ISO 50001. In summary there was no consistent documentation of energy data existing in the Bosch SLP plant. Therefore this study tried, as a first step of the EB creation process, to organize already existing data into a uniform document. It is important to mention that the selection of the variables depends on the focus of the company.

Table 12 shows an example of the most relevant and available variables that should be included in an EB in the case of Bosch SLP. It was established for a one-year period, however, a clearer detection of the plant's energy consumption tendency would be possible using a longer time span. It has to be noted that some data is still not available (n.a.) for documentation, nevertheless would be useful for a more extensive and detailed documentation.

Establishing an EB on plant level is a great first step on the way to a more EE plant operation and an accurate documentation of energy data. However, general measures on plant level will not have the same impact and accuracy as measures on area/sector or process level. Therefore the elaboration of an EB on the mentioned smaller scales can be very beneficial. In this context, Table 13 represents a possible EB on area or sector level. An area in the case of Bosch SLP could be one of the production areas such as MOE1, MOE 2, MOE 3, MOE 4 etc. that can function as sublevels within the plant. Another sublevel could be defined as sectors such as the lighting or HVAC sector. Those sectors represent large energy consumers, however cannot be seen as part of a single area since they are existent throughout the whole plant. They do, however, greatly influence energy consumption and could therefore be considered as a separate sector.

Table 12: Energy baseline Bosch SLP – plant level (own elaboration)

Energy baseline Bosch SLP – plant level												
Month	**Jan 15**	**Feb 15**	**Mar 15**	**Apr 15**	**May 15**	**Jun 15**	**Jul 15**	**Aug 15**	**Sep 15**	**Oct 15**	**Nov 15**	**Dec 15**
Electricity (kWh)	923.624	886.580	1.010.550	994.279	1.022.393	1.026.356	1.107.382	1.096.507	1.043.807	1.084.431	967.900	716.404
Electricity utility bill (Mexican pesos)	1.277.187	1.142.802	1.198.007	1.106.188	1.098.459	1.085.576	1.154.889	1.181.815	1.217.601	1.221.488	1.087.242	802.014
Natural Gas (Liters)	1.940	1.771	1.777	1.820	2.041	2.005	2.081	2.062	2.010	2.029	1.724	1.400
Natural Gas utility bill (Mexican pesos)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LP Gas (m^3)	5	3	2	3	4	5	3	5	4	4	4	3
LP gas utility bill (Mexican pesos)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Management cars/ car pool (km traveled)	38.253	36.924	47.706	39.318	42.442	37.447	30.610	42.973	37.221	49.027	45.179	54.261
Car pool cost (Mexican Pesos)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Indirect CO_2 emissions (t)	513	492	562	551	568	569	611	608	578	603	538	404
CO_2 index (tCO2/Mio. €)	109,83	116,99	112,44	109,61	115,58	121,70	124,69	121,80	118,62	111,81	110,45	109,57
Production (pieces produced)	3.095.502	2.789795	4.586.195	4.995.964	5.000.673	4.480.740	4.854.840	4.952.255	4.830.700	5.217.977	4.500743	3.226.111
Power factor	94,17	93,91	93,33	93,54	92,85	93,17	92,66	92,83	92,91	93,12	93,58	94,58

Table 13: Energy baseline Bosch SLP – area or sector level (own elaboration)

Energy baseline Bosch SLP – area or sector level												
Month	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15	Oct 15	Nov 15	Dec 15
Electricity (kWh)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Natural Gas (Liters)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LP Gas (m^3)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Production (pieces produced)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Production time	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

In order to zoom in even more an EB can be established on process level. The optimal conditions would be achieved if an EB on process level were existent in all PLs throughout the plant. However, in the initial phase the documentation of processes identified as the main consumers is adequate. In more advanced EnMSs, a closer monitoring of all operation elements is recommended. Within the scope of this thesis an EB was developed as an example for the MC 1 process over a seven-day period. The variables considered in the EB are shown in Table 14 for one day in order to represent the general procedure.

Table 14: Energy baseline Bosch SLP – process level (own elaboration)

Energy baseline Bosch SLP – process level							
Date	**Time laps**	**Total average power (kWh)**	**Total average energy (kWh)**	**Total average power factor**	**Production (pieces produced)**	**Production down time (min.)**	**Reason for down time**
20th April 2016	00:00 – 01:00	23,47	1761,20	0,86	72	0	-
	01:00 – 02:00	25,48	1786,67	0,88	72	0	-
	02:00 – 03:00	24,92	1811,59	0,85	72	0	-
	03:00 – 04:00	24,69	1836,27	0,85	72	0	-
	04:00 – 05:00	24,93	1861,21	0,85	72	0	-
	05:00 – 06:00	23,61	1884,82	0,82	60	0	-
	06:00 – 07:00	25,31	1910,12	0,85	72	0	-
	07:00 – 08:00	23,58	1933,71	0,84	72	0	-
	08:00 – 09:00	24,70	1958,40	0,82	72	0	-
	09:00 – 10:00	23,86	1982,27	0,84	72	0	-
	10:00 – 11:00	24,10	2006,36	0,85	72	0	-
	11:00 – 12:00	23,75	2030,11	0,84	72	0	-
	12:00 – 13:00	23,85	2053,96	0,83	72	0	-
	13:00 – 14:00	23,20	2077,16	0,84	60	0	-
	14:00 – 15:00	24,78	2101,94	0,88	72	0	-
	15:00 – 16:00	23,68	2125,63	0,85	72	0	-
	16:00 – 17:00	23,78	2149,41	0,82	72	0	-
	17:00 – 18:00	23,30	2172,71	0,84	72	0	-
	18:00 – 19:00	24,75	2197,46	0,84	72	0	-
	19:00 – 20:00	24,08	2221,55	0,84	72	0	-
	20:00 – 21:00	22,98	2244,53	0,85	72	0	-
	21:00 – 22:00	24,70	2269,22	0,84	54	0	-
	22:00 – 23:00	23,80	2293,02	0,84	66	0	-
	23:00 – 24:00	25,11	2318,13	0,86	66	0	-

Responsible personnel should edit the templates presented above on a continuous basis in order to keep a constant documentation of all relevant information. In the case of future changes, in the operation process of the plant, for example due to expansions, the EB can be modified and adapted in accordance to those changes e.g. through the aggregation or elimination of variables. The EB and future energy databases should be saved in the company's intranet in order to be accessible for all personnel assigned to the task of energy data maintenance.

5.2.5 Energy performance indicators Bosch SLP

EnPIs are used to monitor the effectiveness of implemented EE measures and should be documented as part of the energy database. Every company is responsible for the adequate selection of their own EnPIs since the usefulness of an indicator varies according to the operations performed in an organization. As part of this thesis a variety of EnPIs have been selected to evaluate the energy performance of Bosch SLP. As was the case in the previous chapters, a distinction between the different levels has also been made in the current subchapter. It is important to mention that for the purpose of this subchapter only EnPIs were chosen that count with the sufficient data availability needed for their demonstration. Since the area/sector level does not count for any available data, there will be no indicators presented for that level. In this context the following section will present all selected EnPIs on plant as well as on process level.

Plant level

Based on data availability, only a few indicators have been selected on plant level. The first obvious indicator would be *Total energy consumption*. However, using this indicator as an absolute indicator does not necessarily supply relevant information. Due to possible plant extensions in the future, a higher value measured under future circumstances does not automatically indicate an inefficient use of energy resources, but can be explained for example by an annexed production area. Therefore it is necessary to create a relative indicator:

$$E_u = \frac{kWh}{Tp} \tag{1}$$

where,

E_u: *Energy per unit*

kWh: *Energy consumption of the plant*

Tp: *Total production of the plant*

This indicator shows the direct relation between energy consumption and pieces produced in the same time span and should not react with drastic elevations to possible plant extensions. A graph based on the mentioned indicator for the year 2015 is presented in the following figure.

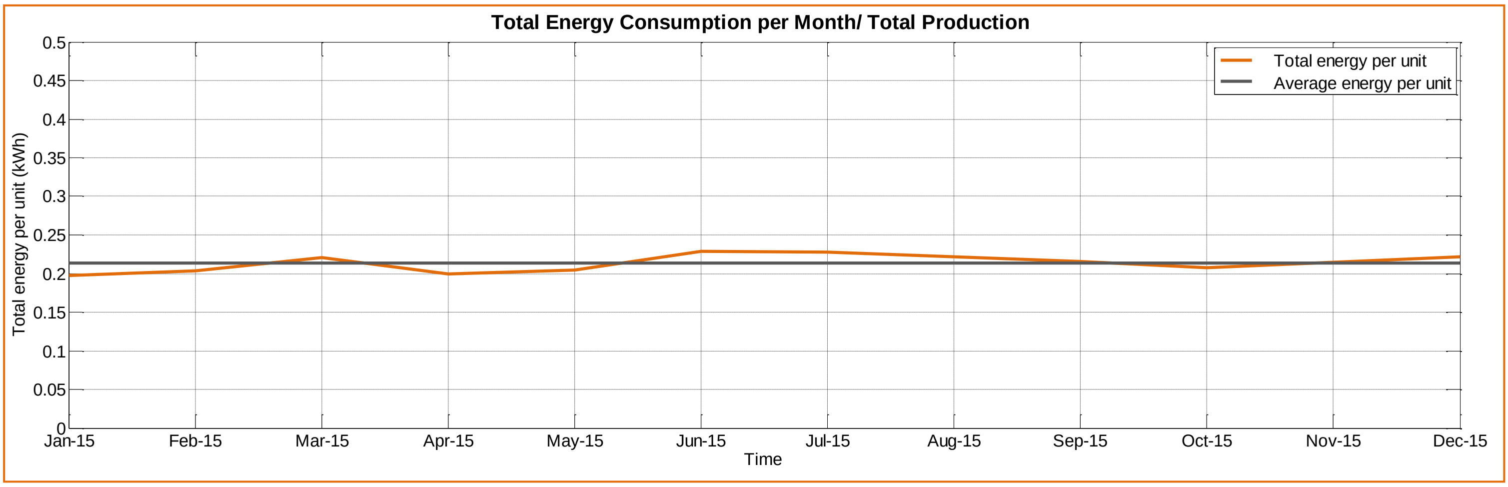


Figure 31: Energy consumption per unit produced (own elaboration)

It can be observed that the energy used to produce one unit ranges between 0.19 and 0.22 kWh with the average energy per unit being 0.21. Through a more EE adaptation of the system, this value could decrease effectively leading to a lower overall energy consumption. In any case, if more production units are installed and the plant expands in the future the total energy consumed per unit produced should not significantly exceed the current range.

Another EnPI used on plant level is *Total power factor*. This indicator is presented on the monthly utility bill issued by the National Electricity Commission (CFE for its abbreviation in Spanish) and gives valuable information about the correct utilization of energy in the plant. In more general terms it can be defined as the amount of energy that was converted into work. The PF ranges from 0 to 1. The ideal power factor value is 1, indicating that all the energy consumed by appliances has been transformed into work. On the other hand, a PF of less than 1 means that more energy is required to produce useful work. Considering the above, a PF below 90% means that energy is wasted by an organization and is linked to an unnecessary fine added to the monthly utility bill. However, a bonus is added when the PF exceeds the 90% limit, giving an incentive for an EE operation (CFE, 2012). A graph presenting the PF of Bosch SLP in 2015 is displayed in the following figure.

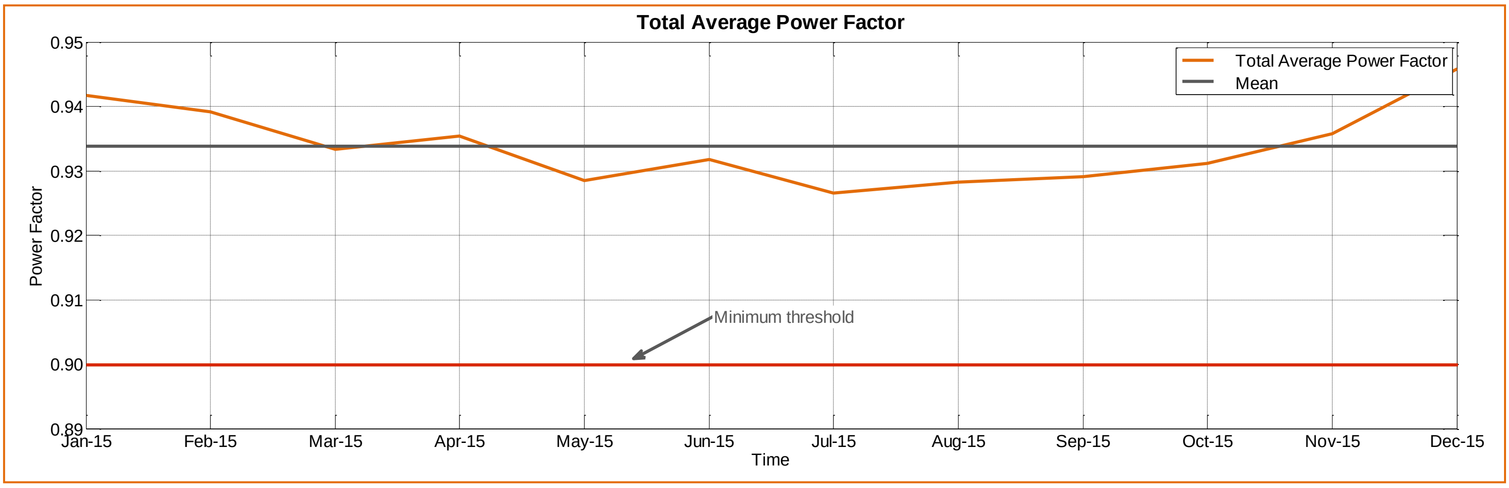


Figure 32: Total Average Power Factor Bosch SLP plant (own elaboration)

In the case of the Bosch SLP plant the mean value obtained from the total average PF data per month shows that the plant exceeds the minimum threshold of 90% and consequently receives a bonus discount on its monthly utility bill. Any effort to improve the PF would not necessarily result in economic benefits since the compensation requires investments. Therefore an analysis of technical and economic feasibility has to be conducted before the decision-making process.

Process level

The monitoring of energy data on process level, especially when main energy consumers have been identified, can be very beneficial for the reduction of energy consumption on plant level. The proper measuring equipment is thereby a key factor as has been explained in the previous sections of this thesis. In this context, the larger the selection of measured variables provided by the measuring device, the more indicators can be developed in a later process. The device selected for this project counts with a great variety of different variables that serve as a basis for the development of EnPIs. In an initial attempt the following indicators were selected.

The first indicator presented on process level is called *Total average power per hour* measured in kWh and is used to monitor the energy consumption per hour. The question of *“why not use the Total energy per hour value provided by the measuring device?”* might arise in the context of proposing this indicator. In order to answer this question the IEEE (2000) provides the following equation defining energy:

$$W = \int_{t0}^{t+t0} P \, dt^{*} \tag{2}$$

---

[*] P = active power determined for the condition of voltages and currents having slowly varying amplitudes.

where,

W: *Energy (kWh)*

P: *Power (kW)*

t: *time (h)*

The equation demonstrates that energy is an accumulative value of power. Therefore, the use of energy as a variable for further calculations of indicators would result in a wrong interpretation of the situation. For that reason the values obtained through the calculation of *Total average power per hour* give a more accurate prospect of energy consumption and are therefore also used for the calculation of energy costs and billing purposes.

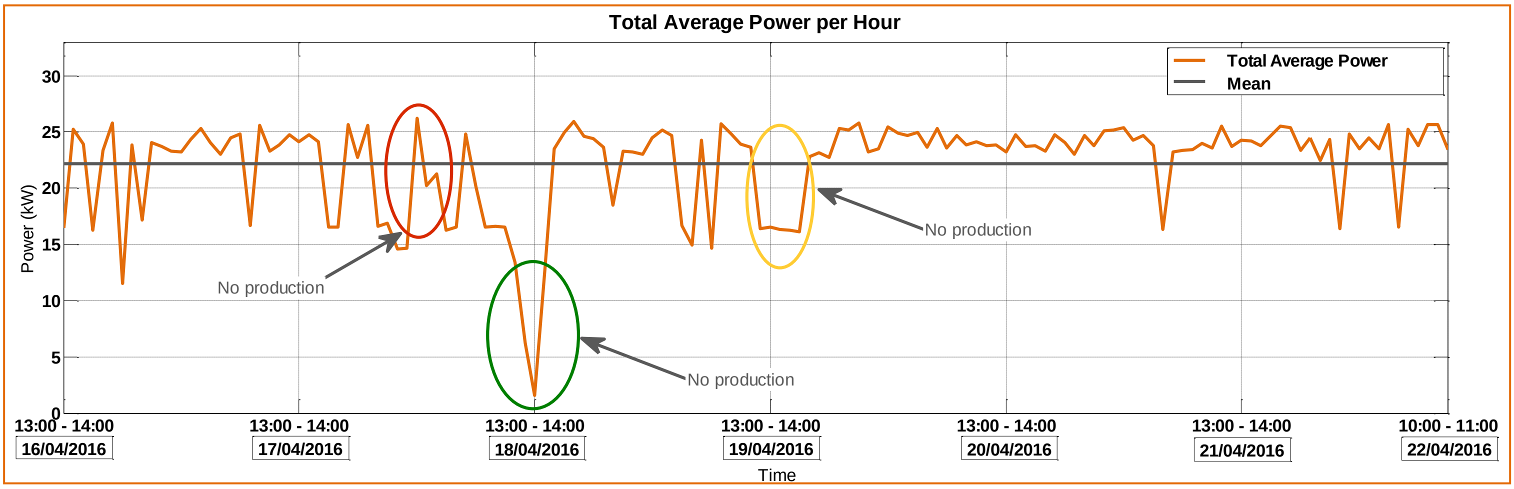


Figure 33: Total average power per hour MC 1 production line Bosch SLP (own elaboration)

Three highlighted parts can be observed in the graph displayed in Figure 33, all corresponding to timeframes of no production. Some differences can however be detected between the three outstanding values. Even though the value highlighted in red does not register any production during the time of measuring, a considerably high energy consumption value can be observed, reaching the same values measured during time of actual production. The value highlighted in yellow can be found below the mean power line, however, also reaches values of neighboring measurements where actual pieces were produced. The curve drop highlighted in green between the previously mentioned exceptions depicts solely business as it should be. Meaning that when production drops, energy consumption should automatically drop accordingly. Annex I portrays the different reasons for production stops during the measuring period such as material shortages, shortage of staff or packaging as well as maintenance. Subsequently the action plan proposes some measures to reduce such periods of missing production.

The *Total average power factor* as an indicator on process level is not as significant as it is on plant level, since there is no fine to be expected when a single MAE does not reach the minimum threshold of 0.9 predetermined by CFE. However, it is interesting to observe that the MC 1 process is on average clearly under the mentioned limit as can be seen in Figure 34. As long as the overall PF of the plant is above 0.9, as is the case for the Bosch SLP plant, a lower PF on process level is not considered an alarming discovery.

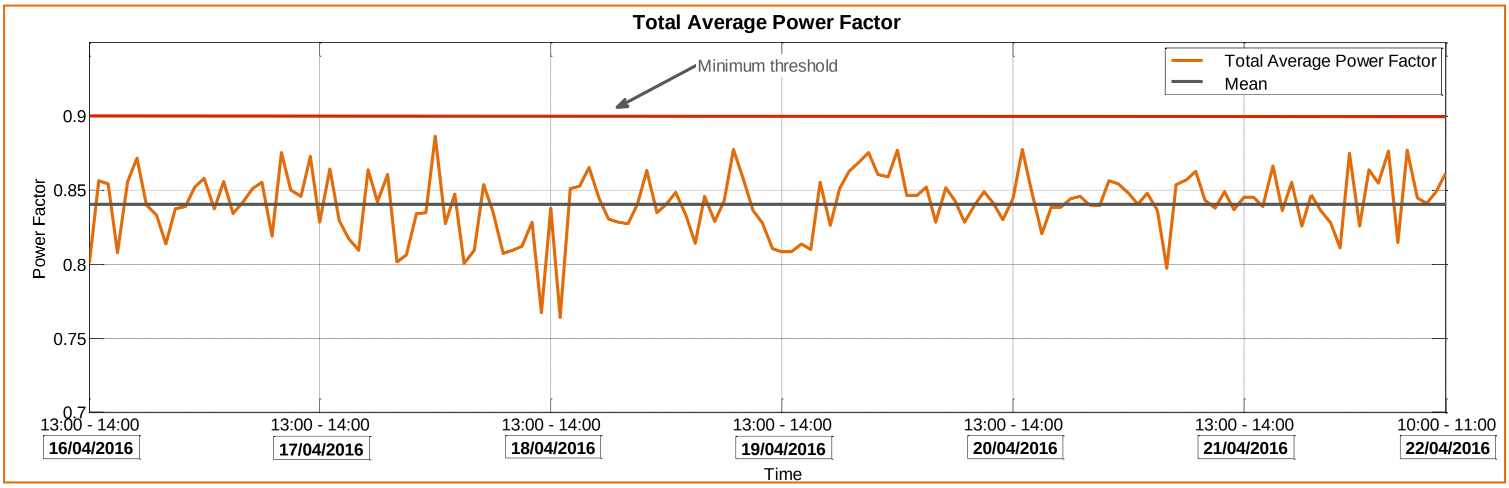


Figure 34: Total average power factor MC 1 production line Bosch SLP (own elaboration)

In order to conclusively describe the following indicators it is important to mention the different energy pricing rates in Mexico. Depending on the time zone an organization is located in, the hours of highest energy consumption in the area of location as well as the sector of operation, the energy-pricing rate differs. Since Bosch SLP is located in the central zone of the country and operating in the industrial sector, the following table shows the energy pricing rate and schedule corresponding to the Bosch SLP plant.

Table 15: Energy rate and schedule applicable for Bosch SLP (CFE, 2016a, 2016b)

Energy pricing rate and schedule			
Weekday	Low	Intermediate	High
Monday – Friday	00:00 – 06:00	06:00 – 20:00 22:00 – 24:00	20:00 – 22:00
Saturday	00:00 – 07:00	07:00 – 24:00	-
Sunday/ Holidays	00:00 – 19:00	19:00 – 24:00	-
Price ($/kWh)	0,6695	0,7144	2,1887

Under consideration of the previously mentioned energy pricing rates the indicator of *Energy cost per hour of consumption* can be established. With this indicator, the hours of highest costs can easily be identified and cost-effective measures can be taken accordingly. Since the energy pricing rates are direct reflections of the hours of highest energy consumption in the area, shifts to less demanded day times could be beneficial and relieve the system. It could contribute to a more efficient use of all energy resources distributed through the supply system since less energy is lost.

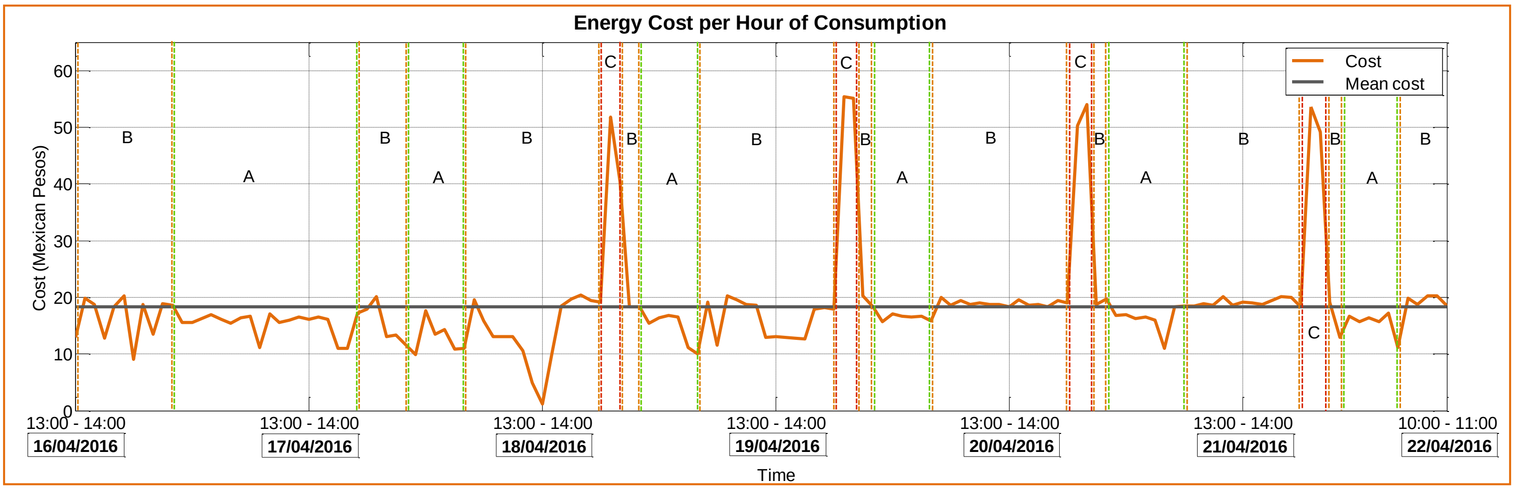


Figure 35: Energy cost per hour of consumption MC 1 production line Bosch SLP (A=low energy pricing rate; B=intermediate pricing energy rate; C=high energy pricing rate) (own elaboration)

Even though the following indicator *Production per hour* cannot be measured by the multi-channel recording power meter, it is an important indicator that has to be put into relation with the obtained energy data. As has been explained previously, an increase in energy consumption is not necessarily an indication of an inefficient use of energy, but can be related to an increase in production volume. However, when energy consumption is detected through the measuring device, but production records show no production during the time, it is valid to talk about an inefficient use of energy. The described scenario can be observed in Figure 36 and is highlighted through circles in the figure.

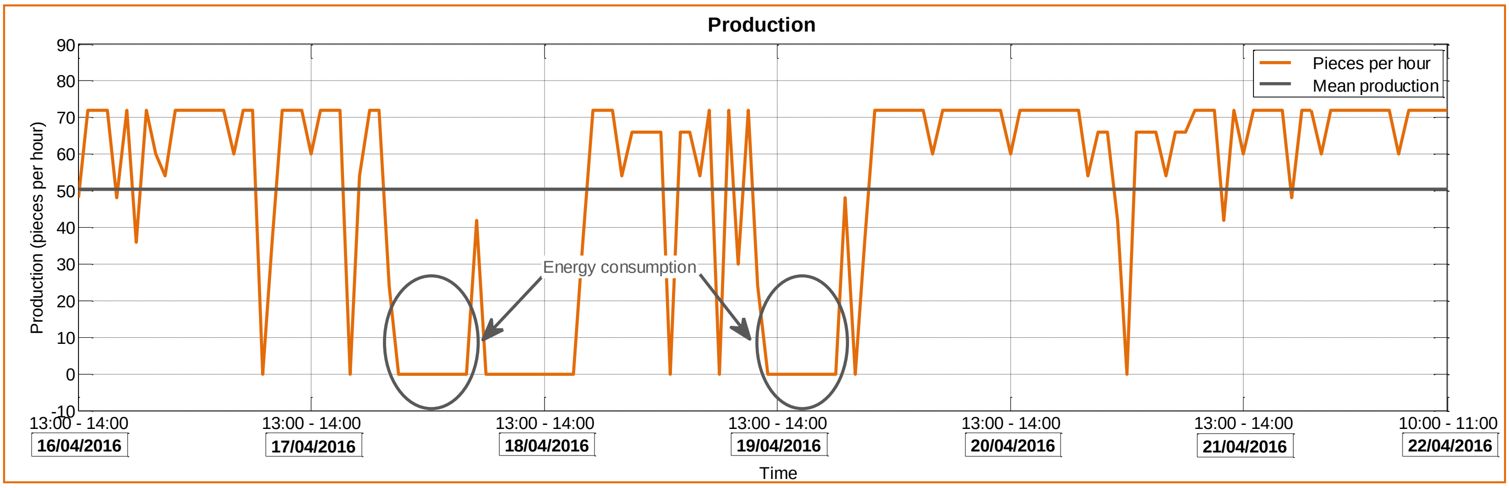


Figure 36: Production MC 1 production line Bosch SLP (own elaboration)

Taking into account the previously mentioned indicators, it was possible to propose a new, relative indicator displaying *Cost per unit*, meaning the cost of consumed energy per hour in relation to the units produced.

$$C_U = \frac{C_h}{P_h} \qquad (3)$$

where,

C_u: Energy cost per unit of production

C_h: Energy cost per hour of consumption

P_h: Production per hour

The average cost per unit shown in Figure 37 can be found between 0.2 and 0.3 Mexican Pesos per unit produced. The irregular peaks detected in the figure indicate a rather low production, elevating the price per unit noticeably during some time spans. On the other hand there are some sections where the graph line drops to 0 Mexican Pesos, normally indicating 0 costs per unit. This is, however, clearly misleading since the values used for this graph were only determined through the two variables of cost and units produced, resulting in a mathematical error for the times of 0 production. The fact that there was no production at certain time periods, however, does not mean that there was no energy consumption or costs generated. Actually the opposite was true in the majority of the cases detected for MC 1 during the measuring time (compare with Figure 33). No production was registered while the power meter recorded energy consumption, simultaneously leading to the generation of energy costs and in consequence elevating the production costs in general.

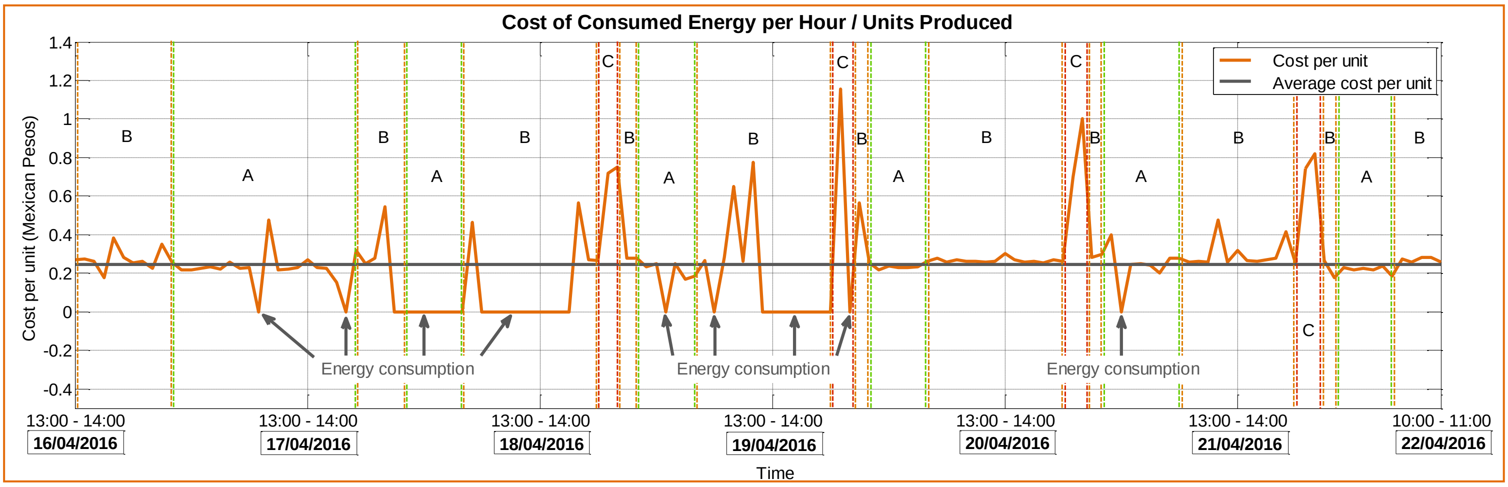


Figure 37: Cost per unit produced MC 1 production line Bosch SLP (A=low energy pricing rate; B=intermediate energy pricing rate; C=high energy pricing rate) (own elaboration)

The mentioned indicators have to be seen as a first proposal that can be appropriate for the Bosch SLP plant. In the next step those indicators have to be discussed with the responsible directors on different hierarchy levels in order to determine the suitability of the proposed indicators. For the future path of the plan a reevaluation of the indicators has to take place on a continuous basis in order to adapt them to changes and newly developed circumstances.

5.2.6 Energy objectives and targets Bosch SLP

During the development process of energy management objectives and targets for the Bosch SLP plant, it is important to consider all previously established energy policy goals as well as to base the formulation on identified significant energy users and saving opportunities. It is also crucial to take into account legal and other requirements as well as established EnPIs. The energy management objectives and targets can be developed for the whole plant as well as for individual sectors, departments or processes. Considering the previously mentioned facts, the energy management objectives and targets for Bosch SLP will be established on plant as well as on process level.

Plant level

The majority of energy management objectives and targets on plant level are influenced by internal company goals determined on corporation level. Some of the objectives are documented in the company's sustainability report of 2015. Consequently the following energy management objectives and targets for Bosch SLP can be proposed:

Objective	Reduce relative CO_2 emissions by 15% until 2020 as compared to the baseline year of 2015.
Target	Increase the use of renewable energies by 10% until 2020 compared to the baseline year of 2015.

Since September 2015, the 13 industrial sites located in Mexico, between them Bosch SLP, obtain about 70% of their electrical energy from wind energy. This change decreases the environmental impact as well as generates financial benefits and stable prices (BOSCH, 2015B). In order to increase the percentage of renewable energy use in the future, Bosch SLP should implement self-motivated solar panels on the industrial site. According to the industrial site officials a similar project will start in the near future, and is also proposed as part of the action plan in Subchapter 5.2.7.

Objective	Improve Energy Efficiency by 20% until 2020 as compared to the baseline year of 2007.
Target 1	Install electric power sub meters in 100% of MAE identified as main consumers until the 3rd quarter of 2017.
Target 2	Install a high power processor until the 4th quarter of 2017.

The installation of utility sub meters is a viable option to achieve a detailed documentation and monitoring procedure of energy consumption of individual MAE. Especially through the control of equipment that has been identified as high-energy consumers, the responsible staff can draw important conclusions and adapt their operation processes in order to decrease energy usage. The installation of a high power processor will also be beneficial to the decision-making process of energy management, since it automatically provides information about power flow.

Objective	Train 100% of employees on adequate use of MAE from an energy standpoint by the end of the 4th quarter of 2017.
Target 1	Hold monthly awareness training courses.
Target 2	Train 20% of employees each quarter for the next five quarters.

For a successfully functioning EnMS it is crucial to transmit the overall goal of the reduction of energy consumption to all employees in the plant and involve them in the implementation process. Responsible officials have to understand that without the support of its staff members the certification procedure will eventually fail. Therefore it is important to invest in training and awareness campaigns especially during the Do phase of the PDCA cycle, and further update the staff on a regular basis. It is, for example, recommended that documents such as the company's energy policy are published in order to guarantee open access when required. Furthermore, information and activities pursued by the management to monitor and control energy usage should be made available to all staff members. The proper employee involvement and distribution of information is necessary for the staff members to understand:

- "The actual or potential impact of their actions.
- The role and responsibilities within the organization in achieving the targets does not have punitive purposes, but boosts and encourages the responsible contribution of all.
- The timeframe and means available in order to achieve the foreseen objective." (SOGESCA, 2013)

Process level

The formulation of energy targets and objectives on process level can contribute to the faster completion of the overall company goals and can improve EE of the selected processes. Due to the fact that for the purpose of this thesis project an in-depth analysis was only conducted for one PL, the objectives and targets proposed in this section will only address the MC 1 process and serve as examples.

Objective	Reduce 50% of downtime energy loss by the 1st quarter of 2018 in comparison to the baseline year of 2015.
Target 1	Improve internal communication between plant departments.
Target 2	Create a cost-effective program for energy dispatch.

The implementation of an energy dispatch would help to increase the efficient use of energy. Detailed objectives and targets that could form part of the energy dispatch are presented as follows.

Objective	Reduce production downtime due to packaging shortages by 50% until the 3rd quarter of 2017 as compared to the baseline year of 2015.
Target	Invest in 100 additional spare packaging boxes, available at all times, until the 2nd quarter of 2017.

Objective	Reduce production downtime due to material shortages by 50% until 2018 in comparison to the baseline year of 2015.
Target	Improve internal communication between production areas and the logistics department through a newly implemented card-color system.

During data collection a variety of production downtime periods were identified that generated energy consumption and cost without producing unit numbers. Some of those downtime periods were caused due to a lack in internal organization that could easily be avoided. Especially in the case of material and packaging shortages production stops can be reduced or evaded in the long run. Some possibilities include the improvement of internal communication strategies as well as a sufficiently stocked packaging unit.

In order to assure the proper documentation of all energy management objectives and targets it is recommended to use an appropriate template. An example that can be used is shown in the following table.

Table 16: Energy management objectives template (modified according to Doe, 2011)

Energy objectives report to management	
Date:	Organization: Robert Bosch Mexico Automotive Systems S.A. de C.V.
Objective	
Related Target	
Departments Affected	
Operational Impact	
Implementation Requirements	
Responsible Parties	
Estimated Savings/Benefits	
Potential Problem Areas	
Planned start date: to be defined	Estimated completion date: to be defined
Team members: to be defined	Department: to be defined
…	…
…	…

After the definition process of energy management objectives and targets has ended, a revision of the results by the TM is recommended. Once all objectives and targets have been approved, they have to be spread among all employees responsible for a successful completion. It is not unusual for companies to redesign targets after some time. In some cases the organization has to make some adjustment in the database, adapting or exchanging initial data in order to make it relevant for the monitoring process of the overall objectives (DOE, 2011).

5.2.7 Action plan Bosch SLP (Recommendations)

The development of an action plan is the last and one of the most important parts of the planning phase, since it determines the further proceedings of the EnMS implementation process. This section of the thesis will introduce a set of actions that should be accomplished to secure a successful conclusion of the ISO 50001 certification process. The action plan can help to achieve the previously suggested objectives and targets, but furthermore can go beyond that scope and provide measures on operational as well as on administrative and management level. Through the determination of individual tasks, timeframes, control points, monitoring benchmarks and reporting criteria as well as the assignment of responsibilities, the action plan functions to verify the proper documentation of milestones. Unlike in previous chapters of the thesis, this section will not divide its focus between plant and process level. The overall goal of the investigation was to exemplary demonstrate and introduce a method to implement an EnMS according to ISO 50001 in order to then duplicate the method in other processes of the plant, and to lead the path to obtain the international certification on plant level in the future. Therefore a proposal for an action plan on process level would not have as much impact as a prospective action plan on plant level. Reaching the final stage of the planning phase gives reason to leave the MC 1 process and focus on a global approach of the implementation procedure incorporating all departments of Bosch SLP.

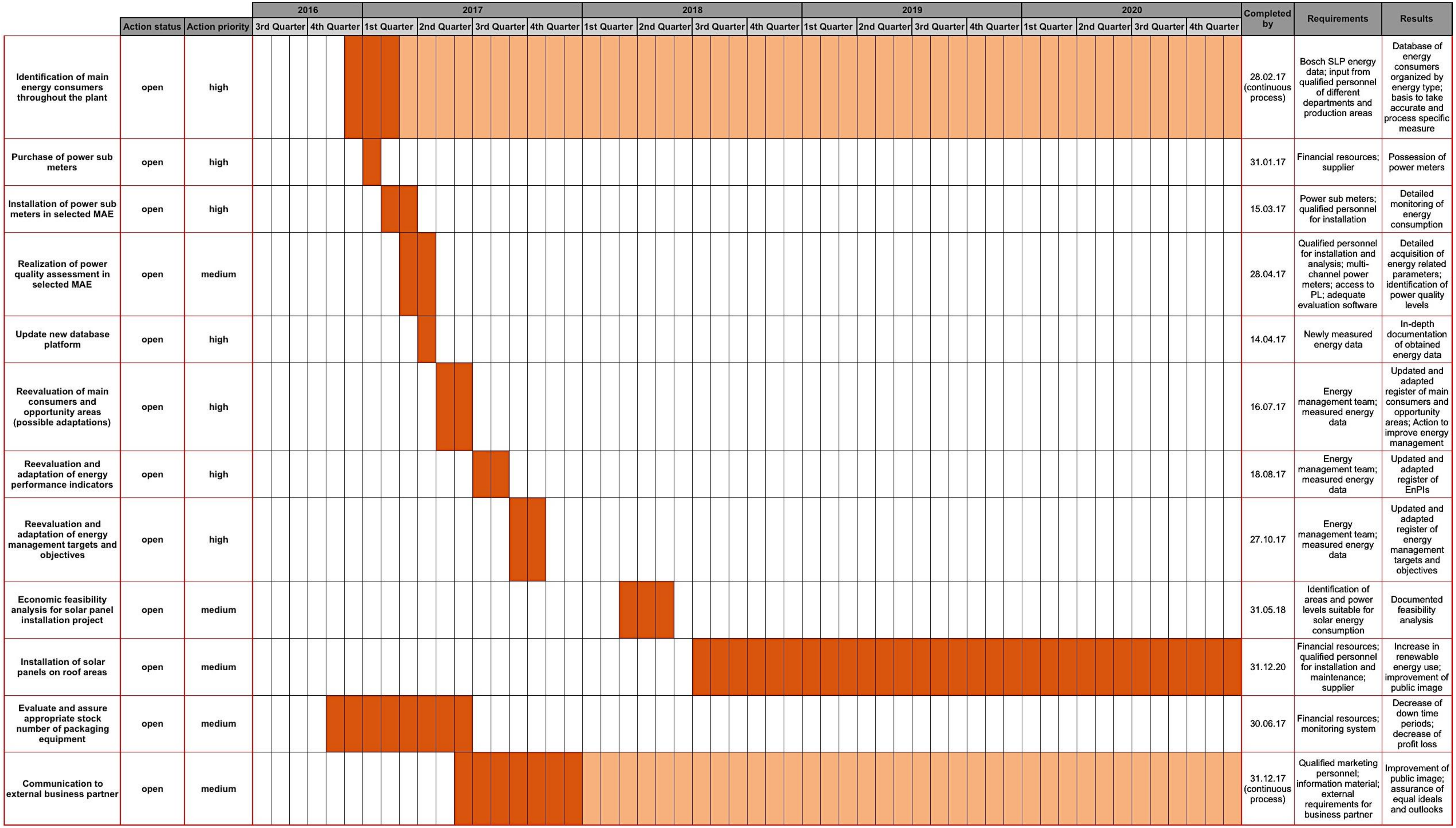
After taking responsibility, displaying commitment and forming an energy management team that is able to complete the planning phase and further paths successfully, management officials have to undertake necessary measures to continue with the implementation process of the EnMS. Therefore, the proper allocation of resources has to be a priority in order to execute the action plan properly and initiate further decisions. Resources include human resources, specialized skills, technology and financial resources. It is thereby important to distribute and document responsibilities from the beginning (SOGESCA, 2013). The preparation of an action timeline assists in keeping track of the progress as well as setbacks during the PDCA cycle. The following table displays an action plan for Bosch SLP until 2020. The time period chosen is based on the medium length time span of some proposed measures and projects.

Table 17: Action plan Bosch SLP (part 1) (own elaboration)

			2016						2017												2018												2019												2020												Completed by	Requirements	Results
	Action status	Action priority	3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter					
Top management responsibility	open	high	■	■	■	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	30.09.16 (continuous process)	Responsible leadership	Change in Bosch SLP "Code of conduct"
Appointment of energy manager	open	high				■																																																	31.10.16	Suitable staff leader	Leadership for energy management team
Formation of an energy management team	open	high					■	■	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	31.12.16 (continuous process)	Suitable staff members	Responsible personnal for energy management
Possible recruitment of new staff	open	medium					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	continuous process	Suitable job applicants; available budget; definition of job profile	Additional support for energy management team
Development of an energy management policy	completed	high	■																																																				01.07.16	ISO 50001 requirements; well defined company image	Compliance document for energy management
Launch and sign energy policy	open	high					■																																																15.11.16	Completed and approved energy policy	Official confirmation of energy management guidelines
Collection of legal information	completed	high	■																																																				01.07.16	Available legal documents; Access to internal and external information	Knowledge of legal requirements
Establishment of a preliminary energy database	completed	low	■																																																				01.07.16	Bosch SLP energy data; Access to PL; MC1 measurement data	Bosch SLP general energy data; MC1 energy data
Definition of preliminary energy performance indicators	completed	low	■																																																				01.07.16	Bosch SLP energy data; Access to PL; MC1 measurement data	Plant based EnPIs; MC1 based EnPIs
Identification of preliminary opportunity areas throughout the plant	completed	medium	■																																																				01.07.16	Bosch SLP energy data; Access to PL; MC1 measurement data	Suggestion of adequate measures
Register of already existing energy data	completed	high	■																																																				01.07.16	Bosch SLP energy data; Access to PL; MC1 measurement data	Completed and detailed database
Establishment of an intranet folder for energy management	open	medium						■																																															31.12.16	Suitable intranet platform; experienced IT staff	Centralized control and access of energy data
Development of a legal register	open	high						■																																															31.12.16	Suitable intranet platform; applicable legal information	Legal backup; legal documentation system
Launch of energy management database	open	medium						■																																															31.12.16	Completed database template	Centralized control and access of energy data
Employee involvement and training	open	high				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																			31.12.17	Qualified trainer; room for workshops; blocked period of time	Sensitization of employees in energy and sustainability questions
Reinforce internal communication between departments	open	high					■	■	■	■	■	■	■	■	■	■	■	■	■	■	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	31.12.17 (continuous process)	Frequent meetings of department heads	Exchange of knowledge and experiences; mutual monitoring

■ **main action period** ▨ **period of continuous process**

Table 18: Action plan Bosch SLP (part 2) (own elaboration)



			2016						2017												2018												2019												2020												Completed by	Requirements	Results
	Action status	Action priority	3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter			2nd Quarter			3rd Quarter			4th Quarter					
Identification of main energy consumers throughout the plant	open	high						▓	▓	▓	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	28.02.17 (continuous process)	Bosch SLP energy data; input from qualified personnel of different departments and production areas	Database of energy consumers organized by energy type; basis to take accurate and process specific measure
Purchase of power sub meters	open	high							▓																																														31.01.17	Financial resources; supplier	Possession of power meters
Installation of power sub meters in selected MAE	open	high								▓	▓																																										15.03.17	Power sub meters; qualified personnel for installation	Detailed monitoring of energy consumption
Realization of power quality assessment in selected MAE	open	medium									▓	▓																																									28.04.17	Qualified personnel for installation and analysis; multi-channel power meters; access to PL; adequate evaluation software	Detailed acquisition of energy related parameters; identification of power quality levels
Update new database platform	open	high										▓																																									14.04.17	Newly measured energy data	In-depth documentation of obtained energy data
Reevaluation of main consumers and opportunity areas (possible adaptations)	open	high											▓	▓																																							16.07.17	Energy management team; measured energy data	Updated and adapted register of main consumers and opportunity areas; Action to improve energy management
Reevaluation and adaptation of energy performance indicators	open	high													▓	▓																																					18.08.17	Energy management team; measured energy data	Updated and adapted register of EnPIs
Reevaluation and adaptation of energy management targets and objectives	open	high															▓	▓																																			27.10.17	Energy management team; measured energy data	Updated and adapted register of energy management targets and objectives
Economic feasibility analysis for solar panel installation project	open	medium																				▓	▓	▓																															31.05.18	Identification of areas and power levels suitable for solar energy consumption	Documented feasibility analysis
Installation of solar panels on roof areas	open	medium																								▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	31.12.20	Financial resources; qualified personnel for installation and maintenance; supplier	Increase in renewable energy use; improvement of public image
Evaluate and assure appropriate stock number of packaging equipment	open	medium					▓	▓	▓	▓	▓	▓	▓	▓																																							30.06.17	Financial resources; monitoring system	Decrease of down time periods; decrease of profit loss
Communication to external business partner	open	medium												▓	▓	▓	▓	▓	▓	▓	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	░	31.12.17 (continuous process)	Qualified marketing personnel; information material; external requirements for business partner	Improvement of public image; assurance of equal ideals and outlooks

▓ main action period ░ period of continuous process

Table 17 & Table 18 demonstrate an action plan for the Bosch SLP plant, incorporating a list of possible action, their status and priority level. Subsequently a timeline is incorporated in the action plan template highlighting the period reserved for the implementation process of each action. Since some actions need continuity over a longer time span, a differentiation was made between the main action period and the period of continuous process. With the purpose of monitoring the achievements of the actions, it is important to set dates of completion that mark individual milestones. In order to be able to plan and to point out the dimensions of the individual actions, it is recommended to tabulate all resources required as well as expected results. It is certainly necessary to replace or update the actions over time in order to proceed with the PDCA cycle of continuous improvement.

During data acquisition, a variety of opportunity areas have been identified and actions have been proposed to capitalize on them in order to improve the overall energy performance. However, some already well-functioning aspects also have to be highlighted to enhance and build upon. An example can be made during maintenance when the MC 1 process was shut down. The downtime period was chosen adequately in accordance to the energy pricing rates. Therefore the PL was under maintenance during the two-hour high-pricing period. Such actions should become an everyday practice for all production areas of the plant (see Annex I).

5.3 Final company report

In order to finalize the thesis project in the Bosch SLP plant, an executive summary has to be delivered to the plant's TM, demonstrating the main findings of the research as well as further steps that have to be taken in order to obtain the ISO 50001 certification. In the executive summary, the main sections should be divided as follows:

- A general description of the existing MS pointing out the high level of structural congruence between the existing and proposed MS
- An overview of the current situation regarding energy consumption on plant level and exemplary on process level for the MC 1 process
- The proposed action plan including a list of recommendations leading to an improvement in the overall EE of the plant as well as the MC 1 process
- A listing of potential benefits that can be obtained through the implementation of the recommendation strategies such as the completion with legal and other requirements, reduction in costs through a reduction in energy consumption, improved public presentation and image etc.

It is important to integrate personal experiences and observations as well as actual results of measured energy performance of the company in the context of energy management. The emphasis should be on the improvement aspect of the project trying to increase the company's overall performance and should not be about pointing fingers. Especially the environmental performance should be highlighted since such advantages are often left aside. In addition to the environmental benefits of an implemented EnMS, the executive summary should contain long-term financial advantages. Those might, at a first glance, be even more attractive to the TM, since the overall purpose of the industrial plant is to generate profit. Also the improvement in public image should be emphasized, often leading to consumer preference and increasing the competitiveness of the organization. Future phases of the PDCA cycle that need to be completed before obtaining the ISO 50001 certification are presented in greater detail in the following chapter.

6 Steps towards the full implementation of ISO 50001 in Bosch SLP

The content of Chapter 6 is primarily directed towards the plant management, providing a synthesis of the actual implementation progress of an EnMS and future recommendation strategies. The overall goal of this section is to show future decision makers the current status in a possible certification procedure in Bosch SLP and point out areas of necessary improvement. Therefore the different steps of the planning phase are evaluated regarding their level of completion. In this context material is presented that highlights essential parts of the planning phase that need to be obtained and edited in order to receive an ISO 50001 certification and stay certified in the long-run. In addition, other phases of the PDCA cycle are explained that have not yet been presented, however, need to follow the planning phase in order to obtain an official ISO 50001 certification.

6.1 Progress of the planning phase in Bosch SLP

The measures introduced in Chapter 5 are specific examples for the Bosch SLP plant, and have been adapted according to the company's conditions. Therefore they should not be applied one-to-one to other production sites. The exchange of knowledge and experiences, however, should be interchanged more frequently between industrial sites within the corporation as well as the same industrial branch.

This thesis can be seen as a first step and approach to the ISO 50001 certification of Bosch SLP. However, without the right mindset and motivation of the responsible management the final goal of an ISO 50001 certification will not be achieved. From the present point of view there is still a large number of aspects that has to be dealt with in order to complete the PDCA cycle of an EnMS successfully. During the investigation project, various methods were used and findings were obtained that can result in a profitable outcome for Bosch SLP. However, in the pursuit of completing the overall objective some obstacles had to be overcome. Especially the phase of data collection was often interrupted due to an inconsistent documentation procedure and operational and administrative difficulties. In the most part this could have been avoided through a more official treatment of the investigation project and the formulation and signing of a confidentiality agreement.

Due to the fact that an EnMS in Mexico is neither a requirement established by law nor requisite demanded by the Bosch corporation, the current motivation degree of Bosch SLP can be classified as rather low. In general, three areas of opportunities in administration were identified that still need to be improved:

- Availability of information
- Organization of data and information
- Commitment

Considering the above, the following table displays a self-evaluation checklist for the ISO 50001 planning phase. A demonstration of clearly listed steps is presented, indicating if they have already been accomplished or still need to be further developed and tackled by Bosch SLP. The complete checklist, including the Do, Check and Act phase can be found in Annex II.

Table 19: Self-evaluation Checklist ISO 50001 planning phase Bosch SLP (modified according to TÜV Nord, 2014)

Resources, Roles, Responsibility and Authority			
Requirements	Conformity		
	Yes	No	N/A
1. Have the roles, responsibilities and authorities for energy management been defined and documented?		X	
2. Have a Management Representative and an Energy Management Team been designated?		X	
3. Have the roles, responsibilities, and authorities for the Management Representative and Energy Management Team been defined?		X	
4. Have the required resources (e.g. personnel, technology, finance) for implementation and control of the energy management system been provided by the management?		X	
5. Does the personnel appointed in energy management have the competence required?			X

Energy Policy			
Requirements	Conformity		
	Yes	No	N/A
1. Has the organization defined and documented its energy policy?	X		
2. Is the energy policy appropriate to the nature and the scale of and the impact on the organization's energy use and consumption?	X		
3. Does the policy include commitments to • Continual improvement of energy efficiency? • Compliance with applicable legislation and other requirements? • Support purchase of energy-efficient products and	X		

services?			
4. Does the energy policy provide a framework for setting energy objectives and targets?	X		
5. Has the energy policy been documented, implemented, maintained and communicated to all persons working for or on behalf of the organization?		X	
6. Has the energy policy been documented, implemented, maintained and communicated to all persons working for or on behalf of the organization?		X	

Legal and other requirements

Requirements	Conformity		
	Yes	No	N/A
1. Has a procedure been developed and implemented to identify applicable regulatory, legal and other requirements?	X		
2. Has the organization identified, implemented, and access to the applicable legal requirements and other requirements, which are related to the energy-use consumption and efficiency?	X		
3. Has the organization determined how the applicable legal requirements and other requirements apply to its energy use, consumption and efficiency?	X		
4. Are current copies of all applicable regulatory and other requirements accessible to personnel as necessary?		X	

Energy Review, Energy Baseline, and Energy Performance Indicators

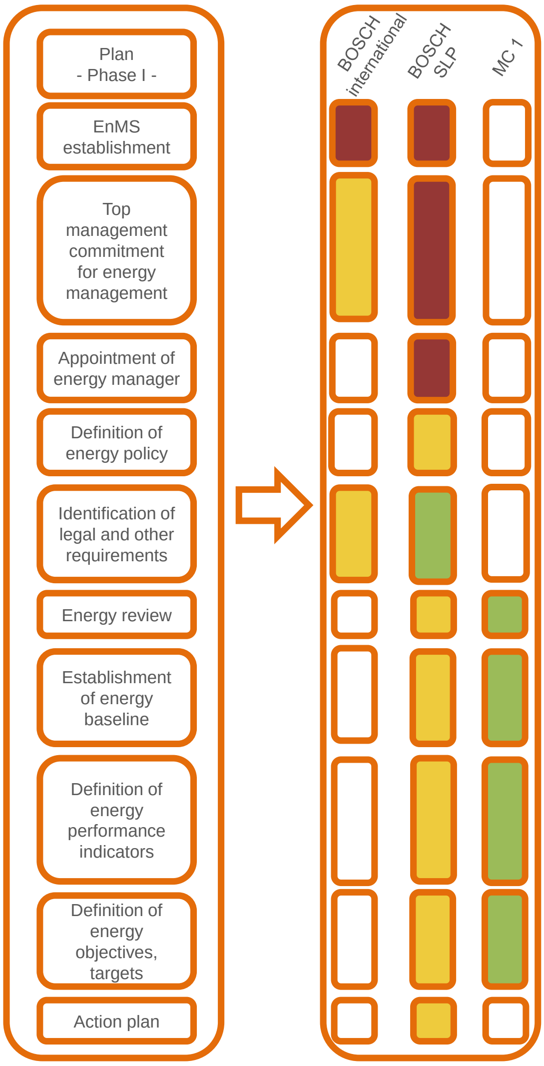
Requirements	Conformity		
	Yes	No	N/A
1. Has a procedure been established, implemented and maintained to identify the baseline and Energy Performance indicators?	X		
2. Has energy baseline related to potential significant energy use been considered in establishing and implementing the EnMS?	X		
3. Has the organization identified the areas of significant energy use?	X		
4. Has the organization determined the current energy performance related to identified significant energy uses?		X	
5. Are all significant energy uses controlled by objectives, targets, and programs, procedures or monitoring?		X	

6. Has the organization identified other relevant variables affecting significant energy uses?		X	

Energy Objectives, Energy Targets and Energy Management Action Plan

Requirements	Conformity		
	Yes	No	N/A
1. Have documented energy objectives and targets been established at relevant functions and levels within the organization?	X		
2. Are the energy objectives and energy targets specific, measurable, concrete and understandable?	X		
3. Are the objectives and targets consistent with the energy policy?	X		
4. Has an energy performance evaluation system been established to periodically review the achievement of the objectives and targets?		X	
5. Have action plans including the following items for the achievement of energy objectives and targets been established and implemented? • Designation of responsibility for achieving objectives and targets at each relevant function and level of the organization • The means and timeframe by which the programs are to be achieved • The statement of the method by which an improvement in energy performance shall be verified • The statement of the method of verifying the results of the action plans	X		
6. Have the action plans been documented and updated at defined intervals?		X	

Taking into account the answers obtained through the self-evalutation checklist, an initial conclusion can be drawn regarding the implemetation progress of an EnMS in the Bosch SLP plant. A traffic-light system was used in Figure 38 to demonstrate advances of the planning phase on „Bosch international“, „Bosch SLP“ as well as on „MC 1“ process level, taking up the diagram used in Figure 18.



Plan - Phase I -	BOSCH international	BOSCH SLP	MC 1
EnMS establishment	🟥	🟥	☐
Top management commitment for energy management	🟨	🟥	☐
Appointment of energy manager	☐	🟥	☐
Definition of energy policy	☐	🟨	☐
Identification of legal and other requirements	🟨	🟩	☐
Energy review	☐	🟨	🟩
Establishment of energy baseline	☐	🟨	🟩
Definition of energy performance indicators	☐	🟨	🟩
Definition of energy objectives, targets	☐	🟨	🟩
Action plan	☐	🟨	☐

Figure 38: Progress of ISO 50001 planning phase for Bosch SLP (green=high; yellow=medium; red=low) (own elaboration)

Throughout this study a variety of deficits were noticed that have to be overcome in the future in order to guarantee a smooth development process for the whole Bosch SLP plant. Especially in respect of the implementation of an international standard such as the ISO 50001 norm, the flow of information and data needs to improve drastically. Currently all industrial plants of the Bosch corporation work independently in regard to the implementation of EnMSs.

"[The implementation of ISO 50001] is left to each industrial site independently. The content of ISO standards must be implemented, however, an official certification is not a requirement. If a plant decides not to get an external certification, it needs to operate upon an internal audit system. Currently ISO 50001, unlike occupational safety and environmental protection, is not listed in the demand portfolio informing about necessary management systems. I think, however, that it will not be long until a

demand for implementation is communicated." (B. SCHWAGER, personal communication, March 18th, 2016)

Therefore Bosch SLP is left alone during the decision-making and implementation process, which on the one hand gives room for flexibility and individual responsibility while on the other can lead to a situation where no one feels responsible and therefore the achievement level stays low. In this regard, recommendation strategies and guidelines regarding ISO 50001 certifications issued by the headquarter is advisable in order to initiate the implementation process and give incentives. A proactive approach is desirable, especially when taking into consideration the fact that the company is known for its sustainable corporate culture. Advantages of an ISO certification are the proper and detailed documentation of operation and awareness structures that help define the internal governance of the company. In this context, the formation of a responsible department is necessary in order to guarantee continuous communication between the headquarter and the individual production sites.

In order to receive more detailed results by measuring a variety of energy parameters, a power quality assessment should be realized throughout the plant. The implementation period is, however, more extensive and investment costs are higher in comparison to a regular energy audit.

Since the implementation of an EnMS can be rather expensive due to the complexity of some actions, a valid option could be the cooperation between the industry and educational institutions. Government funded research projects such as the technological innovations module for large enterprises (INNOVATEC) as part of the incentives program for innovation (PEI for its acronym in Spanish) support the industry in order to increase sustainable economic growth and innovation (LÓPEZ-RIVAS, 2016).

During the implementation procedure for the whole plant, the company should, in addition to the previously presented steps, put greater attention on the quality of EnPIs. The overall goal should not be the quantity of indicators put rather quality, meaning that more precise and process-oriented measurements would give more detailed results. Universal indicators can, however, also be beneficial, especially for measurements in general areas/sectors. Furthermore, all MAE should be reviewed with respect to a proper power supply. This involves the revision of electrical standards adequate for the MAE, and ensuring a maximum efficiency in energy consumption.

Furthermore it is necessary to provide sufficient information regarding ISO 50001 guidelines and strategies. The Robert Bosch Intranet offers the access to a variety of international norms in a portal called *Normenmaster*. The general norm of ISO 50001 was offered, however, other norms forming part of the ISO 50000 family such as ISO 50002, 50003, 50004, 50006, 50015 are not available without an explicit solicitation and verification procedure.

6.2 Other phases of ISO 50001

As has been explained throughout the thesis, the planning phase of the PDCA-cycle is the first stage of the implementation process of an EnMS according ISO 50001. It is followed by three additional phases with the final and overall objective of continual improvement. Therefore it is important to continue with the PDCA cycle after a successful implementation of the planning phase.

6.2.1 Do phase

After planning the EnMS, the actual implementation has to start, applying all measures determined in the action plan. In order to guarantee maximal energy savings, all measures determined in the action plan have to be prioritized and translated into a detailed work plan as part of the Do phase. The work plan should, in addition to indications regarding responsible personnel and timeframes of certain activities, always contain information of all resources necessary for the application of the action plan. Only if sufficient financial and technical resources are available, the set energy objectives and targets can be achieved. Additionally the EMO should always systematically document all outcomes resulting from the implemented measures and activities in order to assure the achievement of the proposed energy goals and facilitate cost-effectiveness analysis. Indicators of a successfully functioning action plan are e.g. cost savings, reduction of environmental impacts, positive press reviews and positive employee feedback. It is recommended to create an energy saving register to record all actions related to energy savings. Measures that do not require investments are usually related to organizational changes such as the systematic collection of data, shutdown of MAE in non-working hours or responsibility assignment (KAHLENBORN et al., 2012).

Table 20: Detailed overview of Do phase procedures (KAHLENBORN et al., 2012)

Do phase	
Implementation of action plan	• Ensuring all necessary resources for the implementation of an EnMS • A high demand of personnel is common in the early stages of the implementation process
Employee involvement in energy management	• Creating awareness of EnMS among employees e.g. through intranet, flyer, meetings, info screens • Offering training opportunities in the field of EnMS for staff members
Internal and external communication	• Internal communication is mandatory according to ISO 50001 and closely linked with the previous step • Development of a corporate culture where employees contribute actively in the improvement process • External communication is not mandatory, however, contributes to a positive corporate image
Documentation of energy records	• All aspects (e.g. EE measures, area of application) of the EnMS have to be documented and must be easily accessible • Responsible staff members need access to documentation system • The frequent actualization of the system is fundamental
Control of operations affecting energy performance	• All relevant energy uses should be systematically monitored in order to identify insufficient or non-existent control mechanisms
Energy-efficient processes, design and procurement	• All external and internal processes must be reviewed in terms of EE and energy savings • Incorporation of energy efficient designs in the renovation process of buildings, process or machinery • EE has to be taken into account in the procurement of e.g. machinery, materials and services • The entire life cycle has to be considered in the calculation of energy consumption and EE

6.2.2 Check phase

After implementing the action plan and its related measures, the responsible energy management team has to verify the effectiveness of the EnMS by examining its energy performance (TÜV NORD, 2014). A frequent comparison of expected and actual energy consumption is helpful to quickly identify inefficient energy use. Thus, energy consumption can be analyzed, and the achievement of energy objectives and targets can be monitored (KAHLENBORN et al., 2012).

Table 21: Detailed overview of Check phase procedures (KAHLENBORN et al., 2012; TÜV NORD, 2014)

Check phase	
Monitoring, measurement and analysis	• The monitoring procedure should at least include the following aspects: ➢ Identification of relevant energy uses and other results of the energy review ➢ Identification of all significant aspects related to relevant energy uses ➢ Revision of EnPIs ➢ Revision of adequacy of the action plan as well as all set objectives and targets ➢ Assessment of actual against expected energy consumption
Evaluation of compliance with legal and other requirements	• Mechanism to assure the compliance with legal and other requirements • Periodically monitored through the energy management team
Internal audit	• An internal audit serves e.g. in the improvement process of operating functions regarding the EnMS, energy management programs or goals as well as in the develop of new optimization measures • An internal audit should be conducted on an annual basis by qualified staff members or external experts • Development of audit checklists to use as guidelines during the audit • During the audit an auditor should: ➢ Determine the actual energy performance ➢ Check the performance of the EnMS and its processes and related systems ➢ Compare the results with the energy objectives and targets ➢ Provide information for benchmarking ➢ Identify operational problems, weaknesses and their causes ➢ Identify opportunities for continual improvement.
Non-conformities, corrective and preventive actions	• In the event of non-conformities, preventive and corrective measures have to be introduced and monitored to assure a successful implementation • ISO 50001 requests a self-contained identification and elimination of any disturbance in the EnMS
Control of records	• To present a problem-free operation of the EnMS, companies must provide reliable records

	• Those records must at least include the following aspects: ➢ "Methodology, criteria and result of energy review ➢ Opportunities for improving energy performance ➢ Energy baseline ➢ Energy performance indicators ➢ Training records ➢ Internal communication records ➢ Decision on whether to externally communicate its EnMS and energy performance criteria and results ➢ Design activity results ➢ Monitoring and measurement results of key operational characteristics ➢ Calibration records ➢ Compliance evaluation results ➢ Internal audit programs and results ➢ Non-conformance records ➢ Corrective and preventive action records ➢ Management review agenda and minutes" (TÜV Nord, 2014)

6.2.3 Act phase

The act phase is the last step of the implementation process before starting with the procedures of continual improvement. The management review is thereby the most important aspect of the act phase, since it will contribute to evaluate the EnMS under the terms of suitability, adequacy and effectiveness. It is important to mention that not all aspects of the EnMS have to be reviewed simultaneously, but can be extended over longer periods. The concept of continual improvement should be considered in the management review by assessing the energy performance regarding the compliance with energy policies, objectives and targets (TÜV Nord, 2014). If ISO 50001 requirements for an EnMS are not fulfilled countermeasures have to be taken (Kahlenborn et al., 2012).

Table 22: Detailed overview of Act phase procedures (TÜV NORD, 2014)

Act phase	
Management review	• "Review of energy policy, objectives, targets and evaluation of overall progress in achievement • Findings of previous management review and EnMS audit; • Evaluation of the effectiveness of EnMS, EnPIs and energy performance • Review of changes in: legislation, expectations and requirements of interested parties, products/activities of the organization, advances in technology, market preference, etc. • Evaluation of follow-up actions in relation to nonconformities • Projection of energy performance in the next period • Revision on policies, objectives, targets, resources or other elements of EnMS, if necessary • Review of resources allocation • Identification of room for improvement"

6.3 Assumptions regarding the successful implementation of an EnMS

Since as of today, it is not possible to analyze the Do, Check and Act phase for the Bosch SLP study case, due to the development progress of the project, this subchapter indicates the preparedness of Bosch SLP to continue with the PDCA cycle. The future challenge will be to duplicate the progress made for the MC 1 process in the rest of the Bosch SLP plant. Therefore favoring and disadvantaging aspects for the implementation of an EnMS are presented as follows.

Aspects favoring the implementation of an EnMS in Bosch SLP:

- The introduction of an EnMS can be built upon the already existing and certified QMS and EMS ISO 9001 and ISO 14001. Therefore the organizational effort is reduced considerably, since existing documents of QMS and EMS can be extended.
- Bosch SLP counts with a CO_2 reduction program that mainly focuses on energy reduction, making the implementation of an EnMS a viable option
- Bosch SLP is expanding its production site. Therefore the implementation of an EnMS could be taken into account in the planning process e.g. installation of sub meters in all production lines

Aspects disadvantaging the implementation of an EnMS in Bosch SLP:

- A deficiency, especially in TM commitment, was detected that has to be resolved in order to proceed with the following tasks.
- Other methodologies need to be implemented considering additional energy sources such as pressure or heating among others, in order to obtain a more accurate result.
- Other certifications such as OSHAS 18001 have been granted priority over ISO 50001 at the moment.
- Currently there are no technological devices available in the plant that can facilitate the implementation of an EnMS e.g. sub meters
- Currently there is no trained personnel available in the plant that could assist with the implementation of an EnMS

Conclusions and recommendations

Due to resource scarcity, the topic of EE is becoming increasingly important, especially in the context of industrial development. Given this background, the introduction of an EnMS according to ISO 50001 can contribute to the achievement of continuous energy savings and efficiency in an organizational environment.

In accordance to the objectives outlined for the purpose of this thesis, the first part focused on a basic overview of the concepts related to MS in general and EnMSs in particular. Models and terms such as the PDCA cycle that are related to the international norm ISO 50001 were presented in greater detail. On this basis it can be concluded that:

- The structure and procedure of ISO 50001 is based on the standards of ISO 9001 and ISO 14001
- The implementation process can be facilitated with already existing QMS and EMS
- Employees familiar to the implementation procedure of ISO norms can more easily adapt their knowledge to the ISO 50001 standard

Furthermore, a general overview of legal frameworks was provided for Mexico due to the location of the case study, as well as for the EU as an example for stricter legal backgrounds regarding energy audits and EnMSs. On this basis it can be concluded that:

- EU legislation has progressed in the field of EE incorporating energy audits or EnMSs as a requirement for large enterprises
- Mexican energy legislation needs to be tightened in order to assure the obligatory accomplishment of currently only proposed suggestions in the legislation
- The execution of energy audits or implementation of EnMSs must be an obligations for large enterprises

Throughout the thesis general guidelines for the implementation of an EnMS were described as a basis for the initiation of the PDCA cycle. On this basis it can be concluded that:

- It is not possible to create a uniform guide for the implementation of an EnMS due to the complexity and the unique characteristics of organizational structures

- A particular approach depends on different parameters such as the type of production, number of employees, the corporate structure, energy consumption and many other aspects
- Each company can be guided by the general steps proposed in the ISO 50001 norm, however needs to adapt them according the their independent and individual necessities

In this regard, the thesis proposed an individual methodology for the implementation of an EnMS for the Bosch SLP plant with the long-term goal to incorporate EE as a continuous process into the operational structure, and thereby improve the energy performance of the company.

Therefore an introduction to the Bosch corporation was provided in order to get an impression of the different business sectors of the company, putting special focus on its environmental policies. On this basis it can be concluded that:

- Bosch SLP counts with a solid basis for the implementation of an EnMS due to its already existing EMS and QMS

The planning phase of the PDCA cycle for an EnMS was first introduced in Chapter 3, where general guidelines were and information was presented. Subsequently the same steps were followed in Chapter 5, however, applying them to the Bosch SLP case study. In this context energy policies for Bosch SLP were elaborated and a potential distribution of responsibilities was assigned to the different department managements. It is important to mention that this study differentiates between process and plant level during the implementation of the planning phase. Therefore, when focusing in greater depth on the methodology amplified for the purpose of this study, a detailed energy audit was completed for the MC 1 process, by measuring energy parameters through a multi-channel power meter. The obtained data was then used to identify opportunity areas and establish an EB, energy management objectives and targets on process level. Already existing energy data from utility bills was reorganized and analyzed in order to realize an energy review on plant level. As a final step of the planning phase, an action plan was proposed, however solely on plant level, since the overall goal for the future should be to duplicate the detailed energy audit throughout the plant. As part of the action plan, a variety of recommendations regarding suitable energy savings measures and activities, needed for the implementation of an EnMS, were suggested.

It has to be noted that during the investigation process some limitations and shortcomings of the methodological approach had been identified. On account of the demand for detailed and comprehensive information, a preliminary period for extensive data collection is needed. However, in conducting this study it was proven that the methodology can be implemented without the availability of all required information. Yet the significance of the results increases notably with data disposability. In conclusion, it can be argued that all objectives proposed for this research project were accomplished and properly discussed regarding shortcomings and its applicability for the Bosch SLP plant.

Strategic role of ISO 50001

After a detailed review of all literature sources corresponding to this research, it has to be stated that the implementation of ISO 50001 certified EnMSs alone cannot be the key to reach an overall sustainable energy consumption. On this basis it can be concluded that:

- The improvement of energy performance of industrial companies cannot be achieved solely through the compliance with applicable regulation or the implementation of EnMS standards, but needs to be supported by an organizational shift that effectively optimizes resource use
- To achieve long-term changes of the socioeconomic-ecological system, a transition has to occur introducing new policy frameworks into society.

A great advantage of ISO 50001 is its international legitimation and the possibility to compare companies to each other with respect to all requirements established by the ISO norm. Especially global players such as the Bosch corporation can use an internationally accepted certification to benefit from it in the global market. On this basis it can be concluded that:

- Companies that generally interact in local markets might not have as much of an interest in an international certification
- Some companies might rather concentrate on other options such as governmental subsidies or process enhancements that are cheaper and result in the same economic advantage in the long run.

A limitation of EE policies can be discovered in the phenomenon called the “rebound effect”. On this basis it can be concluded that:

- An improved EE performance could increase the energy consumption, rather than achieving energy demand reductions
- A holistic approach and analysis of probable impacts, taking into account their bases, contributes to a better understanding of possible trade-offs.

In conclusion, the implementation of an EnMS according to ISO 50001 cannot solely improve EE and decrease energy consumption. However, it can assists in the introduction process. Aspects such as government policies, consumer behavior, company preference or international energy prices influence energy consumption noticeably. Therefore governments, society and industry have to work together to achieve a more sustainable use of energy resources in the long term.

Other debates related to energy management

The majority of international corporations issuing annual sustainability reports seek primarily for an improved corporate image. In that context, GHG emissions function as the principle indicator utilized by organizations to demonstrate their willingness to reduce energy consumption and display their environmental commitment and sustainable efforts. On this basis it can be concluded that:

- The calculation of CO_2 emissions can elevate an EnMS to the next stage showing clearly the possible reduction potentials, and thereby providing an advanced logic to the topic of energy audits
- It is crucial not to use CO_2 emissions as an absolute indicator, but putting it in relation to, for example, total production, in order to provide a more detailed view of the organization's energy performance available to all stakeholders involved

It was detected that EnMSs are not the only tools that can be used to increase the sustainable and efficient use of energy resources in the industrial sector. They can, however, be used in conjunction with qualified specialists, adequate technical information, as well as improved management instruments to detect and economically exploit the existing potential for energy savings in companies.

Recommendations for further applications and research

In order to obtain a more holistic approach of energy management in general and the implementation of an EnMS in particular, further research should be done to close existing gaps in the field of investigation.

As has been stated throughout the thesis, the implementation of an EnMS is a continuous process that requires input from all employees throughout the different stages. However, it is the responsibility of the TM to guarantee the proper education and awareness of personnel on all organizational levels. On this basis it can be recommended that:

- A strategic educational program should be integrated into the business strategy that reflects upon environmental issues. This gives room for future research in the field of corporate environmental education.

Management officials should integrate energy management into the company's business structure, instead of using regulatory compliance for guidance. Therefore it is important to utilize resources in a sustainable manner. A general problem is the fact that market prices for energy and raw materials solely reflect direct costs, but do not include ecological costs or in other words the generated environmental impact. In this context a solution should be found for corporations to be able to measure their environmental impact more accurately.

The lack of information transfer noticed during the study displays another opportunity for further investigation. Therefore a system should be developed that guarantees the information exchange between industrial sectors, organizations of the same sector as well as within the Bosch corporation itself. Especially the extensive internal exchange of knowledge is crucial to improve the implementation of EE measures, as well as the general concept of EnMSs. The definition of global indicators for the Bosch corporation, particularly for industrial sites of the same business branch, can be beneficial in the development process of internal energy management guidelines and policies. The experiences and strategies of other plants could improve energy performance for Bosch SLP and vice versa, as soon as knowledge transfer systems are established.

Furthermore, additional indicators should be proposed for the Bosch SLP EnMS, amplifying the criteria and principles into the designing process. Subsequently the revision of other national and/ or international standards, agreements or EnMSs should be considered in order to affirm the appropriateness of the ISO 50001 certification for the Bosch SLP plant. The possibility of other methods besides interviews, energy consumption measurements and observations should be confirmed and if possible applied to obtain additional data for an energy consumption assessment.

To amplify the study results a detailed calculation of CO_2 emissions should be conducted. The initial phase should concentrate on actual CO_2 emissions for the establishment of a CO_2 emission baseline. An additional phase should focus on the possible CO_2 emission savings that can be obtained through the implementation of an EnMS and the thereby initiated structural change.

As part of a more complete analysis, the incorporation of an economic feasibility assessment should be exploited. Detailing the investment costs of certain measures and their cost recovery period should be principle concerns. This way, management officials can clearly see the financial benefits of EE measures and an improved energy performance and are more likely to invest in the long run.

Based on the reviewed literature, a benefit of consumer preference was indicated through the implementation of EnMSs. In this context, future research projects should focus on the verification of those indications. This way it can be determined how an ISO certification influences consumer behavior, the acquisition of new clients, and the loyalty of long-term customers.

The overall goal should, however, be to transfer the acquired knowledge and methodology to other industrial sites and economic sectors. This way further investigation projects can benefit from the information obtained in this study and use it as guidelines for further study projects.

References

ACOLTZI-ACOLTZI, H., & PÉREZ-REBOLLEDO, H. (2011). ISO 50001: Gestión de Energía.

AFKHAMI, B., AKBARIAN, B., BEHESHTI, N., KAKAEE, A. H., & SHABANI, B. (2015). Energy consumption assessment in a cement production plant. *Sustainable Energy Technologies and Assessments*, *10*, 84–89. http://doi.org/10.1016/j.seta.2015.03.003

BAFA. (2015). *Merkblatt für Energieaudits*. Eschborn.

BERNSTEIN, L., ROY, J., DELHOTAL, K. C., HARNISCH, J., MATSUHASI, R., PRICE, L., TANAKA, K. WORRELL, E. YAMBA, F. FENGQI, Z. (2007). *Industry* (Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, United Kingdom and New York, USA.

BMLFUW. (2014). Energetische Ausgangsbasis. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft Österreich.

BMLFUW, & AEA. (2014). Rechtsregister. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft Österreich; Austrian Energy Agency.

BOSCH. (2005). *Robert Bosch: 50 years in Mexico* (First edit). Mexico City.

BOSCH. (2009). *Guideline: Climate Protection and CO2 Management*.

BOSCH. (2012). Interview mit Prof. Dr. Klaus Töpfer. Retrieved from http://www.bosch.com/de/com/sustainability/stakeholder_in_dialog/toepfer/toepfer.html

BOSCH. (2013a). *Bosch Limited: Annual Report 2013*.

BOSCH. (2013b). Hechos y Cifras.

BOSCH. (2013c). Objetivos y metas 2014.

BOSCH. (2013d). Sales by Business Sector. Retrieved March 23, 2015, from http://www.bosch.com/en/com/bosch_group/bosch_figures/business_sectors/business-sectors.php

BOSCH. (2014a). Fakten 2014. Retrieved February 23, 2015, from http://www.bosch.de/de/de/about_bosch_home_1/about-bosch-in- germany.php

BOSCH. (2014b). Manual el sistema de gestión de seguridad, salud y medio ambiente.

BOSCH. (2015a). Energiepolitik Robert Bosch Fahrzeugelektrik Eisenach GmbH.

BOSCH. (2015b). *Nachhaltigkeitsbericht 2015*. Retrieved from https://unternehmen.union-investment.de/dms/umh-newsroom/downloadservice/studien/Nachhaltigkeit/Nachhaltigkeitsstudie_2015_Booklet/Nachhaltigkeitstudie_Ergebnisbericht/20150624_Nachhaltigkeitstudie_Ergebnisbericht.pdf

BOSCH. (2015c). *Principles of Work Safety and Environmental Protection*.

BOSCH. (2015d). RBNA HSE Sustainability Performance 2015.

BOSCH. (2015e). SlpP 2015_CO2-t-PDCA_plant_level_1. San Luis Potosi.

BOSCH. (2015f). Throttle Body Assembly. Retrieved June 19, 2016, from https://www.boschautoparts.com/en/auto/throttle-devices/throttle-bodies

BOSCH. (2015g). Unternehmens- und Geschäftsbereiche. Retrieved March 23, 2015, from http://www.bosch.com/de/com/bosch_group/business_sectors_divisions/business_sectors_divisions_2.ph p

BOSCH. (2015h). Unternehmensgeschichte. Retrieved February 23, 2015, from http://www.bosch.de/de/de/our_company_1/history_1/history.html

BOSCH. (2015i). *Welcome to San Luis Potosí Plant: Gasoline Systems*.

BOSCH. (2016a). Corporate Leadership.

BOSCH. (2016b). Envirnmental Management. Retrieved March 22, 2016, from www.bosch.com/en/com/sustainability/environment/environmental_management_5/environmental_management.html

BOSCH. (2016c). Environmental Management. Retrieved February 12, 2016, from http://www.bosch.com/en/com/sustainability/environment/environmental_management_5/environmental_ management.html

BRANDL, G., & KANZIAN, R. (2013). Energiemanagementsysteme nach ISO 50001: Tipps für die Umsetzung. Vienna: WIFI Unternehmensservice der Wirtschaftskammer Österreich.

CEN/CENELEC. (2011). *EN ISO 50001: Energiemenegementsysteme - Anforderungen mit Anleitung zur Anwendung (ISO 50001:2011)*. Brussels.

CFE. (2012). Factor de Potencia. Comisión Federal de Electricidad.

CFE. (2016a). Consultar tarifas de regiones Central, Noreste, Noroeste, Norte, Peninsular y Sur. Retrieved June 22, 2016, from http://app.cfe.gob.mx/Aplicaciones/CCFE/Tarifas/Tarifas/tarifas_negocio.asp

CFE. (2016b). Tarifas generales en alta tensión. Retrieved June 22, 2016, from http://app.cfe.gob.mx/Aplicaciones/CCFE/Tarifas/Tarifas/Tarifas_industria.asp?Tarifa=CMAAT&Anio=2016

CONUEE. (2013). Normas Oficiales Mexicanas de Eficiencia Energética Balance al 2013. Retrieved April 4, 2016, from https://www.gob.mx/conuee/documentos/normas-oficiales-mexicanas-de-eficiencia-energetica

DENA. (2009). Energiemanagement. Retrieved March 18, 2016, from http://www.industrie-energieeffizienz.de/energiemanagement.html

DENA. (2015). Energieaudit. Retrieved April 5, 2016, from http://industrie-energieeffizienz.de/energiekosten-senken/energieeffizienz-prozesse/energieaudit/ablauf/

DOE. (2011). DOE eGuide for ISO 50001: Define and document objectives and targets. Retrieved June 28, 2016, from https://ecenter.ee.doe.gov/EM/SPM/Pages/Step3_1_3.aspx

DRANETZ. (2005). PowerGuide 4400: User's guide. New York.

EBEL, B. (2003). *Qualitätsmanagement: Konzepte des Qualitätsmanagements; Organisations und Führung; Ressourcenmanagement und Wertschöpfung* (second). NBW Verlag.

EERE. (2014). ISO 50001 Energy Management Standard. Retrieved April 12, 2016, from http://energy.gov/eere/amo/iso-50001-energy-management-standard

FISCHEDICK, M., ROY, R., ABDEL-AZIZ, A., ACQUAYE, A., ALLWOOD, J. M., CERON, J.-P., GENG, Y., KHESHGI, H., LANZA, A., PERCZYK, D., PRICE, L., SANTALLA, E., SHEINBAUM, C., TANAKA, K. (2014). *Industry*. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, USA.

GHOSCH, N. K., & BLACKHURST, M. F. (2014). Energy savings and rebound effect with multiple energy services and efficiency correlation. *Ecological Economics*, (105), 55–66.

GIRBIG, P., GRASER, C., JANSON-MUNDEL, O., SCHUBERTH, J., & SEIFERT, E. K. (2016). *Energiemanagement gemäß DIN EN ISO 50001: Systematische Wege zu mehr Energieeffizienz*. (DIN Deutsches Institut für Normung e.V., Ed.) (second). Berlin, Vienna, Zürich: Beuth. Retrieved from https://books.google.com.mx/books?id=SIwrCwAAQBAJ&pg=PA66&lpg=PA66&dq=Energetische+bewertung+iso+50001&source=bl&ots=a32sXZRRlk&sig=z1BZ1vo83UdnM_g5aNnnsKZ3O5g&hl=de&sa=X&ved=0ahUKEwigwpP096XMAhUsn4MKHUFUAZU4ChDoAQg9MAY#v=onepage&q=Energetische bewertung

HALILA, F., & TELL, J. (2013). Creating Synergies Between SMEs And Universities For ISO 14001 Certification. *Journal of Cleaner Production*, *48*, 85–92.

HANLEY, N., MCGREGOR, P., SWALES, K., & TURNER, K. (2009). Do increases in energy efficiency improve environmental quality and sustainability? *Ecological Economics*, (68), 692–709.

HERNÁNDEZ-PINEDA, A., CARMONA-VÁZQUEZ, G., FLORES-DÍAZ, L., & SOSA-GRANADOS, R. (2014). *Manual para la implementación de un sistema de gestión de la energía*. Mexico City.

HKEIA. (2013). *Iso 50001*.

HOLBROOK, J. (2009). Introduction to Environmental Management Systems and related Standards. Retrieved March 17, 2016, from http://www.snh.org.uk/publications/on-line/advisorynotes/46/46.htm

HUANG, E. G. T. (2011). *Understanding the Requirements of the Energy Management System Certification: A Discussion about the Challenges, Impacts and*

Opportunities for Energy Efficiency.

IEA. (2008). Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis. *OECD/IEA*. Paris: International Energy Agency. Retrieved from http://iea.org/efficiency/CD-EnergyEfficiencyPolicy2009/1-Croos-sectoral/1-Indicators_2008.pdf

IEA. (2014). *World Energy Investment Outlook: Special Report*. *International Energy Agency*. Paris.

IEEE. (2000). *The Authoritative Dictionary of IEEE Standards Terms*. New York.

IRREK, W., & THOMAS, S. (2008). *Energieeffizienz - die Begrifflichkeit*. Retrieved from http://www.wupperinst.org/uploads/tx_wibeitrag/energieeffizienz_definition.pdf

ISO. (2011). International Standard ISO 50001:2011: Energy management systems - Requirements with guidance for use. Geneva: Interantional organization for standarization. http://doi.org/10.5594/J09750

ISO. (2014). ISO 50002:2014 Energy audits - Requirements with guidance for use.

ISO. (2015). *ISO 50001: A practical guide for SMEs*. Geneva.

JOVANOVIĆ, B., & FILIPOVIĆ, J. (2016). ISO 50001 standard-based energy management maturity model – proposal and validation in industry. *Journal of Cleaner Production*, *112*, 2744–2755. http://doi.org/10.1016/j.jclepro.2015.10.023

KAHLENBORN, W., KABISCH, S., KLEIN, J., RICHTER, I., & SCHÜRMAMM, S. (2012). *Energiemanagementsysteme in der Praxis: ISO 50001: Leitfaden für Unternehmen und Organisationen*.

KISSANI, I., & MOKRINI, A. (2013). Alternative Technologies for controlling CO2 emissions and energy costs minimization in manufacturing processes. *International Journal of Supply Chain Management*, *2*(2), 19–31.

KRARTI. (2000). *Energy audit of building systems: An engineering approach* (First Edit).

KRSTINIĆ-NIŽIĆ, M., & BRAČIĆ, M. (2014). *Effective Use of Resources in Tourist Facilities - Focus on energy efficiency* (Vol. 39).

LIEBACK, J. U., BUSER, J., GNEBNER, D., BEHRENDT, N., & FELKER, Y. (2016). In 18 Schritten über 3 Stufen zum effizienten Energiemanagement nach ISO 50001: Ein

Leitfaden. Berlin: GUTcert. http://doi.org/10.1017/CBO9781107415324.004

LÓPEZ-RIVAS, M. (2016). El financiamiento público a la industria en México. Retrieved July 5, 2016, from http://avanceyperspectiva.cinvestav.mx/Inicio/ArtMID/5298/ArticleID/55/El-financiamiento-p250blico-a-la-industria-en-M233xico

MAJERNÍK, M., BOSÁK, M., STOFOVÁ, L., & SZARYSZOVÁ, P. (2015). Innovative Model of Integrated Energy Management in Companies. *Quality Innovation Prosperity*, *19*(1), 22–32. http://doi.org/10.12776/qip.v19i1.384

MAŇKO, M., & KOSǏKOVÁ, A. (2012). ISO 50001 as the basis for implementing an environmental management system. *Journal of Production Engineering*, *16*(1), 97–99.

MATSILIZA, L., MUROVE, C., & GRON, H. R. (2004). *Capacity building in energy efficiency and renewable energy*.

MCKANE, A., PRICE, L., & DE LA RUE DU CAN, S. (2008). Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transition Economies. *United Nations Industrial Development Organization*. Vienna: United Nations Industrial Development Organization. http://doi.org/http://industrial-energy.lbl.gov/node/29

NEEA. (2013). *Energy Baseline Methodologies for Industrial Facilities*. Walnut Creek.

OECD. (2014). *An introduction to energy management systems: Energy savings and increased industrial productivity for the iron and steel sector*.

OECD, & IEA. (2014). *Capturing the Multiple Benefits of Energy Efficiency*. Paris.

PROFECO. (2008). Ley Para El Aprovechamiento Sustentable De La Energía. Mexico City.

PROFEPA. (2014). *Informe de auditoría ambiental: Robert Bosch México Sistemas Automotrices, S.A De C.V.* San Luis Potosi.

PURCEL, F., & JIMÉNEZ, A. (2013). *D2.4: Energy performance indicators & common audit procedure*.

RADONJIC, G., & TOMINC, P. (2007). The Role Of Environmental Management System On Introduction Of New Technologies in The Metal And Chemical/Paper/Plastics

Industries. *Journal of Cleaner Production*, *15*, 1482–1493.

REZAEI, A. R., CELIK, T., & BAALOUSHA, Y. (2011). Performance measurement in a quality management system. *Scientia Iranica*, *18*(3), 742–752. http://doi.org/10.1016/j.scient.2011.05.021

SEMARNAT, & INE. (2010). Potencial de mitigación de gases de efecto invernadero en México al 2020 en el contexto de la cooperación internacional. Mexico City: Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)/ Instituto Nacional de Ecología. Retrieved from http://www2.inecc.gob.mx/descargas/cclimatico/Potencial_mitigacion_GEI_Mexico_2020_COP.pdf

SOGESCA. (2013). How to develop a Sustainable Energy Action Plan integrated with an Energy Management System based on ISO 50001: 2011: Guidelines, 49.

STERN, D. (2012). Modeling international trends in energy efficiency. *Energy Economics*, *34*(6), 2200–2208.

THOLLANDER, P., & PALM, J. (2013). *Improving Energy Efficiency in Industrial Energy Systems: An Interdisciplinary Perspective on Barriers, Energy Audits, Energy Management, Policies, and Programs* (1st ed.). London: Springer London. http://doi.org/10.1007/978-1-4471-4162-4

TSUNG-YUNG, C., SHANG-LIEN, L., & YUNG-YIN, T. (2012). Establishing an Integration-Energy-Practice Model for Improving Energy Performance Indicators in ISO 50001 Energy Management Systems. *Energies*, *5*(12), 5324–5339. http://doi.org/10.3390/en5125324

TÜV NORD. (2014). *Energy Management Systems* (Vol. 50001).

UGA. (2015). *Systematisches Umweltmanagement Mit EMAS Mehrwert schaffen Die Unterschiede zwischen EMAS und ISO 14001*. Retrieved from https://www.lubw.baden-wuerttemberg.de/servlet/is/2712/mit-emas-mehrwert-schaffen_vergleich-iso14001_2010.pdf?command=downloadContent&filename=mit-emas-mehrwert-schaffen_vergleich-iso14001_2010.pdf

UNIDO. (2013). Practical Guide for Implementing an Energy Management System. Vienna: United Nations Industrial Development Organization.

WAGNER, M., & SCHALTEGGER, S. (2002). *Umweltmanagement In Deutschen Unternehmen: Der Aktuelle Stand Der Praxis*. Lüneburg.

WORLD ENERGY COUNCIL. (2013). *Energy Efficiency Policies – What works and what does not*.

WORRELL, E., BERNSTEIN, L., ROY, J., PRICE, L., HARNISCH, J., & DE LA RUE DU CAN, S. (2009). *Industrial Energy Efficiency and Climate Change Mitigation*. Berkeley, CA.

Annex I

TOTP(kW)Pro[kW] total average power per hour	TOTPEnerg(kWh) Total average energy per hour	TOTFPPro[pu] total average power factor	real date adapted to SLP	real time adapted to SLP	Pieces produced per day	Pieces produced per hour	Average pieces produced per day	Energía tarifa base ($/kWh) low	Energía tarifa intermedia ($/kWh) intermediate	Energía tarifa punta ($/kWh) high	Energy category	Energy cost per hour of consumption	Energy cost per produced piece	Average cost of consumed energy per hour	average cost of consumed energy per hour/ produced pieces	Reason for down time
16,473	16,473	0,801	16.04.16	13:00-14:00		48	61,6363636	0,6695	0,7873	2,1887	intermediate	12,9691929	0,27019152	16,5483303	0,27019152	
25,217	41,69	0,8566	16.04.16	14:00-15:00		72		0,6695	0,7873	2,1887	intermediate	19,8533441	0,27574089		0,27574089	
23,882	65,572	0,8541	16.04.16	15:00-16:00		72		0,6695	0,7873	2,1887	intermediate	18,8022986	0,26114304		0,26114304	
16,277	81,849	0,8076	16.04.16	16:00-17:00		72		0,6695	0,7873	2,1887	intermediate	12,8148821	0,17798447		0,17798447	
23,342	105,191	0,8557	16.04.16	17:00-18:00		48		0,6695	0,7873	2,1887	intermediate	18,3771566	0,38285743		0,38285743	
25,768	130,959	0,8719	16.04.16	18:00-19:00		72		0,6695	0,7873	2,1887	intermediate	20,2871464	0,28176592		0,28176592	
11,548	142,507	0,8401	16.04.16	19:00-20:00		36		0,6695	0,7873	2,1887	intermediate	9,0917404	0,25254834		0,25254834	
23,828	166,335	0,8332	16.04.16	20:00-21:00		72		0,6695	0,7873	2,1887	intermediate	18,7597844	0,26055256		0,26055256	
17,137	183,472	0,8134	16.04.16	21:00-22:00		60		0,6695	0,7873	2,1887	intermediate	13,4919601	0,224866		0,224866	
24,054	207,526	0,8372	16.04.16	22:00-23:00		54		0,6695	0,7873	2,1887	intermediate	18,9377142	0,35069841		0,35069841	
23,684	231,21	0,8389	16.04.16	23:00-24:00		72		0,6695	0,7873	2,1887	intermediate	18,6464132	0,25897796		0,25897796	
23,287	254,497	0,8522	17.04.16	00:00-01:00	1314	72	54,75	0,6695	0,7873	2,1887	low	15,5906465	0,21653676	15,3929761	0,21653676	
23,253	277,75	0,8579	17.04.16	01:00-02:00	1314	72		0,6695	0,7873	2,1887	low	15,5678835	0,2162206		0,2162206	
24,31	302,06	0,8372	17.04.16	02:00-03:00	1314	72		0,6695	0,7873	2,1887	low	16,275545	0,22604924		0,22604924	
25,286	327,346	0,8561	17.04.16	03:00-04:00	1314	72		0,6695	0,7873	2,1887	low	16,928977	0,23512468		0,23512468	
24,02	351,366	0,8343	17.04.16	04:00-05:00	1314	72		0,6695	0,7873	2,1887	low	16,08139	0,22335264		0,22335264	
23,038	374,404	0,8421	17.04.16	05:00-06:00	1314	60		0,6695	0,7873	2,1887	low	15,423941	0,25706568		0,25706568	
24,448	398,852	0,8511	17.04.16	06:00-07:00	1314	72		0,6695	0,7873	2,1887	low	16,367936	0,22733244		0,22733244	
24,853	423,705	0,8552	17.04.16	07:00-08:00	1314	72		0,6695	0,7873	2,1887	low	16,6390835	0,23109838		0,23109838	
16,664	440,369	0,8187	17.04.16	08:00-09:00	1314	0		0,6695	0,7873	2,1887	low	11,156548	n/a		11,156548	material shortage
25,577	465,946	0,8752	17.04.16	09:00-10:00	1314	36		0,6695	0,7873	2,1887	low	17,1238015	0,47566115		0,47566115	material shortage
23,311	489,257	0,8498	17.04.16	10:00-11:00	1314	72		0,6695	0,7873	2,1887	low	15,6067145	0,21675992		0,21675992	
23,851	513,108	0,8459	17.04.16	11:00-12:00	1314	72		0,6695	0,7873	2,1887	low	15,9682445	0,22178117		0,22178117	
24,763	537,871	0,8725	17.04.16	12:00-13:00	1314	72		0,6695	0,7873	2,1887	low	16,5788285	0,23026151		0,23026151	
24,109	561,98	0,8284	17.04.16	13:00-14:00	1314	60		0,6695	0,7873	2,1887	low	16,1409755	0,26901626		0,26901626	
24,769	586,749	0,8643	17.04.16	14:00-15:00	1314	72		0,6695	0,7873	2,1887	low	16,5828455	0,2303173		0,2303173	
24,117	610,866	0,8294	17.04.16	15:00-16:00	1314	72		0,6695	0,7873	2,1887	low	16,1463315	0,2242546		0,2242546	
16,525	627,391	0,8173	17.04.16	16:00-17:00	1314	72		0,6695	0,7873	2,1887	low	11,0634875	0,15365955		0,15365955	
16,503	643,894	0,8097	17.04.16	17:00-18:00	1314	0		0,6695	0,7873	2,1887	low	11,0487585	n/a		11,0487585	material shortage/technical malfunction
25,648	669,542	0,8637	17.04.16	18:00-19:00	1314	54		0,6695	0,7873	2,1887	low	17,171336	0,3179877		0,3179877	
22,759	692,301	0,8423	17.04.16	19:00-20:00	1314	72		0,6695	0,7873	2,1887	intermediate	17,9181607	0,24886334		0,24886334	
25,605	717,906	0,8607	17.04.16	20:00-21:00	1314	72		0,6695	0,7873	2,1887	intermediate	20,1588165	0,27998356		0,27998356	
16,615	734,521	0,8015	17.04.16	21:00-22:00	1314	24		0,6695	0,7873	2,1887	intermediate	13,0809895	0,54504123		0,54504123	
16,905	751,426	0,8063	17.04.16	22:00-23:00	1314	0		0,6695	0,7873	2,1887	intermediate	13,3093065	n/a		13,3093065	work break
14,608	766,034	0,8342	17.04.16	23:00-24:00	1314	0		0,6695	0,7873	2,1887	intermediate	11,5008784	n/a		11,5008784	work break

TOTP(kW)Pro[kW] total average power per hour	TOTPEnerg(kWh) Total average energy per hour	TOTFPPro[pu] total average power factor	real date adapted to SLP	real time adapted to SLP	Pieces produced per day	Pieces produced per hour	Average pieces produced per day	Energía tarifa base ($/kWh) low	Energía tarifa intermedia ($/kWh) intermediate	Energía tarifa punta ($/kWh) high	Energy category	Energy cost per hour of consumption	Energy cost per produced piece	Average cost of consumed energy per hour	average cost of consumed energy per hour/ produced pieces	Reason for down time
14,671	780,705	0,8346	18.04.16	00:00-01:00	480	0	20	0,6695	0,7873	2,1887	low	9,8222345	n/a	16,8495611	9,8222345	work break
26,238	806,943	0,8865	18.04.16	01:00-02:00	480	0		0,6695	0,7873	2,1887	low	17,566341	n/a		17,566341	work break
20,226	827,169	0,8276	18.04.16	02:00-03:00	480	0		0,6695	0,7873	2,1887	low	13,541307	n/a		13,541307	work break
21,281	848,45	0,8473	18.04.16	03:00-04:00	480	0		0,6695	0,7873	2,1887	low	14,2476295	n/a		14,2476295	work break
16,26	864,71	0,8007	18.04.16	04:00-05:00	480	0		0,6695	0,7873	2,1887	low	10,88607	n/a		10,88607	work break
16,51	881,22	0,8094	18.04.16	05:00-06:00	480	0		0,6695	0,7873	2,1887	low	11,053445	n/a		11,053445	work break
24,842	906,062	0,8537	18.04.16	06:00-07:00	480	42		0,6695	0,7873	2,1887	intermediate	19,5581066	0,4656692		0,4656692	
20,177	926,239	0,8355	18.04.16	07:00-08:00	480	0		0,6695	0,7873	2,1887	intermediate	15,8853521	n/a		15,8853521	shortage of staff
16,536	942,775	0,8073	18.04.16	08:00-09:00	480	0		0,6695	0,7873	2,1887	intermediate	13,0187928	n/a		13,0187928	shortage of staff
16,596	959,371	0,8096	18.04.16	09:00-10:00	480	0		0,6695	0,7873	2,1887	intermediate	13,0660308	n/a		13,0660308	shortage of staff
16,542	975,913	0,8123	18.04.16	10:00-11:00	480	0		0,6695	0,7873	2,1887	intermediate	13,0235166	n/a		13,0235166	shortage of staff
13,412	989,325	0,8283	18.04.16	11:00-12:00	480	0		0,6695	0,7873	2,1887	intermediate	10,5592676	n/a		10,5592676	shortage of staff
6,254	995,579	0,7673	18.04.16	12:00-13:00	480	0		0,6695	0,7873	2,1887	intermediate	4,9237742	n/a		4,9237742	shortage of staff
1,5525	997,1315	0,8378	18.04.16	13:00-14:00	480	0		0,6695	0,7873	2,1887	intermediate	1,22228325	n/a		1,22228325	shortage of staff
12,66	1009,7915	0,764	18.04.16	14:00-15:00	480	0		0,6695	0,7873	2,1887	intermediate	9,967218	n/a		9,967218	shortage of staff
23,502	1033,2935	0,851	18.04.16	15:00-16:00	480	0		0,6695	0,7873	2,1887	intermediate	18,5031246	n/a		18,5031246	shortage of staff
24,986	1058,2795	0,8529	18.04.16	16:00-17:00	480	0		0,6695	0,7873	2,1887	intermediate	19,6714778	n/a		19,6714778	shortage of staff
25,932	1084,2115	0,8653	18.04.16	17:00-18:00	480	36		0,6695	0,7873	2,1887	intermediate	20,4162636	0,56711843		0,56711843	
24,594	1108,8055	0,844	18.04.16	18:00-19:00	480	72		0,6695	0,7873	2,1887	intermediate	19,3628562	0,26892856		0,26892856	
24,405	1133,2105	0,8304	18.04.16	19:00-20:00	480	72		0,6695	0,7873	2,1887	intermediate	19,2140565	0,2668619		0,2668619	
23,667	1156,8775	0,8284	18.04.16	20:00-21:00	480	72		0,6695	0,7873	2,1887	high	51,7999629	0,71944393		0,71944393	
18,493	1175,3705	0,8274	18.04.16	21:00-22:00	480	54		0,6695	0,7873	2,1887	high	40,4756291	0,74954869		0,74954869	
23,303	1198,6735	0,8407	18.04.16	22:00-23:00	480	66		0,6695	0,7873	2,1887	intermediate	18,3464519	0,27797654		0,27797654	
23,191	1221,8645	0,8632	18.04.16	23:00-24:00	480	66		0,6695	0,7873	2,1887	intermediate	18,2582743	0,27664052		0,27664052	
23,027	1244,8915	0,8348	19.04.16	00:00-01:00	744	66	31	0,6695	0,7873	2,1887	low	15,4165765	0,23358449	19,2365728	0,23358449	
24,473	1269,3645	0,8405	19.04.16	01:00-02:00	744	66		0,6695	0,7873	2,1887	low	16,3846735	0,24825263		0,24825263	
25,155	1294,5195	0,8486	19.04.16	02:00-03:00	744	0		0,6695	0,7873	2,1887	low	16,8412725	n/a		16,8412725	packaging shortage
24,704	1319,2235	0,8334	19.04.16	03:00-04:00	744	66		0,6695	0,7873	2,1887	low	16,539328	0,25059588		0,25059588	
16,704	1335,9275	0,8141	19.04.16	04:00-05:00	744	66		0,6695	0,7873	2,1887	low	11,183328	0,16944436		0,16944436	
14,953	1350,8805	0,8459	19.04.16	05:00-06:00	744	54		0,6695	0,7873	2,1887	low	10,0110335	0,18538951		0,18538951	
24,287	1375,1675	0,8291	19.04.16	06:00-07:00	744	72		0,6695	0,7873	2,1887	intermediate	19,1211551	0,2655716		0,2655716	
14,673	1389,8405	0,8428	19.04.16	07:00-08:00	744	0		0,6695	0,7873	2,1887	intermediate	11,5520529	n/a		11,5520529	packaging shortage
25,745	1415,5855	0,8777	19.04.16	08:00-09:00	744	72		0,6695	0,7873	2,1887	intermediate	20,2690385	0,28151442		0,28151442	
24,817	1440,4025	0,85705	19.04.16	09:00-10:00	744	30		0,6695	0,7873	2,1887	intermediate	19,5384241	0,6512808		0,6512808	
23,889	1464,2915	0,8364	19.04.16	10:00-11:00	744	72		0,6695	0,7873	2,1887	intermediate	18,8078097	0,26121958		0,26121958	
23,624	1487,9155	0,8281	19.04.16	11:00-12:00	744	24		0,6695	0,7873	2,1887	intermediate	18,5991752	0,77496563		0,77496563	
16,386	1504,3015	0,8104	19.04.16	12:00-13:00	744	0		0,6695	0,7873	2,1887	intermediate	12,9006978	n/a		12,9006978	packaging shortage
16,528	1520,8295	0,8085	19.04.16	13:00-14:00	744	0		0,6695	0,7873	2,1887	intermediate	13,0124944	n/a		13,0124944	packaging shortage
16,358	1537,1875	0,8085	19.04.16	14:00-15:00	744	0		0,6695	0,7873	2,1887	intermediate	12,8786534	n/a		12,8786534	packaging shortage
16,255	1553,4425	0,8136	19.04.16	15:00-16:00	744	0		0,6695	0,7873	2,1887	intermediate	12,7975615	n/a		12,7975615	packaging shortage
16,128	1569,5705	0,8101	19.04.16	16:00-17:00	744	0		0,6695	0,7873	2,1887	intermediate	12,6975744	n/a		12,6975744	packaging shortage
22,78	1592,3505	0,8551	19.04.16	17:00-18:00	744	0		0,6695	0,7873	2,1887	intermediate	17,934694	n/a		17,934694	packaging shortage
23,139	1615,4895	0,8261	19.04.16	18:00-19:00	744	0		0,6695	0,7873	2,1887	intermediate	18,2173347	n/a		18,2173347	packaging shortage
22,7	1638,1895	0,8509	19.04.16	19:00-20:00	744	0		0,6695	0,7873	2,1887	intermediate	17,87171	n/a		17,87171	packaging shortage
25,314	1663,5035	0,8627	19.04.16	20:00-21:00	744	48		0,6695	0,7873	2,1887	high	55,4047518	1,15426566		1,15426566	
25,163	1688,6665	0,8692	19.04.16	21:00-22:00	744	0		0,6695	0,7873	2,1887	high	55,0742581	n/a		55,0742581	maintenance
25,818	1714,4845	0,8755	19.04.16	22:00-23:00	744	36		0,6695	0,7873	2,1887	intermediate	20,3265114	0,56462532		0,56462532	
23,241	1737,7255	0,8606	19.04.16	23:00-24:00	744	72		0,6695	0,7873	2,1887	intermediate	18,2976393	0,25413388		0,25413388	

TOTP(kW)Pro[kW] total average power per hour	TOTPEnerg(kWh) Total average energy per hour	TOTFPPro[pu] total average power factor	real date adapted to SLP	real time adapted to SLP	Pieces produced per day	Pieces produced per hour	Average pieces produced per day	Energía tarifa base ($/kWh) low	Energía tarifa intermedia ($/kWh) intermediate	Energía tarifa punta ($/kWh) high	Energy category	Energy cost per hour of consumption	Energy cost per produced piece	Average cost of consumed energy per hour	average cost of consumed energy per hour/ produced pieces	Reason for down time
23,47	1761,1955	0,859	42480	00:00-01:00	1674	72	69,75	0,6695	0,7873	2,1887	low	15,713165	0,2182384	21,1016883	0,2182384	
25,476	1786,6715	0,877	20.04.16	01:00-02:00	1674	72		0,6695	0,7873	2,1887	low	17,056182	0,23689142		0,23689142	
24,917	1811,5885	0,8465	20.04.16	02:00-03:00	1674	72		0,6695	0,7873	2,1887	low	16,6819315	0,23169349		0,23169349	
24,685	1836,2735	0,8465	20.04.16	03:00-04:00	1674	72		0,6695	0,7873	2,1887	low	16,5266075	0,22953622		0,22953622	
24,934	1861,2075	0,8519	20.04.16	04:00-05:00	1674	72		0,6695	0,7873	2,1887	low	16,693313	0,23185157		0,23185157	
23,612	1884,8195	0,8282	20.04.16	05:00-06:00	1674	60		0,6695	0,7873	2,1887	low	15,808234	0,26347057		0,26347057	
25,305	1910,1245	0,8514	20.04.16	06:00-07:00	1674	72		0,6695	0,7873	2,1887	intermediate	19,9226265	0,27670315		0,27670315	
23,581	1933,7055	0,8426	20.04.16	07:00-08:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,5653213	0,25785168		0,25785168	
24,697	1958,4025	0,8284	20.04.16	08:00-09:00	1674	72		0,6695	0,7873	2,1887	intermediate	19,4439481	0,27005483		0,27005483	
23,863	1982,2655	0,8401	20.04.16	09:00-10:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,7873399	0,26093528		0,26093528	
24,096	2006,3615	0,8491	20.04.16	10:00-11:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,9707808	0,26348307		0,26348307	
23,753	2030,1145	0,8413	20.04.16	11:00-12:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,7007369	0,25973246		0,25973246	
23,848	2053,9625	0,83	20.04.16	12:00-13:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,7755304	0,26077126		0,26077126	
23,2	2077,1625	0,8441	20.04.16	13:00-14:00	1674	60		0,6695	0,7873	2,1887	intermediate	18,26536	0,30442267		0,30442267	
24,778	2101,9405	0,8775	20.04.16	14:00-15:00	1674	72		0,6695	0,7873	2,1887	intermediate	19,5077194	0,27094055		0,27094055	
23,685	2125,6255	0,8488	20.04.16	15:00-16:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,6472005	0,2589889		0,2589889	
23,784	2149,4095	0,8206	20.04.16	16:00-17:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,7251432	0,26007143		0,26007143	
23,304	2172,7135	0,8383	20.04.16	17:00-18:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,3472392	0,25482277		0,25482277	
24,751	2197,4645	0,8385	20.04.16	18:00-19:00	1674	72		0,6695	0,7873	2,1887	intermediate	19,4864623	0,27064531		0,27064531	
24,083	2221,5475	0,844	20.04.16	19:00-20:00	1674	72		0,6695	0,7873	2,1887	intermediate	18,9605459	0,26334092		0,26334092	
22,98	2244,5275	0,8456	20.04.16	20:00-21:00	1674	72		0,6695	0,7873	2,1887	high	50,296326	0,69856008		0,69856008	
24,697	2269,2245	0,8402	20.04.16	21:00-22:00	1674	54		0,6695	0,7873	2,1887	high	54,0543239	1,001006		1,001006	
23,8	2293,0245	0,8395	20.04.16	22:00-23:00	1674	66		0,6695	0,7873	2,1887	intermediate	18,73774	0,28390515		0,28390515	
25,107	2318,1315	0,8562	20.04.16	23:00-24:00	1674	66		0,6695	0,7873	2,1887	intermediate	19,7667411	0,29949608		0,29949608	
16,382	2883,3915	0,8111	21.04.16	23:00-24:00	1500	72		0,6695	0,7873	2,1887	intermediate	12,8975486	0,17913262		0,17913262	
24,848	2908,2395	0,875	22.04.16	00:00-01:00		72	70,9090909	0,6695	0,7873	2,1887	low	16,635736	0,23105189	17,2836498	0,23105189	
23,521	2931,7605	0,8256	22.04.16	01:00-02:00		72		0,6695	0,7873	2,1887	low	15,7473095	0,21871263		0,21871263	
24,445	2956,2055	0,8636	22.04.16	02:00-03:00		72		0,6695	0,7873	2,1887	low	16,3659275	0,22730455		0,22730455	
23,466	2979,6715	0,855	22.04.16	03:00-04:00		72		0,6695	0,7873	2,1887	low	15,710487	0,21820121		0,21820121	
25,652	3005,3235	0,8764	22.04.16	04:00-05:00		72		0,6695	0,7873	2,1887	low	17,174014	0,23852797		0,23852797	
16,549	3021,8725	0,8145	22.04.16	05:00-06:00		60		0,6695	0,7873	2,1887	low	11,0795555	0,18465926		0,18465926	
25,208	3047,0805	0,8768	22.04.16	06:00-07:00		72		0,6695	0,7873	2,1887	intermediate	19,8462584	0,27564248		0,27564248	
23,747	3070,8275	0,8446	22.04.16	07:00-08:00		72		0,6695	0,7873	2,1887	intermediate	18,6960131	0,25966685		0,25966685	
25,679	3096,5065	0,841	22.04.16	08:00-09:00		72		0,6695	0,7873	2,1887	intermediate	20,2170767	0,28079273		0,28079273	
25,664	3122,1705	0,8489	22.04.16	09:00-10:00		72		0,6695	0,7873	2,1887	intermediate	20,2052672	0,28062871		0,28062871	
23,425	3145,5955	0,8609	22.04.16	10:00-11:00		72		0,6695	0,7873	2,1887	intermediate	18,4425025	0,25614587		0,25614587	

Annex II

Self-evaluation checklist Do-, Check-, Act-phase (TÜV NORD, 2014)

Competence, Training and Awareness			
Requirements	Conformity		
	Yes	No	N/A
1. Are all the personnel, related to significant energy uses, competent on the basis of appropriate education, training, skills or experience?			
2. Have training needs associated with the control of its significant energy uses and the operation of its EnMS been identified?			
3. Have procedures been established to assure that all the personnel working for or on behalf of the organization are aware of • the importance of conformity with the energy policy, procedures and the requirements of the EnMS? • their roles, responsibilities and authorities in achieving the requirements of the EnMS? • the benefits of improved energy performance? • the impacts, actual or potential of their activities and how their activities and behavior contribute to the achievement of energy objectives and targets and the potential consequences of departure from specified procedures?			
4. Are training records, certificates and licenses maintained to demonstrate the competence?			

Communication			
Requirements	Conformity		
	Yes	No	N/A
1. Does the organization communicate internally with regard to its energy performance and the EnMS?			
2. Are procedures maintained for communication of energy issues between various levels of the organization?			
3. Has the organization established and implemented a process by which any person working for, or on behalf of, the organization can make comments or suggestions to EnMS?			
4. Has the organization decided whether its energy policy, EnMS and energy performance should be communicated externally?			
5. If so, are there any documented and implemented external communication plans?			

Documentation			
Requirements	Conformity		
	Yes	No	N/A
1. Have the core elements of the EnMS and their interaction been documented in paper and/or electronic form?			
2. Are the following EnMS elements documented? • Scope and boundaries of the EnMS • Energy policy • Energy objectives, targets and action plans; and • Documents required by ISO 50001, e.g. energy review			

Control of Documents			
Requirements	Conformity		
	Yes	No	N/A
1. Are procedures maintained to ensure periodic review and appropriate approved distribution and revision of all required documents?			
2. Are current versions and changes of all required documents identified?			
3. Are documents of external origin that are to be necessary for the planning and operation of the EnMS identified and controlled?			
4. Is all documentation legible, readily retrievable and identifiable, and revision level or date identified?			
5. Is all documentation legible, readily retrievable and identifiable, and revision level or date identified?			

Operational Control			
Requirements	Conformity		
	Yes	No	N/A
1. Have the operations and maintenance activities, which are related to significant energy uses and are consistent with energy policy, objectives and action plans, been identified and planned with the following considerations? • Establishing and setting criteria for the effective operation and maintenance of significant energy uses; • Operating and maintaining facilities, processes, systems and equipment in accordance with operational criteria; and • Appropriate communication of the operational controls to personnel working for the organization.			

Design

Requirements	Conformity		
	Yes	No	N/A
1. Have procedures been implemented to identify and consider energy performance improvement opportunities and operational controls in the design of new, modified and renovated facilities, equipment, systems and processes?			
2. Are the design considerations documented?			

Procurement of Energy Services, Products, Equipment and Energy

Requirements	Conformity		
	Yes	No	N/A
1. Have the criteria for assessing energy use, consumption and efficiency over the lifetime of the product, equipment or service been established and implemented?			
2. Are specifications for items being purchased clearly defined and documented in the energy performance related requirements?			
3. Have energy performance related requirements been communicated to suppliers?			
4. Have suppliers been made aware that energy performance is part of the evaluation criteria?			

Monitoring and Measurement

Requirements	Conformity		
	Yes	No	N/A
1. Have procedures been documented and implemented to monitor the following key characteristics of operations that can have significant impacts? • Significant energy uses and other outputs of the energy review • Relevant variables related to significant energy uses; • Energy performance indicators (EnPIs); • Effectiveness of the action plans in achieving objectives and targets; and • Evaluation of actual versus expected energy consumption.			
2. Are records available to track performance and conformity with the key characteristics?			
3. Has the energy measurement plan been defined and implemented?			
4. Are all monitoring equipment appropriately maintained and calibrated?			

Evaluation of Compliance			
Requirements	Conformity		
	Yes	No	N/A
1. Are documented procedures established, implemented and maintained for periodical evaluation compliance with relevant energy legislation and other requirements related to energy use and consumption?			
2. Is the compliance status with regard to relevant energy legislation and other requirements related to energy use and consumption evaluated?			

Internal Audit			
Requirements	Conformity		
	Yes	No	N/A
1. Have internal audit procedures been developed and implemented?			
2. Has the internal audit schedule been developed?			
3. Are the internal audits conducted to ensure that the EnMS • Conforms to planned arrangements for energy management according to ISO 50001 standard requirements? • Conforms with the energy objectives and targets established? • Is effectively implemented and maintained, and improves energy performance?			
4. Are audit reports and records documented?			
5. Are the auditors conducting the audits competent and in a position to conduct the audits objectively and impartially?			

Non conformity, Corrective Action and Preventive Action			
Requirements	Conformity		
	Yes	No	N/A
1. Have procedures been established to define the responsibility for handling, investigating and controlling, and mitigating nonconformity?			
2. Does the organization address the actual and potential nonconformities by making corrections, and by taking corrective and preventive actions with the following elements? • Reviewing nonconformities or potential nonconformities; • Determining the causes of nonconformities or potential nonconformities; • Evaluating the need of action to ensure that nonconformities do not occur or recur; • Determining and implementing the appropriate action needed;			

• Maintaining records of corrective and preventive actions; and • Reviewing the effectiveness of the corrective and preventive actions taken			
3. Are procedures changed and / or updated as a result of corrective action and preventive action?			

Control of records

Requirements	Conformity		
	Yes	No	N/A
1. Have procedures been established and implemented for the identification, retrieval and retention of records?			
2. Are records legible, identifiable and traceable to the relevant activities?			
3. Does the organization retain the following records? • Training records; • Audit results; • Management review records; • Information on applicable energy laws and other requirements; • Inspection, maintenance and calibration records; • Information on significant energy use and energy performance indicators; • Procurement records; • Permits; • Monitoring data; • Details of non-conformities, incidents, complaints and follow-up actions; • Contractors and suppliers records; and • Process and product information.			

Management Review

Requirements	Conformity		
	Yes	No	N/A
1. Do periodic management reviews take place to ensure the continuing suitability, adequacy and effectiveness of the EnMS?			
2. Are management review records retained?			
3. Are the management reviews carried out based on the following documents or information? • EnMS audit reports; • Evaluation of compliance with legal requirements and other requirements to which the organization subscribes; • Achievement of EnMS objectives and targets; • Communications and complaints on EnMS internally;			

• Energy policy; • Energy performance and related Energy performance indicators (EnPIs) of the organization; • Status of corrective and preventive actions; • Follow-up actions from previous management reviews; • Projected energy performance of the following period; • Changing circumstances, including developments in legal and other requirements related to its energy use; and • Recommendations for improvement.			
4. Are the actionsmanagement reviews included in the decisions or related to: • Energy performance of the organization; • Energy policy; • Energy performance indicators (EnPIs); • Objectives and targets of the EnMS; and • Allocation of resources.			

Annex III

Interview questions
1. Relative CO_2 emissions are to be reduced by 25% until 2020. On what basis have these objectives been developed and determined? Have you already developed further, long-term goals? If yes, could you specify? How does the process of establishing such environmental objectives work?
2. Bosch belongs with 92% to the Robert Bosch Stiftung GmbH. Has this special ownership structure effects on the realization of sustainability goals such as reducing CO2 emissions for example through more freedom in the planning of long-term goals? If yes, could you specify?
3. The plant in San Luis Potosi produces scope 2 indirect CO_2 emissions, for example through the use of electricity. Do any Bosch internal Energy Audit Policies exist that allow you to identify strengths and weaknesses in production processes? If yes, how is the procedure of energy audits according to internal guidelines?
4. Does the company have any experiences with EnMS certified through ISO 50001? Will an ISO 50001 certification be a requirement in the future claimed by the management for all Bosch plant?
5. Energy consumption and CO_2 emissions at the Bosch plant in San Luis Potosi is currently represented for the whole plant and tackled by simple reduction measures. It is, however, not broken down process-specifically for individual production lines and machines. Is there a plant that performs similar production processes and can show more effective improvements in energy efficiency and CO_2 reduction? If yes, can you specify? Is it possible to establish contact for information exchange?
6. To my knowledge, every plant is independently responsible for CO_2 reduction measures and there is no comprehensive or adequate documentation of best practice success cases. Is that correct? If yes, why? How can the individual locations increase the exchange and dissemination of best practices?
7. Are there incentives or sanctions for industrial sites in the case of success or failure with respect to the reduction of CO_2 emissions? If yes, could you specify? How and by whom is the compliance monitored? Only through external audits/ certifications? Or also through internal reporting and monitoring/ evaluation?
8. Does every industrial site responsible for the funding of adaptation strategies to reduce CO_2 emissions (for example, solar systems) or does a central budget exists for greater investments of the Bosch Corporation?

9. Are energy balances of the products (such as efficiency of pumps) and the energy balance for production, charged and accounted for separately or together (e.g. product lifecycle)? Are concepts of circular economy in product and process design taken into account?