Hochschule für Angewandte Wissenschaften Hamburg
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Bachelors Thesis

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Energy efficiency and implementation of measures to reduce CO_2 emission at production facilities in Vietnam

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In general, the increase of energy efficiency is considered to be an often very cost efficient possibility to reduce CO_2 emissions. In order to reduce the CO_2 emission in a specific production facility of Robert Bosch in Vietnam, the top 10 energy consumers in the facility are determined and subsequently measured. Solutions to increase the energy efficiency of these consumers are explored and the economical aspects of necessary investments to implement the solutions will be considered.

Bachelorarbeit eingereicht im Rahmen der Bachelorprüfung

im Studiengang Maschinenbau/Entwicklung und Konstruktion
am Department Maschinenbau und Produktion
der Fakultät Technik und Informatik
der Hochschule für Angewandte Wissenschaften Hamburg
in Zusammenarbeit mit:

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Facilities Management (HcP/FCM)
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Abgabedatum: 12.09.2013

Abstract

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Bachelor Thesis title

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Keywords

Energy efficiency, production facilities, Vietnam, CO_2 emission

Abstract

The thesis describes the necessity for energy efficiency with focus on production facilities in developing countries. Starting with present situation on the worldwide energy market, the thesis describes the consequences of rising energy demand and in consequence rising CO_2 emission. Also policies for energy efficiency and ideas for retrofitting machines and equipment for energy efficient use are being explained. Especially for a production facility in Vietnam barriers and concrete measures are being analyzed.

Jakub Dec

Thema der Bachelorarbeit

Energie Effizienz und Implementierung von Maßnahmen zur Reduzierung des CO_2 Ausstoßes von in Vietnam errichteten Produktionsstätten

Stichwörter

Energie Effizienz, Fertigungsanlagen, Vietnam, CO_2 Ausstoß

Kurzzusammenfassung

Diese Bachelorarbeit beschäftigt sich mit der Notwendigkeit von Energie Effizient besonders im Hinblick auf Produktionsstätten in Entwicklungsländern. Beginnend mit der momentanen Lage auf dem weltweiten Energie Markt, werden Folgen von zunehmender Energie Konsum erläutert. Ebenso werden Richtlinien und Ideen für eine Energie effiziente Anpassung von Produktion Umgebungen erläutert. Am Beispiel einer Fertigungsstätte in Vietnam werden Barrieren aufgezeigt und konkrete Lösungen analysiert.

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List of abbreviations

AC	Air conditioner
AHU	Air handling unit
AS	Assembly line
ATC	Air control unit
Btu	British thermal unit
CVT	Continuously Variable Transmission
DDC	Direct digital control
EEA	European Environment Agency
EIA	U.S. Energy Information Administration
EL	Element line
FCM	Facility Management Department
GDP	Gross domestic production
GHG	Greenhouse gases
GS	Gasoline Systems
HBQ	Oil quenching bath
HcP	Ho Chi Minh City plant
HFC	Hydrofluor carbons
HHV	Higher Heating Value
HTO	High temperature roller
HVAC	Heating, ventilation, and air conditioning
ICT	Information and Communication Technologies
IRR	Internal rate of return
ISO	International Organization for Standardization
LED	Light-emitting diode
LL	Loop line

LLGHG	Long-lived greenhouse gase
LPG	Liquefied Petroleum Gases
MFG	Manufacturing Department
NDRC	National Development and Reform Commission
NTO	Low temperature roller
OECD	Organization for Economic Co-operation and Development
PDCA	Plan, Do, Check and Act
PLC	Programmable Logic Controller
PV	Photovoltaic
PW	Process water
ROI	Return of Investment
Scf	Standard cubic feet
SEFI	Sustainable Energy Finance Initiative
TbP	Tilburg plant
TEF	Technical Equipment and Functions Department
VND	Vietnamese Dong

Greek letters

α	$W/m^2 * K$	Heat transfer coefficient
η	-	Efficiency
Δ	-	Difference
σ	$\frac{W}{m^2 * K^4}$	Bolzman constant
ε	-	Emission grade
δ	-	Density

Formula symbols

P_{out}	W	Power input
P_{out}	W	Power output
$CO_{2_{tot}}$	t CO_2	Total CO_2 emission
NGU	Mio Euro	Total net turnover
(P)MAT	Mio Euro	(Plan) material costs
$CO_{2_{rel}}$	$t\ CO_2/Mio\ Euro$	Relative CO_2 emission
p	bar, Pa	Pressure
p_N	bar	Pressure under normal condition
V	m^3,scf	Volume
V_N	Nm^3	Volume under normal condition
$\dot{V}$	$\frac{m^3}{h}$	Volume flow
T_N	K	Temperature under normal condition
R	$J/mol * K$	Gas constant
n	mol	Chemical amount
$\dot{Q}$	W	Heat flow
T_S	K	Surface temperature
T_0	K	Surrounding temperature
A	m^2	Surface area
$\dot{\boldsymbol{m}}$	${}^{kg}/_{s}$	Mass flow
t	°C	Temperature
c_p	$J/Kg * K$	Specific isobar heat capacity
H	W	Enthalpy
pc	-	pieces
kWp	kW	kilo watt peak

1. Introduction

Energy in all form is an important resource in all areas of human life. It doesn't matter if it's the energy provided by fossil fuels to get a car or airplane in motion, the energy to heat up water for a comfortable bath after a hard working day or the energy for supplying a production facility.

Depending on the source of this energy it is limited. Especially the use and harvesting of fossil fuels is bound to great interference with the environment. The results are air pollution through CO_2 by combustion and the greenhouse effect. The great risks undertaken to develop new sources of fuel on the ocean ground or created by accidents in transporting the fuels to their destination on the sea way also lead to big environmental catastrophes. The rising demand for energy and the developing of new sources has also a big influence on the economy. Energy is a good and has its price. The more critical aspect is to waste energy by not applying it efficient. Huge production facilities with big demand for energy are responsible for this trend and are closely linked to the CO_2 emission.

The question is how it is possible to develop strategies and measures to improve energy efficiency in production facilities without interfering with the quality of the product and the production capacity.

It is important to have a basic overview in what forms the energy is supplied to the facilities and the manufacturing equipments. The energy is either supplied in form of electricity, liquid or gas for combustion or industrial gas required for the process. By knowing the consumption of each parts and equipments in the facilities it is easy to analyze where the biggest potential for energy efficiency is and to develop measures to increase the efficiency. It is also important to eliminate obvious waste of energy from not properly functioning or unnecessary equipment from the start. In this way a basis for further investment is created and secured that money is not wasted on equipment or infrastructures that turn out to be shut down in the end. A facility in most cases is not just about the equipments but also about the managers, leaders, operators and workers behaviors. For this purpose is to determine what is necessary to achieve set targets and how to solve the problems occurring on the way to achieve the target. A strategy or policy is needed involving holistically facility with all its employees and sometimes even how to deal with cultural diversity. In the end technical knowhow is needed to calculate the benefit from the ideas and approve the feasibility.

In the first chapter the thesis will analyze the current situation on the worldwide energy market and show trends and examples for the worldwide rising energy demand and production. In the second chapter, the impact on the environment from the rising energy demand will be explained. Special focus is set on the greenhouse effect. The third chapter will explain energy efficiency in general and give examples for successful implementation of energy efficiency policies but also discuss concerns on this topic. The fourth chapter introduces the Robert Bosch Ho Chi Minh City plant (HcP) and the Robert Bosch policies for reducing CO_2 emission for Robert Bosch facilities worldwide. In the sixth chapter measures and ideas are developed for increasing the energy efficiency at HcP including calculations for retrofitting and investment. The final chapter seven is a resume of the project and the results.

2. Background and Motivation

In order to understand the importance of efficiency in energy consumption, it is important to take a look at the current energy situation in the world and also in Vietnam. This chapter discuss the basic sources for energy and provides a quick outlook into future developments on the energy market. The basic data is from the "Statistic Review of World Energy" published by British Petrol in June 2012 (BP p.l.c., 2012). British Petrol is one of the biggest oil suppliers in the world and therefore the focus is set on the development of oil.

2.1. Energy situation worldwide

In 2011 the primary energy consumption worldwide grew by an average 2.5% per year matching approximately its ten years average (BP p.l.c., 2012). It can be observed that the Countries who signed the Convention on the Organization for Economic Co-operation and Development (OECD) had a drop of energy consumption by 0.8% while on the other hand the non-OECD countries had a rise in energy consumption by 5.3% matching the past ten years average (BP p.l.c., 2012).

<u>Oil</u>

Oil is a fossil fuel, meaning it is gained from underground reservoirs and exists in a limited amount. Oil is the main resource to supply energy. The oil market has a share of 33.1% for total energy provided worldwide (BP p.l.c., 2012). The oil consumption grew in 2011 by a value of 0.6 million barrels per day what equals a rise of 0.7% based on the total consumption of 88 million barrels per day in 2011 (BP p.l.c., 2012). Despites the conflict in Libya and other oil producing countries in 2011 the oil production went up additional 1.1 million barrels per day, still oil was recorded to have the lowest global growth rate amongst fossil fuels (BP p.l.c., 2012).

<u>Coal</u>

Alike of oil as fossil fuel, coal contributes 30.3% of energy consumption. It the second largest source for energy (BP p.l.c., 2012). With a rise of 5.4% in consumption, it is also the only fossil fuel to be recorded with an above average growing making it the fastest growing energy form outside renewable energy sources (BP p.l.c., 2012).

Natural gas

The third main supply for energy comes in form of natural gas. Natural gas has a share of 23.1% in global energy consumption and grew by 2.2% in consumption just below average (BP p.l.c., 2012). European natural gas consumption dropped due to continuous growth in renewable power generation by 9.9%. Still global gas production grew by 3.1% (BP p.l.c., 2012).

Others

The rest of energy supply comes from Nuclear power (-4.3%), Hydroelectric (+1.6%) and renewable energy (+17.7%) (BP p.l.c., 2012).

Although there is a positive development in renewable energies, they only have a share of 2.1% in global energy consumptions and the overwhelming part of the energy still comes from fossil fuels (BP p.l.c., 2012). Table 1 shows an overview on energy sources with the worldwide consumption per each source. For better comparison the standard measuring unit for the single energy sources is in tons of oil equivalent referring to the energy provided by combusting oil also known as heat value.

Source	Consumption in million tons of oil equivalent
oil	4,059.1
Natural gas	2,905.6
Coal	3,724.3
Nuclear energy	599.3
Hydroelectricity	791.5
Renewable energy	194.8

Table 1: Overview on worldwide energy consumption (BP p.l.c., 2012)

2.2. Energy situation in Vietnam

The U.S. Energy Information Administration (EIA) gathered data about the energy situation in Vietnam (U.S. Department of Energy, 2013). Figure 1 from the EIA states that around 24% of the energy in Vietnam is provided by oil combustion, 36% by biomass, 20% by coal, 11% by natural gas and 10% by hydroelectric power.

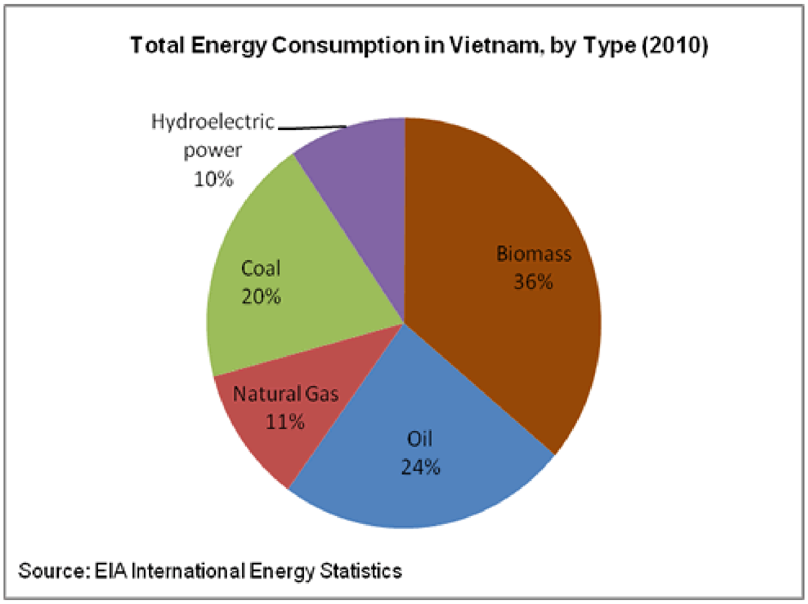

Figure 1: Total energy consumption in Vietnam by Type (International Energy Agency, 2012)

Also relevant to analyze the development and potential of Vietnam, the countries real gross domestic production (GDP) grows by an average of 7.2% per year (U.S. Department of Energy, 2013). Vietnam is listed as a developing country and has to expect at least decent rise in GDP.

Oil

Vietnam is an important crude oil supplier for the region and the domestic market. But through the rapid growth in economy industrialization, the oil production declined since 2004 when it peaked about 400 thousand barrels per day and in 2011 the total oil production of 323,600 barrels per day is standing against a total consumption of 365 000 barrels per day. It is assumed that the demand for oil products will be doubled by 2030 to nearly over 830 000 barrels per day (U.S. Department of Energy, 2013). Figure 2 shows the rising demand for oil in Vietnam. Since 2010, the demand for oil surpassed the production and is still constantly rising.

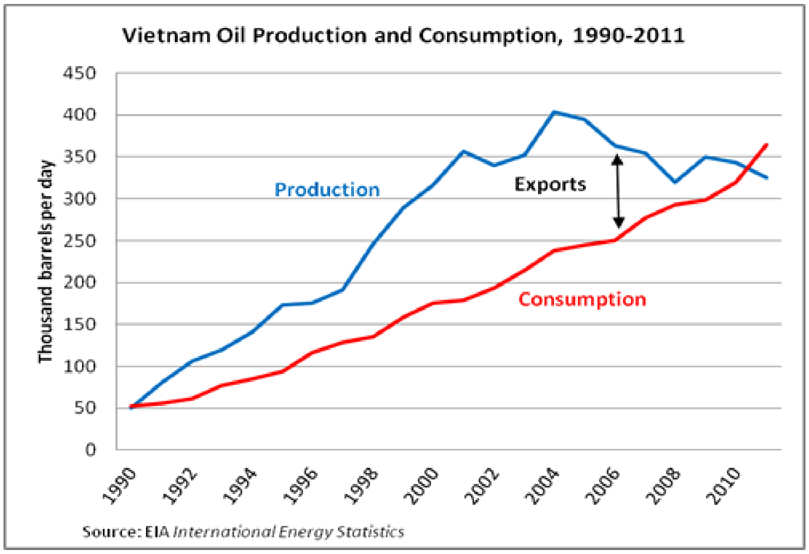

Figure 2: Vietnam Oil Production and Consumption, 1990-2011 (International Energy Agency, 2012)

Natural gas

To secure the further growth in economy and in order to facilitate industrialization; Vietnam is pushing to develop all its natural resources. The natural gas production in Vietnam has risen rapidly since the late 1990's and is used entirely to supply the expanding domestic market. Figure 3 shows that natural gas production in Vietnam, mainly, equals the consumption. In this way, Vietnam is currently self-sufficient in natural gas production (U.S. Department of Energy, 2013).

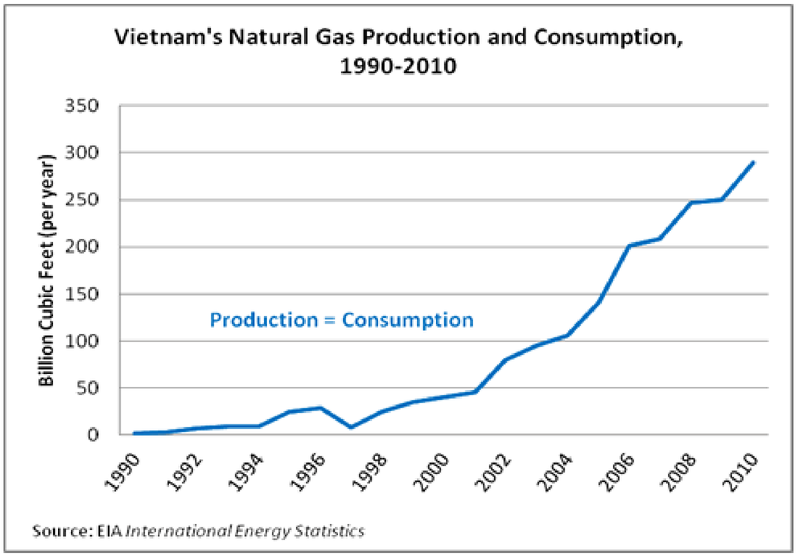

Figure 3: Vietnam's Natural Gas Production and Consumption 1990-2010 (U.S. Department of Energy, 2013)

Coal

With a consumption of 4,961 Million Short Tons of coal, Vietnam had a total consumption of 1.677 quadrillion British thermal unit (Btu) in primary energy in 2010 what equals approximately 1.769×10^{15} kJ. The total Electricity Net Consumption in 2010 was 85.678 Billion Kilowatt-hours (U.S. Department of Energy, 2013).

To promote energy security, efficiency, renewable energy deployment and power market liberalization, the Vietnamese government decides on a power development plan. The following capacity targets per technology and date have been decided:

Technology	Capacity until 2020 [MW]	Capacity until 2030 [MW]
Wind Power	1 000	6 200
Biomass	500	2 000
Hydropower	17 400	n.a.
Pumped storage Hydropower	1 800	5 700
Natural gas	10 400	11 300
Liquid natural gas	2 000	6 000
coal	36 000	75 000
Nuclear Power	n.a.	107 000

Table 2: Vietnam capacity targets for 2020 and 2030 (International Energy Agency, 2012)

Wind energy is set as priority deployment for Vietnam. There is a clear trend to increase the capacity for renewable energies but still fossil fuels have the greatest share in upgraded capacity and are far from being replaced by alternative forms of energy (International Energy Agency, 2012).

3. Global warming and the greenhouse effect

The worldwide energy demand is rising. Especially developing countries are experiencing increasing production capacity and industrial sector. This chapter will show what impact on the environment the rising energy demand and the still great rely on fossil fuel has.

3.1. What is the greenhouse effect?

Greenhouse gases (GHG) are being produced by combusting fossil fuels when the chemical components of the fuel are being oxidized. GHG also occur naturally for example from humans and animals breathing or any oxidizing process involving carbon. Due to human activities, the concentration in the atmosphere increased over the last 250 years rapidly. The most important amongst the GHG are Carbon dioxide (CO_2), Methane (CH_4), Nitrogen oxides (NO_x), Hydrofluor carbons (HFCs) and Sulphur hexafluoride (SF_6) (United Nations, 1998) (Sinha & Labi, 2007). Except for CO_2, a certain fraction of greenhouse gases is removed by physical and chemical reactions in the atmosphere and the gases are recombining to different chemical compositions. The progress of the removal process depends on the atmosphere properties like temperature pressure and background chemical conditions. CO_2 together with CH_4 and N_2O are long-lived greenhouse gases (LLGHGs). LLGHGs are chemical stable and have a long time impact on the climate because they can persist in the atmosphere for centuries. CO_2 is accounted for approximately 90% of the greenhouse gases (Contaldi & Ilacqua, 2003) and is constantly circulating between atmosphere, ocean, land and biosphere therefore has no specific life time. Since the start of industrialization in 1750, the concentration of CO_2 has increased from 280ppm to 379 ppm in 2005 (World Meteorological Organization, 2013) (Treberth, et al., 2009). This increase is nearly five times the increase during the time period of 8000 years prior to industrialization. Also global CO_2 emission grew four times more quickly between 2000 and 2007 than between 1890 and 1990 despites two decades of climate negotiations and environmental save initiatives and programs (Global Carbon Project, 2008). A major point is that two third of the CO_2 emission comes from burning fossil fuel. Therefore the rising energy demand in current state will increase CO_2 emission the same way (World Meteorological Organization, 2013).

3.2. What impact does the greenhouse effect have on the environment?

CO_2 and the other GHG greatly affect the environment and are one of the main causes for global warming (Sinha & Labi, 2007); (European Environment Agency (EEA), 2010). In a natural process, solar energy radiates in waves from the sun to the earth. The solar energy heats up the land and the oceans and radiates back into space. Because of the greenhouse gas some of the sun waves cannot pass the atmosphere and radiate back on earth. With this loop in the process share of waves always radiate back, the earth heat it up even more. As a result the average global temperature had risen by 0.7 °C over the entire 20^{th} century (Treberth, et al., 2009). This rise of temperature has major effects on the global environment. At this point it has to be mentioned that there are wide spread theories about the impact of human activities on this topic and a lot of estimations about the level of global warming in the future. However all agree that the global temperature will rise even more considering the current development in CO_2 emission policy. This will result in melting icecaps, rising sea level, irreversible loss of Amazonas rain forest, change in Indian and African monsoon and ocean acidification (Parry, et al., 2007); (World Meteorological Organization, 2013); (Meehl, et al., 2007).

3.3. Decreasing CO_2 in the atmosphere

The only way to reduce the CO_2 in the atmosphere is by to natural processes for example photosensitize. The first thing that comes to mind is how to support or replace this process with technologies. For example by extractive metallurgy it is possible to reduce any oxide compound to its elemental form by applying energy. This process applies on the CO_2 in the atmosphere could save the earth from global warming and recycling the oxidative abilities of the contained oxygen in CO_2 in future could play a role in energy efficiency improvements (Neelameggha, 2008). Researches is already being made to minimize the global warming and CO_2 emission by converting naturally available solar-, wind- and hydro- energy into fuel by using carbon dioxide and water (Shulenberg, 2012). Still the best way to reduce the CO_2 in the atmosphere is to avoid producing it.

4. Energy efficiency and economic aspects

After discussing the energy consumption, CO_2 emission and the influence on the environment, the next step is to think about counter measures. The biggest share of energy consumption and CO_2 intensive energy production comes from the industry sector. Therefore the biggest potential for technological improvements lies there. This chapter not only shows the technological potential for energy efficient solutions but also is about the risks and barriers especially in developing countries. In this Chapter the focus is set on facts and basic information and gives just some examples on energy efficiency. Concrete technical measures to reduce energy consumption and CO_2 emission will be discussed later in this paper.

4.1. Degree of efficiency

A way to reduce CO_2 emission is to use and to produce energy with more efficient equipment. It is best explained with the first law of thermodynamics. Energy can be transferred from one form to another but can neither be created nor destroyed. Forms of energy are for example heat energy, electric energy and mechanical energy, potential and kinetic energy. When burning fossil fuels, heat energy is being produced. In a coal plant we can evaporate water with the heat energy and with a turbine produce electric energy. This electric energy is provided to a household or facility and there transferred for example by an electric motor into mechanical energy or with light bulbs used to lighten up a room. There are many ways to use energy but it has to be considering that every time energy is transferred from one form to another a part of it gets lost. Figure 4 shows a very simple sketch of the heat loss process. Energy is applied on a system represented by the square and during the process energy is lost. For example when we transfer electric energy into mechanical within an electromotor also a part of the energy is transferred into heat because of friction and electric resistance. The heat dissipates into the environment and is of no use for us. Also one form of energy is easier to transport from one place to another. For example electricity is easier to transport than coal or oil. A different amount of energy gets lost depending on the current form of energy and the way it has to be transported.

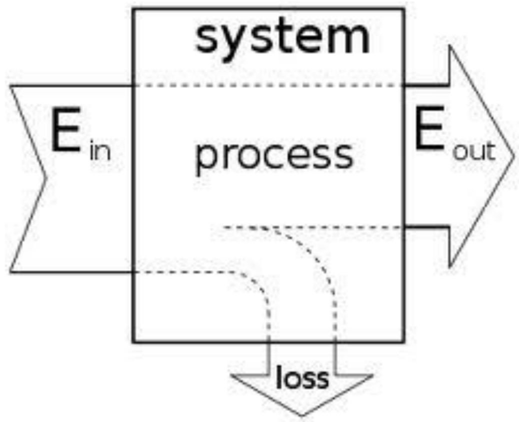

Figure 4: Efficiency Diagram (Zureks, 2011)

When solutions are pushed to keep these loss at minimum it is called energy efficiency. For example, a better insulation and sealing of the pipes, waste heat retrieving or direct replacing with more efficient technologies like light-emitting diodes (LEDs) can optimize energy usage. Energy efficiency of special equipment and complex processes is displayed by their degree of efficiency:

$$\eta = \frac{P_{out}}{P_{in}} \quad (1)$$

P_{in} represents the energy is put in the system and P_{out} represents the energy output that is useful and can be transferred into work.

Basically, a good degree of efficiency can get a maximum output with the available energy or a minimum energy is invested to achieve the desired output. When the degree of efficiency is as close as possible to one, the solution is called energy efficient. This is, of course, not limited to a single machine but can consist of a couple of linked processes.

4.2. Energy efficiency in manufacturing

33% of global energy is consumed in the industrial sector. The manufacturing sector accounts for about 73% of this consumed energy (Evans, 2003) and 10% of all manufacturing industry consumption comes from metal processing industries (U.S. Department of Energy, 2013). The main problem with energy efficiency for manufacturing is the lack of clean distinction, both technically and academically. There is a major mis-balance between the technical innovations of machineries that embrace the manufacturing process like machine tools and the technical improvements consideration for energy efficiency (Park, et al., 2009).

In manufacturing, only 43% of energy input is applied as process work and 57% of the energy is lost or diverted without the intended process activities (Park, et al., 2009). This value leaves a great potential for possible measures to improve the energy efficiency. A report of the European Commission from 2009 for example implies that the potential energy saving in German Industries, including manufacturing industry is approximately between 10% and 25% just through the reduction of the time used for the equipment waiting in start-up mode (Bladh, 2009). Considering Germany as a technological advanced countries savings at other worldwide locations, especially in developing countries, these savings should been greater. Just by reducing the process to multifunctional machines, for example for heavy engine and turbine manufacturing plants, the consumed power can be reduced by 30%. Also 62% of standby power and 85% of hydraulic power in air control units (ATCs) can be saved in the same way (Masao, 2008).

Another big point in manufacturing is the usage of compressed air. Compressed air in a factory requires a total amount of 30% of the consumed energy to build up and to maintain the pressure. Just by dropping the pressure by 0.3 MPa, 30% of energy used by most air compressing units could be saved (Keisuke, 2008).

An example for reducing the energy consumption in manufacturing is Rico Group. Rico Group replaced old facilities with high-efficient facilities, incorporating innovations into the manufacturing process. By changing the conveyor line to a moving carriage it was possible to reduce the energy for this process by 99% from 90 kWh/day to 1 kWh/day. By applying mass flow technology to the toner filling, it was possible to cut the energy consumption by one fourth (Abe, 2009).

Toyota agrees on a “Company Conscious Promotion System” in order to encourage energy saving activities in Toyota. As a result, 33% of energy consumption per sale could be reduced in 2003 compared to 1990 (Ohashi & Kawaguchi , 2005).

These numbers show that energy efficiency in industrial sector is not just like squeezing out the last milliseconds out at an Olympic racetrack but big saving due to energy conservation is vitally to maintain competitive product cost.

4.3. Energy efficiency in building

Main energy consumers in buildings are lightning, appliances, heating and air conditioning (The NEED Project, 2009). In private households, lightning accounts for 25% of electricity use (Andrews, 2009). In business offices, 60% of the electricity is used up for lightning (The NEED Project, 2009). Light is necessary for office activities but often forgotten to be switched off resulting in a lot of wasted energy. Also, in typical the lighting conditions are not customizable for every individual work place. Employees see themselves often caught in the decision of a pitch black working environment or by switching on the light too bright one. Also alternative solutions for lightning are not considered. For example it would be possible to apply sunlight during daytime to en-lighten darker building areas by for example directed mirrors.

Nowadays, an office or home environment is not complete without Information and Communication Technologies (ICT). CO_2 emission from ICT is increasing at a rate of 6% per year and with such growth could represent 12% of worldwide emission by 2020 (The Climate Group, 2008). Also, ICT consumes 35-50% of the total energy consumed at academic institutions (Matthews , et al., 2002) and server farms and telecommuni-cation infrastructures consume around 3% of the world's electric energy. This value is increasing at a rate of 16-20% per year (Fettweis, 2009). In the USA internet alone uses 9.4% of the produced electricity (Nordman, 2009). It is predicted that the CO_2 emission related to personal computers, mobile devices and gaming consoles will in-crease at least by 200% by 2020 compared to 2009 (Bronk, et al., 2010).

4.4. Energy efficiency in the transportation sector

When coming down to the transportation sector, the energy efficiency on pas-senger cars in the European Union was improved by 15% since 1995 (Bundesministerium fuer Umwelt (Germany), 2013). Still today, common technologies for combusting engines and gears have a maximal efficiency of 35% based on 2011 data. Upcoming hybrid cars and electric cars have an efficiency bigger than 90% (Buschmann & Motyka, 2011). The transportation sector accounts for 28% of global energy consumption (Evans, 2003).

4.5. Energy efficiency for private consumers

Due to global networking and cross-linking, consumption of digital media, dependence on energy consuming transportation solutions the acceptance in the population is not very high to abstain from their personal electrical devices but also to consider less energy intensive ways of public transport like replacing the car with a bicycle. With awareness campaigns we can reach the people's minds and influence their actions. Studies show that consumers are willing to pay for measures to neutralize negative effects on CO_2 emission caused by them (MacKerron, et al., 2009); (Akter, et al., 2009); (Goessling & Schumacher, 2010); (Arana, et al., 2012). In the same manner we can sensitize workers and operators at offices and in facilities with energy efficiency audits to use energy more wisely and turn of the light when not required for example. These are small measures with great impact when processed firmly.

In the consumer market a report on energy efficiency by Moritz Buschmann states a possibility to reduce energy consumption in private households by smart metering. When energy consumers have a better overview on what they actually consume, the awareness is bigger and the willingness to contribute to worldwide energy savings could be taken easier in action, by every individual. With a smarter metering device for example the energy consumption for heating and cooling could be decreased by 80% (Buschmann & Motyka, 2011).

4.6. Return on investment from energy efficiency

Energy efficiency often comes along with investment. Mostly, it is not possible to affect systems efficiency just by fastening a screw but additional equipment has to be purchased or non-efficient equipment has to be replaced. The Return of Investment (ROI) is an indicator for economic feasibility. It determines the time after the savings from an investment are higher than the investment cost. While for private households an ROI of even ten years for a heat pump or photovoltaic cells, is considered as feasible. However, in industries shorter ROI of less than five years is usually required. For example for Robert Bosch in Vietnam representing the industrial sector the ROI should be less than three years.

New investments in energy efficient technologies amount five billion USD in 2009. This makes a 17% increase from the previous years and continues the positive trend of 28%

average between 2004 and 2009 (Sustainable Energy Finance Initiative (SEFI), 2010). The global investment potential for increased energy productivity per year is roughly 170 billion USD in total and 83 billion USD for the industrial sector only (Farrell, et al., 2008).

In the USA, the typical payback period is one to two years and the average return on the investment is 200%. The yearly savings from energy efficiency measures are up to 30% in energy and 100 million USD in costs. Also we record a positive impact on employment and job creation (Nelson, 1989); (Nelson & Rosenberg, 1993); (U. S. Department of Energy , 2010); (Tonn & Peretz, 2007).

In developing countries, more than 4/5 of 455 World Bank financed projects had pay-back periods of less than 30 months (Taylor, et al., 2008). On the other hand, two thirds of the available profitable energy efficiency opportunities are located in developing countries (Farrell & Remes, 2009). A survey by the United Nations Industrial Department in 2011 analyzed 357 manufacturing companies from developing countries for investing in at least one project regarding energy efficiency. 119 projects were approved by the survey. Typical projects value was below 100,000 USD with a total sum of investment value in the energy efficiency project of 613.7 million USD. The individual investment range was from 73 USD to 100 million USD (United Nations Industrial Development Organization, 2011). The investments areas were:

- Direct equipment replacement 36%
- Waste reuse 14%
- Residual temperature reuse 14%
- Pipes and insulation improvement 13%
- Improved use of infrastructure 12%
- Fuel optimization

The average internal rate of return (IRR) for these projects is estimated with:

- 25% with three-year project
- 37% with four-year project
- 43% with five-year project
- 50% with ten-year project

Consequently, a high profitability for energy efficiency projects was noticed in comparison with average returns in capital markets over a similar time (Alcorta, et al., 2013). For example the selected long-term return assumption from investing in Gold over 10 -15 years is 6.75% (J.P. Morgan Asset Management, 2012). Also, it is a note worth to mention that countries with higher inflation rates have greater benefit with longer terms. A lot of potential lies in system optimization and improvement in the already existing infrastructures like better sealing and insulation of pipes. This leads to a higher IRR than direct equipment replacing because of the small and easy investment value in such measures. Table 3 shows some industrial sectors with investment value and payback years. Also, relatively small projects with less than 10,000 USD investment value are recorded with high profitability (Alcorta, et al., 2013).

Sector	Number of projects	Investment (US$)	Payback years	IRR 3 years (%)	IRR 4 years (%)	IRR 5 years (%)	IRR 10 years (%)
Automotive/ Autoparts	4	98,250	1.93	26	37	43	51
Cement/ Ceramics	15	43,702,213	2.19	18	29	36	45
Chemicals	14	26,370,874	2.9	2	14	21	32
Equipment manufacturing	16	9,538,587	2.1	20	32	38	47
Food and beverages	9	2,684,000	1.1	74	83	87	91
Metal	14	4,882,517	1.5	45	55	60	66
Paper	12	6,249,000	0.9	96	105	108	111
Textile	22	3,204,540	2.2	17	29	36	44
Others	13	23,602,000	2.4	12	24	31	40
All cases	119	120,332,181	1.95	25	37	43	50

Table 3: Internal rate of return (IRR) for different sectors (United Nations Industrial Development Organization, 2011)

When analyzing the benefits, the risks also play a critical role. Especially for large investments in process industries, technical risks are higher due to the procedural complexities and sequential nature of production processes. Therefore in comparison to lower end industries the return rate in, for example the chemical and cement sector is lower (Alcorta, et al., 2013).

Table 4 shows an overview on the internal rate of return for different types of investments. The best payback comes from investment to improve the piping and insulation, better use of infrastructure and fuel optimizing. But also waste re-use has a good IRR. Table 4 also shows that the IRR from improving existent solutions is better than direct replacing of the equipment. The estimated IRRs are mean values for each respective lifespan.

Type of investment	Number of projects	Investment (US$)	Payback years	IRR 3 years (%)	IRR 4 years (%)	IRR 5 years (%)	IRR 10 years (%)
Better use of infrastructure	14	458,132	1.2	65	74	79	83
Direct equipment replacement	42	36,455,746	2.7	5	18	25	35
Fuel optimizing	12	1,467,156	1.5	45	55	60	66
Pipes and insulation improvements	19	10,373,757	1.3	57	67	72	77
Residual temperature re-Use	20	49,835,719	2.2	17	29	36	44
Waste re-use	12	21,741,671	1.6	39	50	56	62
All cases	119	120,332,181	1.95	25	37	43	50

Table 4: Internal rate of return (IRR) considering type of investment (United Nations Industrial Development Organization, 2011)

4.7. Barriers for energy efficiency in developing countries

There are many challenging circumstances in developing countries for successful energy efficiency policies. There is no guarantee for permanent accessible energy and the supply in the first place. This makes the access to energy more important than the efficient use of it. For example some Nigerian industries receive electricity during a 4.5 hours period per day (Okafor, 2008). Also obtaining information and data on energy efficiency is difficult in developing countries because of high research costs, poor labeling and lack of metering equipment and still when information is available there is a leak of skill to put it in to practical use (Masselink, 2010); (Fokeer, 2010). Another point is that local equipment producers often build their products based on old designs, because they are not aware of current state of the art technologies and also mistrust foreign technology consultations (Sorrell, et al., 2011); (Gosh & Roy, 2011).

For a lot of manufacturers in developing countries there is no point in investing capacity and money in energy efficiency, due to low prices for energy (Masselink, 2009). In 2009, ten developing countries accounted for 70% of the global subsidies for fossil fuels totaled in 312 billion USD. Consumers in non-OECD countries pay less than 50% of the natural gas value (United Nations Industrial Development Organization, 2011).

4.8. Relation between CO_2 emission and economic growth

According to Kuan-Min Wang in his report "The relationship between carbon dioxide emission and economic growth", published in 2011, the Greenhouse gas emission especially in developing countries is closely linked to economic growth. Studies argue that the relationship between CO_2 emission and economic growth is shaped as an inverted U-shape curve. The curve refers to the relation between income in a certain country on the horizontal axis and CO2 emission on the vertical axis. At a relative low level of income, the CO2 emission is at a low level either. With rising income level the energy consumption increases resulting in rising CO_2 emission. When achieving a high income level, the awareness of environmental protection enhances and like already discussed people and government are more willing to spend more resources to enforce policies, regulations and conduction of the environmental policies. Applied to the U-shape curve, the CO_2 emission will be decrease but still in long term, the increase of national income will result in a rise of CO_2 emission. Another point also is that a slowdown of economic growth by controlling CO_2 emission is questionable but is still applied on developing countries it could be implied that developing countries should ignore their environmental problems until they develop, get wealthier and can be located on the decreasing side of the U-shaped curve. In the result the top priority to combat global warming is to focus on the countries with high economic growth and high carbon dioxide emission (Wang, 2011).

An example for governmental policies is the formulation of Chinese National Strategy "National Program on Coping with Climate Change" in July 2007. The target in this paper is set to reduce 40-45% of CO_2 emission subsequently until 2020 based on the data from 2005 by eight pivotal points to these formulation:

- Restructuring the economy, promoting technology advancement and improving energy efficiency
- Optimizing energy mix by developing low-carbon and renewable energy

- Launching national wide tree-planting and a forestation campaign and enhancing ecology restoration and protection
- Strengthening laws and regulations, and policies and measures relevant to addressing climate change
- Further improving institutions and mechanisms
- Attaching great importance to climate change research and capacity building
- Strengthening education, training and public awareness on climate change

Up to date China is one of the biggest energy consumers worldwide and also has one of the biggest growth rates in economy. By establishing energy saving policies, China could make a big contribution to the world, overall CO_2 statistic. (National Development and Reform Commission (NDRC), 2006).
Still, China made the biggest contribution to global CO_2 emission in 2011 with its emission rising by 720 million tons. On the other hand, due to Chinese contribution in improving energy efficiency, the amount of CO_2 emitted per unit of Gross domestic product (GDP) fell by 15% between 2005 and 2011 (International Energy Agency, 2012).

Another example for governmental influence on CO_2 related topics is the nation policy for energy saving in European manufacturing from January 2007. The policy targets a reduction of GHG emission by 20%, ensures that 20% of energy from renewable sources in the EU and also targets a reduction in global primary energy consumption of 20%. The targets are to be accomplished by 2020 (Commission of the European Communities, 2007).

It is clear that with energy efficient equipment, it is possible to obtain the same production with lower energy consumption or obtain larger production with same energy consumption. This would mean lower fixed costs which lead to lower production costs to bigger business volumes. The conclusion is that energy efficiency not only impact green initiatives like lowering CO_2 emissions but also is a big economic value for profit maximization at production facilities (Finnish environment Institute 2008).

4.9. Rebound effect

If a product is more energy efficient, the costs for owning and using this product are lower. For example, when this theory is applied on a more efficient car because of the lower fuel consumption the price per kilometer is lower. With an efficient building the cost for heating per square meter is lower. Lower costs increase the demand on a certain product and lead to higher overall energy consumption. This can either manifest in more frequent usage of a product, more intense use of a product or more units of the same product. Applied on a car, the car would be used more often, it would drive more kilometers and overall more cars are being sold because it would be a cheaper transportation solution (de Haan, 2009). This effect is called the Rebound Effect and is working against our basic intention to reduce the worldwide energy consumption and emission of CO_2 with energy efficiency. What does this mean for a production facility? As discussed before when producing energy efficient the overall production costs are lower. Therefore, the product can be sold for a lower price, the demand rises, the production capacity is being upgraded and the energy consumption for the facility is ramping up.

4.10. ISO 50001

In an attempt for standardized policies for providing the industry with a certificate for energy efficiency, the International Organization for Standardization (ISO) established the ISO 50001 standard in February 2008 (International Organization for Standardization, 2008). This standard constitutes:

- Energy efficiency, performance and supply
- Procurement practice for energy using equipment and systems
- Policy for more efficient use of energy
- Fixed targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the result
- Review how the policy works
- Continually improve energy management

By applying the policy the ISO 50001 standard could influence up to 60% of the world's energy demand (Park, et al., 2009).

Robert Bosch Ho Chi Minh City plant

This chapter provides a basic overview on the Robert Bosch Ho Chi Minh City plant (HcP) and information on the Bosch worldwide project to reduce CO_2. First step is to analyze what drives the project and the motivation in this special case. For this purpose the focus is set on the Robert Bosch GmbH guideline for reducing CO_2 emission (Not published document, Robert Bosch GmbH, 2007) regarding the relevant aspects for the topic. In the general overview, on current development it is stated that protecting the climate starts being the topic more often in public discussions and there is a rising demands for climate protecting policies. Like stated in the previous chapter big facilities are the main consumers of energy and main producers of CO_2 therefore also have the biggest potential to save energy. These circumstances put big, worldwide acting and producing companies with Corporate Social Responsibility such as Bosch under a certain pressure. Bosch is a company producing for end customers and sees the possibility to get a sympathy bonus in people's minds for caring for the environment. None the less saving CO_2 brings an economic advantage for the company by saving fix costs.

4.11. Bosch initial position

In its House of Orientation, Bosch lists protecting the environment as one of its visions. In 2008, Bosch decided on a main target to reduce CO_2 in all locations over the globe to meet these demands but also to reduce energy cost and make room for new innovative solutions and business fields. Based on the values for CO_2 emission in 2007, the relative CO_2 emission is to be reduced by 15% until 2012 and by 25% until 2020. Further guidelines for this task are:

- All CO_2 emissions from Bosch business activities are to be listed.
- The CO_2 emission targets are assigned to the Bosch business units depending on how much CO_2 emission they are responsible for.
- The targets have to be achieved with Bosch intern measures.
- The targets are to be tracked within the business units and reported.

Further it is required to list all production facilities, all research and developing units with more than 50 employees and every other unit with more than 100 employees.
The relative CO_2-Emission is to be calculated using the following equation.

$$CO_{2_{rel}} = \frac{CO_{2_{tot}}}{NGU-(P)MAT} \left[\frac{t\ CO_2}{Mio\ Euro}\right] \quad (2)$$

NGU describes the total net turnover from third party sales, intern sales and intern supplies. (P)MAT describes the (plan) material costs.

Depending on area and department other targets can be agreed like a total CO_2 target in tons or absolute energy target in MWh. Still the focus always stays on CO_2 emission and there are two scopes for impacting areas of the Greenhouse-Gas-Protocols.

- Scope 1: All direct CO_2 emissions from stationary combustion like heating and from mobile combustion like company owned transportation.
- Scope 2: All non-direct CO_2 emissions like bought electricity and long-distance heating

CO2 emission resulting from not company owned activities like production of material at supplier side or external logistics are not to be listed but would be summed up under scope 3 in the Greenhouse-Gas-Protocols.

4.12. HcP and Departments

The Ho Chi Minh City Plant (HcP) is a production facility owned by the Robert Bosch Vietnam Co., Ltd, a branch of Robert Bosch GmbH, and is located in the Dong Nai Industrial Park, near Ho Chi Minh City in Vietnam. The Facility is organized in the Bosch business unit, called Gasoline Systems (GS) and was established in May 2008 with purpose of establishing a short distance relation and logistic advantage in serving the main customer Jatco located in Japan. HcP produces Continuously Variable Transmission (CVT) push belts for automobile automatic gears. The manufacturing process at HcP is realized by the departments Facility Management (FCM), Technical Function (TEF) and Manufacturing (MFG). These three departments are also responsible for the main share of HcP energy consumption.

<u>Manufacturing Department</u>

The Manufacturing Department (MFG) is responsible for the CVT push belt manufacturing processes regarding process specifications like for example required compressed air pressure, required temperature for annealing or hardening processes.

Technical Equipment and Functions Department

The Technical Equipment and Functions Department (TEF) is responsible for the manufacturing equipments and for the customization of the machines to match the process requirements. All problems and issues regarding the production machines are being taken care of by the TEF department.

Facility Management Department

The main topic for Facility Management Department is supplying all incoming energy, compressed air and other fluids over the facility and especially to the manufacturing machines. FCM is also responsible for the heating, ventilation, and air conditioning (HVAC) system, wastewater treatment, cooling down of process water with chillers, lightning and the fire-extinguishing system. The responsibility for coordinating the GS CO_2 reduction program for the year 2013 lies within FCM.

4.13. Production machines and process

The push belt manufacturing process is divided in three basic production lines.

- Element-line
- Loop-line
- Assembly-line

Each line consists of several process steps like washing, deburring, annealing, hardening, fine blanking, welding and rolling. The element and loop production is running parallel and the two products are being assembled, finished and packed for transport at the assembly lines. Currently, loop line 5 (LL5) and loop line 6 (LL6), element line 4 (EL4) and element line 5 (EL5) and Assembly line 1 – 6 (AS1 – 6) are located at HcP. The Target in 2013 for HcP regarding the saving in CO_2 emission is set at 1,511 tons of CO_2 plant wide. 1,511 t CO_2 equals 3,815 MWh considering the present factors for CO_2 emission in Vietnam.

4.14. Concerns and barriers for energy efficiency at HcP

The plant in Ho Chi Minh City got involved really late into the Bosch Gasoline Systems CO_2 reduction program. The “kick off” for the consideration of energy efficiency and concerns meeting the GS target was in February 2013. Therefore the first basic and time consuming steps were to create a basis for energy saving considerations.

In first line, it was important to acquire missing documents on the equipment if available and creating awareness in the concerned departments to support the project. Because of the short time between “kick off” and active involvement in the project, crtical measuring devices for power consumption were still not available. Only about 40% of the equipment has built-in power consumption measuring devices. After purchase of portable measuring equipment, still the time frame for a technician to be available and provide access to the Direct digital control (DDC) was only once a week. With a total of 61 DDC panels, two measuring devices and process durations between a few seconds at the blanking press and several hours with deburring or even 24h for the loop washing machine it was possible to measure the power consumption of an average 6 machines per week. To validate the measures at least two or even better three measurements per panel had to be done. Theoretically, it would take around 30 weeks to get valid data on every single of the equipment in the production area. Also because of security issues and possible impact on the process it is not possible to measure all machines with the portable device. After an electrical accident in May 2013, all measures by opening the DDC panels and removing the isolation covers to get access to the currents were on hold until safety conditions are improved.

In progress of measuring the machines with the DDCs built-in devices also concerns about the accuracy of the devices came up. A good example is the measuring of the loop washing machine. Figure 5 shows the equipment with the biggest consumption at HcP. The results are evaluated from one week data.

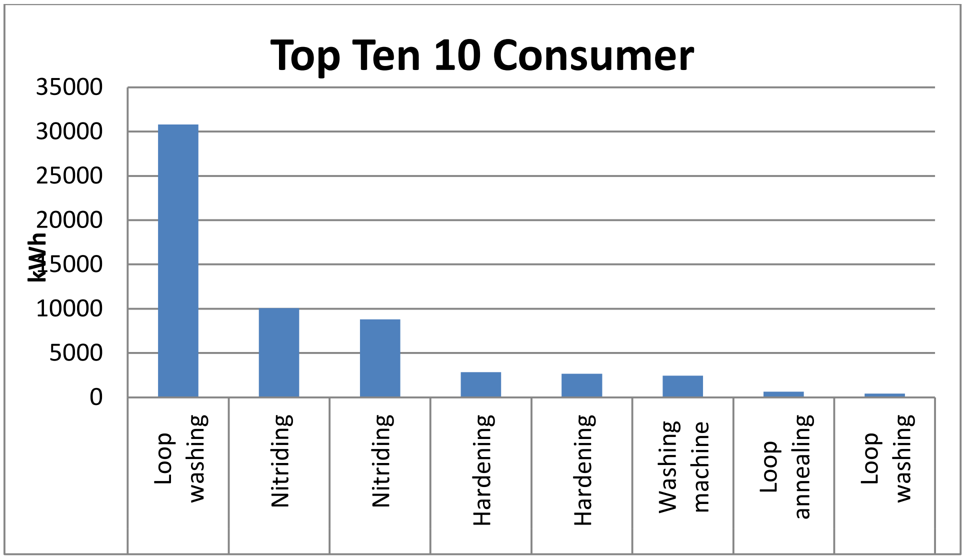

Figure 5: Top10 consumers for a week respective (own measurement)

Comparing two machines of the same kind also same energy consumption was expected. First measures with a build in measuring device showed a critical consumption at one of the loop lines. The consumption for the washing machine was approximately a hundred times bigger compared to the other line. By a second measurement with a portable device directly on the currents inside the DDC panels different data was gathered, see Table 5.

		week 5/15/2013 - 5/22/2013 (build in)			6/20/2013 (Fluke portable) ~ 11am - 2pm		
Nr. DDC panel	**Name of Eqp.**	**consumption [kWh]**	**working hours**	**kW**	**consumption [kWh]**	**working hours**	**kW**
00477 LL5	Loop washing	30,812	167	184.9	114	1.2	95.0
02096 LL6	Loop washing	432	167	2.5	258	1.25	206.4
			Δ	182.3		Δ	-111.4

Table 5: Compare between build in and portable measurement for loop-line washing machine (own measurement)

The numbers clearly show the gap between the two measures. Table 6 shows the hook-up data for the loop washing machine for compare.

Machine	Power	kW
Cooling	12kW	12
Fan WT blow-off	5x3kW +0.75kW	15.75
Blow heat air station	4x3kW	12
Heating warmed air	4x9kW	36
Conveyor	0.15kW	0.15
Others	N/A	
Pumps	(1.1+0.75+0.55+1.85+15+0.022+5.5+0.25 +1.5+0.25+1.5+0.25+1.5+0.25)kW	30.272
Heating station 1	10x6kW	60
Heating station 2	5x6kW	30
Heating station 3	4x6kW	24
Heating station 4	4x6kW	24
Heating station 5	6x6kW	36
	sum	280.172

Table 6: Hook-up data loop-line washing machine (Not published document, Robert Bosch GmbH)

Considering a hook up of 280 kW and excluding any maintenance or emergency shut-downs of the machine during that week an average consumption of 2.56 kW is not possible.

It can also be noticed that the data for the build in measuring devices for loop-line 5 (LL5) exceed the data from LL6 by nearly 100 times. On the other hand, the portable measuring device supplied by FLUKE shows an opposite picture. Consumption for LL5 is just half as much as from the build in device and the consumption for LL6 is radically increased. As a conclusion, the data gathered from the build in measurement devices is useless until a recalibration of the equipment occurred.

In second step, potential measures for energy efficiency had to be investigated and implemented. The documentation of the measures was planned to be realize with a bi-weekly meeting with responsible equipment and manufacturing engineers and brainstorming sessions. Like mentioned before, the awareness in the departments for energy efficient solutions was not given therefore the acceptance and attendance for this meeting was supported by just a few. Considering, this the use of these meetings was limited. “Vietnam is very relaxed with its attitude towards schedules and timelines.

Vietnamese will not upset others in order to force meeting a deadline, and while appointments and schedules need to be set in advance, these should be viewed as flexible. Patience is a necessary attribute to successful cross cultural management in Vietnam." (Anon., n.d.). This circumstances were observed at Bosch Vietnam

Another critical point was the tracking of the feasibility for the energy efficiency initiatives. Limited awareness is also linked to limited contribution to the project and the timeline for feasibility and implementation was constantly delayed by the departments.

Figure 6 shows the common known approach for energy efficiency matters. Like mentioned above, there is a big leak in infrastructure to finish step 1. The benchmarking is not possible without the required equipment and manpower. Investigating potential for energy saving is therefore more time consuming. Without actual data the risk on spending time on ideas less efficient when somewhere in the facility the big consumers and energy waster are waiting for attention is great. The real benefit will be just measurable from the electricity bill for the howl facility. Also the possibility to assign the real savings to each of the retrofitted equipment is limited in the end.

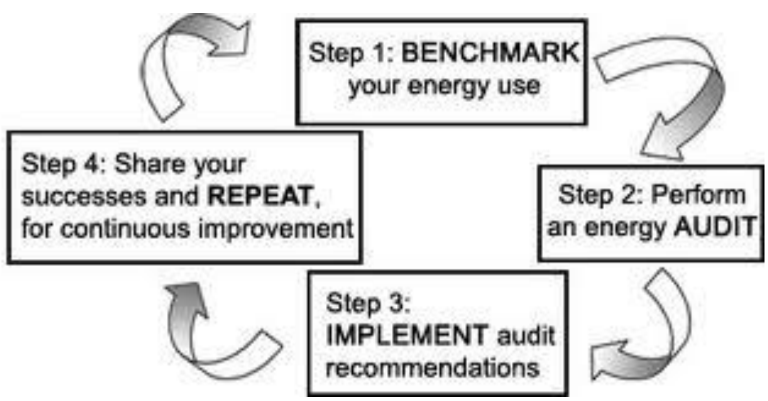

Figure 6: Implementation of energy efficiency (United States Environmental Protection Agency, 2012)

The PDCA (Plan, Do, Check and Act) levels shown in Figure 7 is institutionalized by Robert Bosch worldwide for the project. The PDCA level provides an overview on the status of a project. The structure is a good orientation for tracking the progress of different ideas but in the end had just limited use for the project. Keeping the timeline updated from planning to acting is very time consuming and the process owner responsible for the implementation hardly ever meet the deadline. The problem here is also the not assigned target for the departments. While for the FCM department CO_2

reduction was a fixed target, the TEF and MFG department were running the project on lowest priority and were providing capacity only as limited as possible. The planning and investigation of ideas were mostly following no clean line and only attended occasionally after several requests.

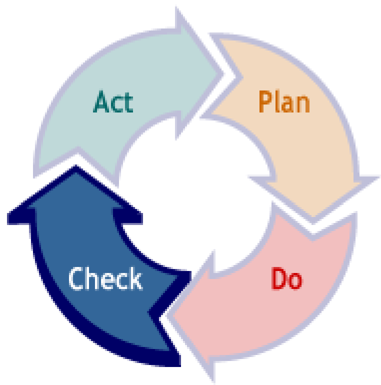

Figure 7: PDCA chart (United States Environmental Protection Agency, 2012)

5. Measures for CO_2 reduction

5.1. CO_2 emission factor

The factor for CO_2 emission in Vietnam is based on consumed electricity, which is 0.396 tons of CO_2 per Megawatt hour (t CO_2/MWh) (International Energy Agency, 2008). The factor depends on the share in renewable and CO_2 neutral energy generation in the given country. A country that mostly depends on combusting fuels for generating electricity has a bigger CO_2 emission factor than one that mostly depends on green or nuclear energy. Table 7 is important for considering CO_2 emission on respective scope two emissions from Robert Bosch worldwide guideline for CO_2 emission.

2006 Emissions Factors for Scope 2 emissions (kg CO_2 per MWh). Source: IEA Data Service "CO_2 Emissions from Fuel Combustion (2008 edition)"	**Country**	**Scope 2 factor**
		Kg CO2/MWh
CAMBODIA	KH	1,004.9344
CHINA	CN	787.5875
HONG KONG	HK	854.6126
INDIA	IN	944.0385
INDONESIA	ID	676.7253
JAPAN	JP	418.346
KOREA, DEMOCRATIC PEOPLE'S REPUBLIC OF	KP	533.1955
KOREA, REPUBLIC OF	KR	464.337
MALAYSIA	MY	655.3582
PHILIPPINES	PH	435.0061
SINGAPORE	SG	536.0586
SRI LANKA	LK	313.7244
TAIWAN, PROVINCE OF CHINA	TW	658.8819
THAILAND	TH	510.9283
VIET NAM	VN	396.3138
Chinese Taipei (listed above as TAIWAN, TW)		658.8819
World		504.8558
OECD North America		513.069
OECD Pacific		495.411
OECD Europe		338.661
Africa		645.488

2006 Emissions Factors for Scope 2 emissions (kg CO_2 per MWh). Source: IEA Data Service "CO_2 Emissions from Fuel Combustion (2008 edition)"	**Country**	**Scope 2 factor**
		Kg CO2/MWh
Latin America		193.5865
Middle East		670.4737
Non-OECD Europe		498.8224
Former USSR		340.6189
Asia (excluding China)		729.3463
Other Africa		488.6113
Other Latin America		508.9928
Other Asia		307.8166
Memo: OECD Total		444.34
Memo: Non-OECD Total		564.6613
Memo: IEA Total		442.665
Memo: European Union - 27		354.1587
Memo: Former Yugoslavia		595.9141
Memo: Annex I Parties		414.4591
Memo: Annex II Parties		436.141
Memo: Annex II North America		511.6472
Memo: Annex II Europe		305.9918
Memo: Annex II Pacific		505.5595
Memo: Economies in Transition		359.0594
Memo: Non-Annex I Parties		652.3668
Memo: Annex I Kyoto Parties		349.615

Table 7: Standard conversion Table for greenhouse gas factors for Scope 2 emissions (International Energy Agency, 2008)

Figure 8 compares the weight in kg of CO_2 per MWh power produced for some Asian countries. Compared to countries and regions in Asia, the emission factor for Vietnam is quiet low.

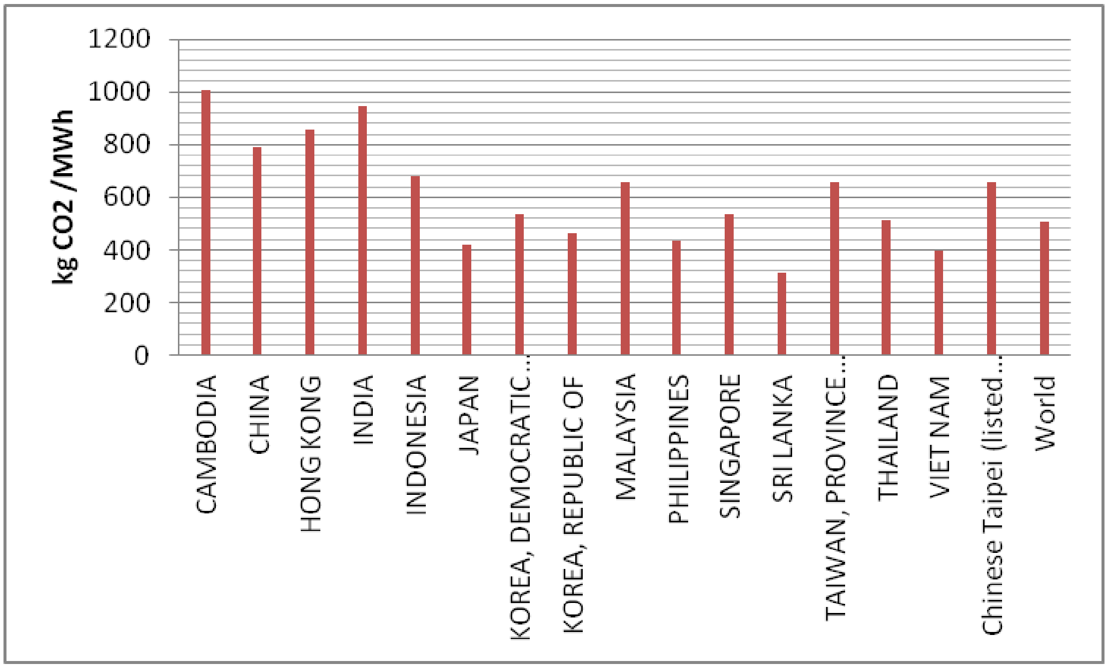

Figure 8: Comparison of CO_2 emission factors in Asia

Considering the use of industrial gases in production and facilities, depending on fuel type, there are different conversion factors. Table 8 is important for considering CO_2 emission on respective scope one emissions from Robert Bosch worldwide guideline for CO_2 emission. Also, it is important, to calculate with the right state of aggregation. It is either to use the volume in Normal m^3 under normal condition (20 ˚C, ~1 bar) or the amount of tons. The data are based on Higher Heating Value (HHV), meaning the heat from the total combustion of the medium and the energy from latent heat from water vaporization is considered.

Fuel Category Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories	Fuel Type green: standard fuel type for calculator	Scope 1 factor	
		kg CO2/ton fuel	kg CO2/Nm³
Crude oil & derived substances	Crude oil	3,100.59	2,480.47
	Orimulsion	2,117.50	n.a.
	Natural Gas Liquids (NGL)	2,837.64	n.a.
	Motor Gasoline	3,069.99	2,271.79
	Aviation Gasoline	3,101.00	2,201.71
	Jet Gasoline	3,101.00	2,201.71
	Jet Kerosene	3,153.15	2,490.99
	Other Kerosene	3,149.22	2,519.38
	Shale oil	2,792.73	2,792.73
	Gas/Diesel oil	3,186.30	2,676.49
	Residual Fuel oil	3,126.96	2,939.34
	Liquefied Petroleum Gases (LPG)	2,984.63	1,611.70
	Ethane	2,858.24	3.61
	Naphtha	3,261.85	2,511.62
	Bitumen	3,244.14	n.a.
	Lubricants	2,946.66	2,946.66
	Petroleum coke	3,168.75	n.a.
	Refinery feedstocks	3,151.90	n.a.
	Refinery Gas	2,851.20	n.a.
	Paraffin waxes	2,946.66	n.a.
	White Spirit & SBP	2,946.66	n.a.
	Other petroleum products	2,946.66	n.a.
Coal & derived substances	Anthracite	2,624.61	n.a.
	Coking coal	2,667.72	n.a.
	Other bituminous coal	2,440.68	n.a.
	Sub-bituminous coal	1,816.29	n.a.
	Lignite	1,201.90	n.a.
	Oil shale and tar sands	952.30	n.a.
	Brown coal briquettes	2,018.25	n.a.

Fuel Category Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories	Fuel Type green: standard fuel type for calculator	Scope 1 factor kg CO2/ton fuel	 kg CO2/Nm³
	Patent fuel	2,018.25	n.a.
	Coke oven coke & lignite coke	3,017.40	n.a.
	Gas coke	3,017.40	n.a.
	Coal tar	2,259.60	n.a.
	Gas works gas	1,718.28	n.a.
	Coke oven gas	1,718.28	n.a.
	Blast furnace gas	642.20	n.a.
	Oxygen steel furnace gas	1,284.92	n.a.
Natural gas	Compressed Natural Gas (CNG)	2,692.80	n.a.
	Natural Gas (not compressed)	2,692.80	1.88
Non-biomass waste fuels	Municipal wastes (non-biomass fraction)	917.00	n.a.
	Industrial wastes	n.a.	n.a.
	Waste oils	2,946.66	n.a.
Peat	Peat	1,034.56	n.a.

Table 8: Standard conversion Table for greenhouse gas Scope 1 emission (IPCC National Greenhouse Gas Inventories Programme, 2006)

5.2. Energy price

The basis for every feasibility report is the energy price in Vietnamese Dong (VND) per kWh. Table 9 shows the electricity price in the Dong Nai province considering time of day:

Energy price per kWh	
a. Normal hours: Price 1,243 VND	
From Monday to Saturday:	
From 04:00 to 09:30	(05 hours and 30 minutes)
From 11:30 to 17:00	(05 hours and 30 minutes)
From 20:00 to 22:00	(02 hours).
- On Sunday:	
From 04:00 to 22:00	(18 hours)
b. Peak hours: Price 2,263 VND	
From Monday to Saturday:	
From 09:30 to 11:30	(02 hours)
From 17:00 to 20:00	(03 hours)
On Sunday: Not applicable	
c. Off-peak hours: Price 783 VND	
All days in a week: from 22:00 to 04:00 (06 hours)	

Table 9: Energy price per kWh in Dong Nai province (Not published document, Robert Bosch GmbH, 2013)

Because most of the equipment is running 24 hours per day and 7 days a week, calculating with an average energy price of 1,310.14 VND per kWh, in most cases is accurate enough.

The conversion factor from Vietnamese Dong (VND) to Euro (EUR) is 100,000 VND equal 3.356 EUR. This equals an average energy price of 0.0439 EUR per kWh.

5.3. Energy data and energy forecast for HcP

5.3.1. HcP compared to leadplant in Tilburg

To have a basis for potential solutions it is important to have a compairson. For HcP the Robert Bosch lead plant is a good indicator for the energy consumption. The lead plant for HcP in Tilburg (TbP) has similar machines but other capacities for the share in loops elements and assembled push belts production. When comparing the data from Table 10 and Table 11 it's obvious, that the loop production at HcP has bigger energy consumption per piece than Tilburg. The elements have a share of 18%, the Loops 51% and the assembly of the finished push belts 0.4 in the total energy consumption at HcP. The relative energy is from the total value of 22,265 MWh for HcP and 29,615 MWh for Tilburg. The energy consumption is a sum for the first half year 2013.

Product	%	relative energy	kWh/pc
Elements	18.42	4,101,213	3.83169
Loops	51.89	11,553,308.5	23.16941
Push belts	0.39	86,833.5	0.067492

Table 10 energy consumption per peace for HcP (Not published document, Robert Bosch GmbH, 2013)

Product	%	relative energy	kWh/pc
Elements	18.38	5,443,395.252	4.09844
Loops	51.51	15,255,130	7.33775
Push belts	0.29	85,885.9969	0.08540

Table 11 energy consumption per peace for lead plant in Tilburg (Not published document, Robert Bosch GmbH, 2013)

In the consequence either issue for energy waste have to be determined or miss function can be assumed. The production at HcP is still haunted by miss function and leak in process quality therefore no such issues could clearly be determinate without risk in product quality. When in future the process at HcP gets more stable this fact is for sure worth some investigation.

5.3.2. Relative CO_2 emission

According to the Robert Bosch guideline for CO_2 reduction the relative CO_2 emission is an indicator for a green facility. Table 12 and Table 13 show the relative CO_2 emission for HcP for 2012 and first half of 2013. It's obvious the curves are not straight but have peaks and down. A peak in absolute CO_2 always comes with a down in costs. The reasons for this trend is mostly from national holydays or big technical issues resulting in shutdown of equipment and production stop. When such even occurs the cost rise, more failure parts are being produces and less money can be collected from sale. Since the beginning of the CO_2 reduction program in February 2013 the rise in CO_2 emission for the facility gradually became smaller. The production capacity for the facility is still ramping up so rise in total CO_2 emission can be avoided just but limited.

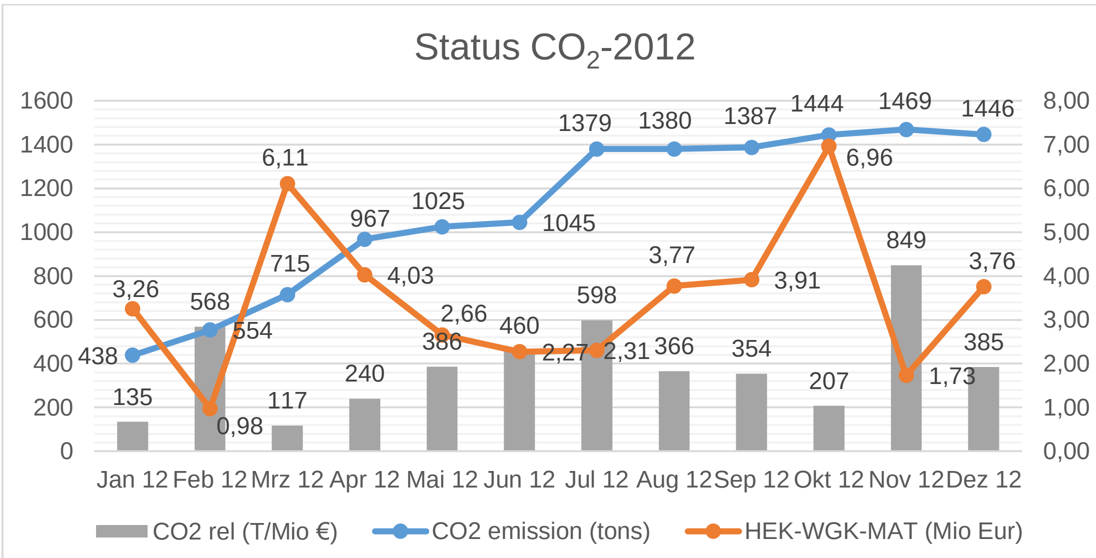

Table 12: HcP relative CO_2 emission 2012 (Not published document, Robert Bosch GmbH, 2012)

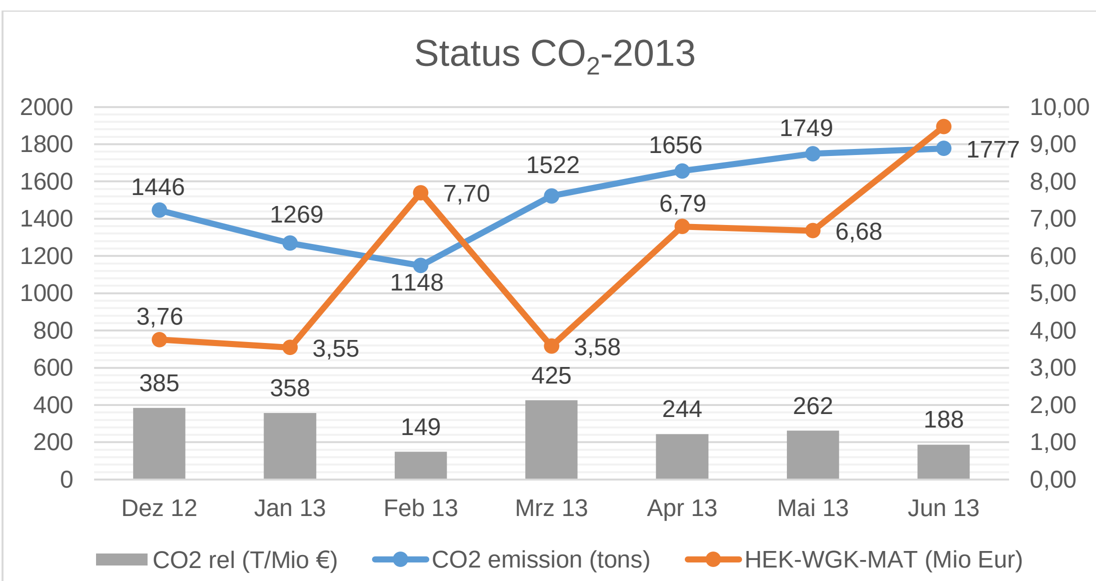

Table 13: HcP relative CO_2 emission 2013 (Not published document, Robert Bosch GmbH, 2013)

5.4. “Low hanging fruit”

The ideas for energy efficiency are split between investment measures where money has to be invested to make modifications on the facility and equipment and so called “low-hanging-fruits” solution. Low-hanging-fruit solutions are short implementation time measures with minimal investment of money. Because the target for CO_2 reduction has to be met by end of 2013, the low hanging fruit solutions are preferred for implementation. Some processes at HcP have an unnecessary and unused comfortable puffer for production capability. By decreasing this puffer, some significant saving is possible without major impact on process specification or quality issues.

5.5. Shut down endomat for element line furnace

An example for a low hanging fruit solution is located in the element lines. Each of the element lines has an own endomat running at not even 50%. Switching off one of the endomats and using the other for both lines is a quick and easy way to save energy with no investment cost. The equipment doesn't require any customization or investment because piping and instruments are available. The endomat is supplied with 2.4 m^3/h propane (C_3H_8) at a pressure of 150 mbar and 25 °C. The standard emission factor for propane in gaseous state is 0.1546 kg CO_2 per standard cubic feet (scf) (Climate Registry, 2012).

Because the consumption is not measured in scf but in m^3/h it has to be calculated to this condition first with the ideal gas law and the conversion 1 scf = 0.02628 Nm^3 (Holson Gases, n.d.).

The standard condition for scf at 70 degrees Fahrenheit and 1 bar is 0.426 Nm^3/h is to be calculated with the ideal gas law:

$$p * V = n * R * T \tag{3}$$

$$V_N = \frac{V_1 * p_1 * T_N}{p_N * T_1} \tag{4}$$

The results in Table 14 show a volume flow of 0.426 Nm^3/h.

Calculation to Normal cubic meter (Nm^3) at 20 °C, 1 bar		
p_1	150	Mbar
V_1	2.4	m^3/h
T_1	25	°C
p_N	1,000	mbar
V_N	0.426318	Nm^3/h
T_N	21.111	°C (70 F)

Table 14: Calculation of C_3H_8 to standard condition (own measurement)

With the emission factor (Table 7) and the conversion factor from scf to Nm^3 the CO_2 emission equals 22 tons of CO_2 per year from gas saving.

The electric saving from shutting down the endomat is 18 kWh which results in a yearly saving of 157.6 MWh and a CO_2 emission of 62 tons of CO_2.

5.6. Conveyor belts loop washing

For Bosch, it is also important to reflect the public image of a green company to employees and customers. Small but visible waste of energy should be taken care of immediately like an unnecessary amount of lights and continuously running conveyor belts not transporting any load.

For the conveyor belts, for example, an idle time of one hour per day when programmed to start stop automatic was calculated. With a measured electricity consumption of 3.96 kWh (8 x 0.37 kW + 4 x 0.25 kW) for the electrical drives pulling the conveyor belts the total saving per year would be 1,445.4 kWh and 0.56 tons of CO_2.

With the average electricity price and a saving of only 68.17 EUR per year applying frequency controllers to the electric motors is not even considered for energy saving because the investment of around 1,500 EUR per drive would by far exceed the benefit.

The loop washing machine is the only process using conveyor belts.

Another idea is to install a switch for starting the conveyor belts. Although it's mostly automatic processes for the production of the continuous variable transmission (CVT), belts most of the conveyor belts are loaded with loops by human operators. The necessity to push a switch when starting to load the machine would erase the image of conveyor belts running without load because one of the prior processes is in maintenance or occurring problems. By pushing the switch a second time after the last loop is loaded a Programmable Logic Controller (PLC) program could automatically switch of the conveyor belts after a fixed time. The same function could be acquired with sensors but as an operator is always available, sensors would be an unnecessary investment for time being.

Start-stop-automatic or an automatic shutdown after five minutes after the machine was not in use was also considered for the production equipment. Especially the equipment dealing with heat and the chemicals at same time is not to be stopped, because for example the medium in the washing and the deburring machines have to keep a homogeneous condition and a stop would influence the products quality.

The communication between the single processes is limited and definitely has potential to be optimized. Optimizing the process would benefit in a maximum productivity and would avoid load less running conveyor belts. But these circumstances are not considered for the topic, because in the opinion of the author it’s not a problem on the equipment side, but rather on the process and staff side. Also the focus and capacities in the responsible departments is on maintaining and keeping the product quality. Investigations for optimizing a process considered as critical and not hundred percent stable for the product quality, are exceeding the available time and manpower for the project.

5.7. Decrease temperature for hardening process

Another point is reconsidering the specifications for some processes. The hardening furnace for the loop line has several chambers. The main chambers where the hardening process takes place, have to be kept at 800 °C to maintain product quality. The entry chamber is regulated to 100 °C, but its only task is to keep the air dry and a stable dew point. Tests and measures for energy consumptions show that there is no impact on the process by reducing the temperature to 80 °C. Even a decrease to 50 °C should be possible. Because it takes very long to cool the furnace down, a longer maintenance time is necessary to make some tests on process stability.

Table 15 shows a saving of 2 kWh when comparing the power consumption with the empty furnace running at 100 and 80°C. Considering the furnace is running continuously this equals a saving of 17,520 kWh per year and 6.943 tons of CO_2 emission per year.

Temperature [°C]	Dew point measurement [°C]	Power Consumption measurement [kW]	Remarks
100	-22.7 to -22.8	16	Empty furnace
80	-22.8 to -22.9	14	Empty furnace
100	-22.2 to -22.3	18	Production

Table 15: Dew point condition inside loop-line hardening furnace (Not published document, Robert Bosch GmbH, 2013)

Considering the average electricity price the saving, of 826.3315 € per year is very low compared to other ideas, but considering a ROI of zero years the saving is still mentionable.

5.8. Heat recovery and insulation on hardening furnace

At HcP some processes deal with heat treatment and temperatures above the surrounding temperature. Additionally the current machines were designed for the lead plan of Robert Bosch CVT division in Tilburg, Netherlands. With cold winters and decent summer temperatures the heat from the machines in some way replaced additional heating equipment for the staff and operators in the facility and there was not much attention paid to a proper outside insulation of machines and piping. In Ho Chi Minh City the situation is different. The average temperature over the year is around 30 degrees. It's not possible to run the facility without a large air handling unit (AHU) to keep acceptable temperatures in the office and production area. The heat coming from the machines brings in additional load for the air conditioner (AC) to handle. An idea is to apply the waste heat from the hardening furnaces to heat the water for the washing process. In first order avoiding and saving the waste energy instead of applying the energy for heat recovery has more value.

5.8.1. Insulation of furnace surface

The surface of the hardening and nitiriding furnace at the element line has an outside surface temperature between 60 °C and 100 °C. The furnace is electrically heated. The loose to the surrounding would be decreased and the necessary energy to keep the process temperature inside the furnace at 400 °C would be reduced. The heat loose through the furnace surface is mainly by convection and radiation.

The convection heat loose from the surface is calculated with:

$$\dot{Q} = A * \alpha * (T_S - T_0) \qquad (5)$$

With the heat transfer coefficient α = 23 W/m^{2}K for vertical metal walls with slightly moving airflow, a furnace surface area of A = 40 m^2, an average surface temperature of T_S = 353 K and a surrounding temperature T_0 = 301 K, the heat loose through convection is around 47,840 W.

Heat loose through radiation is defined with following equation:

$$\dot{Q} = \varepsilon * \sigma * A * {T_S}^4 \qquad (6)$$

With the Bolzman constant $\sigma =$ 5.67E-08 W/m^2*K^4 and the emission grade for plane metallic surfaces ε = 0.8 the heat loose through radiation is 28,220 W.

By adding heat loose by radiation and convection, the heat loose through the furnace surface is around 76,060 W.

By applying insulation material, we can decrease the radiation. The gap between the heat radiation with and without insulation is considered as saved heat energy kept in the furnace and still available for the process, but when the wall is going to be insulated from the outside, the wall will be heated up. The core temperature of the furnace is around 470 °C in the element-line furnaces and even 840 °C in the loop-line furnaces.

Measures from the Robert Bosch CVT lead plant in Tilburg showed that the furnace wall could be heated up to almost 400 °C for the loop line furnaces and that this temperature is a big problem for the construction and also from safety point of view during maintenance. Therefore this idea was no longer investigated.

5.8.2. Heat regeneration from exhaust air

The hardening process is supplied with 10 m^3/h of nitride gas. The gas is dangerous and therefore to be burned immediately after the process just few inches above the furnace. During this exothermic reaction, a lot of heat is released into the facility. The Chemical composite of the exhaust gas is nearly the same like the composite of air and only differs in the share of N_2 (~40%).

The calculation for the heat exchanger is based on the exhaust air data for the element-line. The element-line intern processes are listed as followed:

- HTO (High temperature roller)
- NTO (Low temperature roller)
- HBQ (Oil quenching bath)

Table 16 lists the element line furnace intern processes according to their exhaust air volume flow V in m^3/s and temperature t in °C.

Extractor installation	$\dot{V}$ [m^3/h]	$\dot{m}$ [kg/s]	t [°C]	Remark
Exhaust air NTO 1	800	0.1828	150	Hydro carbon / Clean hot air
Exhaust air NTO 2	800	0.1828	150	Clean hot air
Exhaust gas HBQ 1	500	0.10216667	200	Hydro carbon / Combustion-gases
Exhaust gas HBQ 2	80	0.01634667	200	Combustion-gases
Exhaust gas HBQ 3	50	0.01021667	200	Combustion-gases
Exhaust gas HTO 1	500	0.07180556	400	Combustion-gases
Exhaust gas HTO 2	50	0.00718056	400	Combustion-gases
Exhaust gas HTO 3	30	0.00430833	400	Combustion-gases

Table 16: Exhaust air from element-line furnace (Not published document, Robert Bosch GmbH, 2010)

Based on these data it was an idea to use the exhaust gas to preheat a Volume flow of 2.5 m^3/h process water (PW). The exhaust gas is being mixed after the process and dispensed into the air outside of the facility. Table 17 shows the installments and heating equipment inside the washing machines.

Eqp. and Nr.	Power	kW
Heating station 1	10x6kW	60
Heating station 2	5x6kW	30
Heating station 3	4x6kW	24
Heating station 4	4x6kW	24
Heating station 5	6x6kW	36
	Sum	174

Table 17: Installed heating equipment element-line washing machine (Not published document, Robert Bosch GmbH, 2010)

The process is separated into 5 open tubes. The products are dipped in the tubes during the process, creating an open system like a boiling pot without cover.

The heat recuperation should happen in three steps like explained in Figure 9. In the first step, the three volume flows of the 400 degrees exhaust gases are mixed into one volume flow and applied to a heat exchanger. The output temperature of the first heat exchanger should be 200 degrees. On the second level we apply the same process for the temperature gap between the 200 degrees volume flow and the 150 degree volume flow. On the last level, the gas is cooled down to 60 degrees.

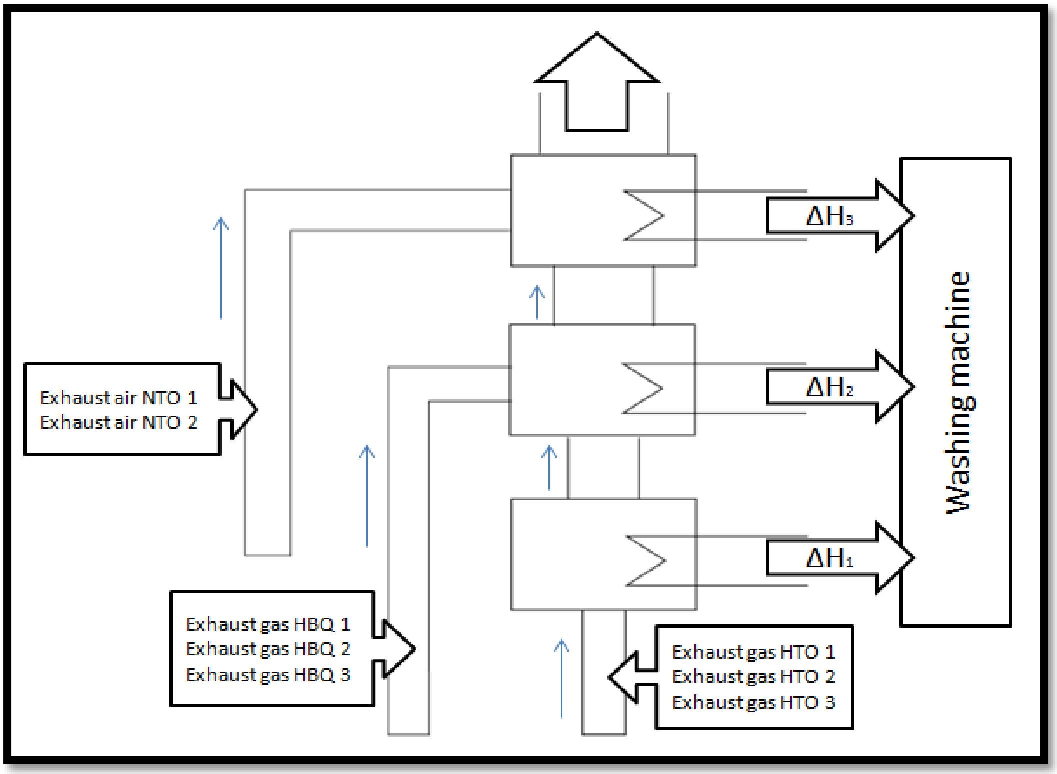

Figure 9: Exhaust gas heat exchanger scheme (own drawing)

The calculation for the heat energy is made with the first law of Thermo Dynamics for isobaric processes.

$$\Delta Q = \Delta H = c_p * \dot{V} * \delta * \Delta T = c_p * \dot{m} * \Delta T \quad (7)$$

The properties of the exhaust air are provided by the online tool www.peacesoft-ware.de based on the data from the University of Florida (Wischnewski, 2013)

Step 1

Decrease in temperature

$\Delta T_1 = T_{HBQ} - T_{HTO} = 200°C - 400°C$.

Mass flow

$\dot{m}_1 = \dot{m}_{HTO1} + \dot{m}_{HTO2} + \dot{m}_{HTO3} = 0.08329\ {kg}/{s}$

Specific isobar heat capacity: $c_{p1} = 1{,}069\ {J}/{Kg * K}$

Density: $\delta_1 = 0.517\ {kg}/{m^3}$

Step 2

Decrease in temperature

$\Delta T_2 = T_{NTO} - T_{HBQ} = 150°C - 200°C.$

Mass flow

$\dot{m}_2 = \dot{m}_1 + \dot{m}_{HBQ1} + \dot{m}_{HBQ2} + \dot{m}_{HBQ3} = 0.21202\ {kg}/{s}$

Specific isobar heat capacity: $c_{p2} = 1{,}026\ {J}/{Kg * K}$

Density: $\delta_2 = 0.7356\ {kg}/{m^3}$

Step 3

Decrease in temperature

$\Delta T_3 = T_{PW} - T_{NTO} = 60°C - 150°C.$

Mass flow

$\dot{m}_3 = \dot{m}_2 + \dot{m}_{NTO1} + \dot{m}_{NTO2} = 0.57762\ {kg}/{s}$

Specific isobar heat capacity: $c_{p3} = 1{,}018\ {J}/{Kg * K}$

Density: $\delta_3 = 0.8226\ {kg}/{m^3}$

With this procedure we can extract a maximum heat energy of 82 kW from the exhaust gas (Table 18). This calculation doesn't consider heat loose through dissipation but insulation of piping and equipment is considered in the investment later. Still the real numbers and benefit will be revealed after implementation and measurement at HcP.

Energy max.	ΔT [K]	kW
ΔH_1 [J/s]	(200°C – 400°C)	-17.8083
ΔH_2 [J/s]	(150°C – 200°C)	-10.8768
ΔH_3 [J/s]	(60°C – 150°C)	-52.9219
		-81.6070

Table 18: Energy from exhaust gas (own calculation)

Like mentioned before, the washing process is an open system therefore not adiabatic. In the rough calculation for energy demand it is assumed ideal heat exchangers with unlimited surface and an adiabatic system. It is therefore still expected that the system has to be supported by electric heating inside the washing process.

The energy saving for this project would be 663 MWh per year. The contribution for the CO_2 project would be 263 t CO_2 per year and furnace. Because the machines in production are running continuously, the calculation is made with the average price of 1,310.14 VND per kWh. By applying the heat to the process 99,212.89 VND per hour could be saved. That equals in a yearly saving of 31,287.70 EUR. The investment for retrofitting the equipment requires three heat exchanger and additional piping and insulation is shown in Table 19.

Product	Quantity	price per unit [€]	Price [€]
eMAX exhaust gas heat exchanger GPH AK 28	2 x	1,475	2,950
eMax exhaust gas heat exchanger GPH AK 50	1x	2,045	2,045
Piping 1 ½''	50 m	8.8 per m	440
Insultation	100	4	400
Installation		5,000	5,000
		Sum	11,275

Table 19: Investment for exhaust gas heat exchanger (own calculation)

With the results from Table 19 the Return of investment is only 0.36 years, matching the Robert Bosch regulation for ROI less than three years.

5.9. Insulation for piping

When thinking about heat loss, the piping for the process water comes into mind. Measurement with the heat camera shows that the drop in temperature from source to consumer is just about ΔT = 1 °C from 32 °C to 31 °C. Each process involving heat treatment has an additional chiller in short range or like for the blanking press is cooled with process cooling water at 32 °C.

5.10. Solar collectors and Photovoltaic

Southern Vietnam is very sunny. The sun radiation to the ground is very strong even during the rain season. The monthly allover data for solar energy relevant cases is displayed in Table 20:

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	5.26	5.79	6.06	5.91	5.24	4.76	4.63	4.34	4.53	4.52	4.68	4.73
Clearness, 0 - 1	0.61	0.61	0.60	0.56	0.50	0.46	0.45	0.42	0.44	0.47	0.53	0.56
Temperature, °C	24.54	25.90	27.13	27.19	26.36	25.52	25.20	25.17	24.90	24.70	24.13	23.86
Wind speed, m/s	7.08	5.96	5.10	3.58	3.00	5.09	5.07	5.63	3.94	4.05	6.22	7.08
Precipitation, mm	16	8	22	61	184	267	262	253	272	255	157	67
Wet days, d	5.5	3.9	4.8	7.8	14.6	16.4	17.5	18.3	19.6	18.5	12.6	9.2

Table 20: Survey on solar energy conditions for Ho Chi Minh City (Tukiainen, 2013)

The Value for the insulation is an indicator for usable sun hours per day. These circumstances make HcP a good location to collect energy from sun radiation. The average duration of a daytime in Ho Chi Minh City is 12.5 hours and leaves some hours where the photovoltaic (PV) cells work with less power (Dateandtime.info, 2013). The peak power (kWp) describes the maximal possible power gained from sun radiation.

A potential solution would be replace the electric heater in the washing process by applying solar collectors to heat the water with sun radiation. In this case it has to be considered that the process is running continuously. Either heat storage has to be applied or a bypass to switch the heating back to electric. The set point for the temperature in the washing machine is very sensitive and the energy coming from sun radiation is not 100% predictable. Expensive regulation and energy storage equipment would be required. Instead of bringing new heat energy into the facility we focus on using the already existing waste heat from the furnaces mentioned above. Therefore solar collectors are just an idea for the thesis and not taken further into consideration.

Other than gathering energy from sun with solar collectors, distributing energy with Photovoltaic is easier. By applying Photovoltaic collectors to the roof top of the facility it would be possible to supply the facility with renewable and CO_2 neutral energy and also establish the facility as green plant. The solar collectors on the roof are a visible statement for energy efficient solutions. Table 21 shows the feasibility calculation for PV modules at HcP. The calculation considers an average value for five hours per day usable sun light and 0.85 as factor for the inclination angle of the modules. The calculation is for a simple PV system and doesn't consider addition investment for battery and other energy storage equipment.

Name	Price	Value	Dimension	Value
Dimension of the roof in HcP is 19178 m2			19,178.00	m2
Sharp ND-240QCJ, 240 Watt 20 Volt Nominal PV module	188.68	EUR/pc	2	m2
Average insolation			5.0375	hours/day
Number of panels needed (use 90% of roof)			10,588.04044	pcs
Investment for pv modules	1,997.7515	TEUR		
Installation fee 180Eur/kWp	457.40	TEUR		
Sum pv modules + installation fee	2,455.1548	TEUR		
other parts (10% of investment price)	245.51548	TEUR		
Sum investment Total	2,700.6703	TEUR		
kWp (240W*pcs)			2,541.129705	kWp
Total kWh (kWp*days/a*in-solation*0.85)			3,971.491911	MWh/a
T CO2			1,572.710797	t CO2
Saving	185.80909	TEUR/a		
ROI			14.5	years

Table 21: Investment cost for PV system at HcP (own calculation)

A photovoltaic system could save up to 1,572 t CO_2 per year. With 14.5 years for the return of investment is much too long for a production facility and does not meet the Robert Bosch criteria of a ROI within less than three years.

5.11. Leakage in compressed air

The FCM department supplies compressed air with a pressure of 7 bar to the production area and equipment. Considering possible loos of pressure because of leakage in pipes and equipment a lot of energy is wasted. The compressors are one of the big energy consumers in the facility and therefore it is very important to make a basic check for air leakage in the compressed air pipes. For this purpose an ultrasonic detection device was purchased to improve the current detection process. Before, leakage detection was just done by paying attention to loud whistling noise from the piping by the operator and repair when needed. The ultra sound device enables the operator to target for detecting noise at a frequency level between 35 kHz and 45 kHz at +6db. This out of human hearing range frequency is produced by turbulent air flow escaping the compressed air piping through micro leakage holes (Figure 10).

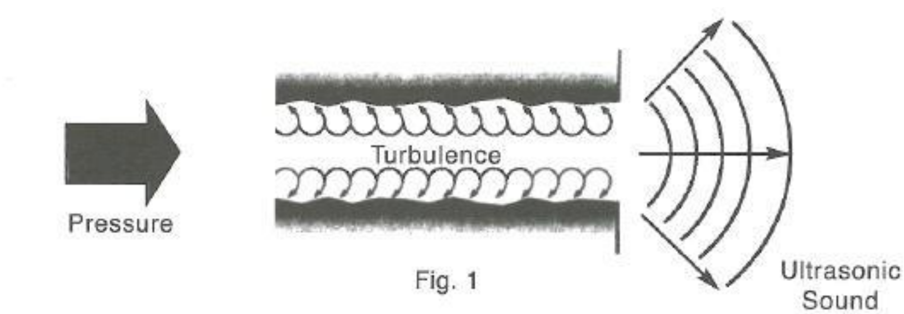

Figure 10: Ultrasonic sound from CDA leakage (Shanghai Beihan Electronics Co.,Ltd, 2013)

Table 22 shows the energy loss per year for a compressed air system running with a pressure of 7 bar.

Diameter hole [mm]	energy loss [kWh]	energy loss per year [kWh/a]	CO_2 saving per yea [t CO_2/a]
1	0.48	4 204	1.66510
3	4.38	38 368	15.19404
5	12.00	105 120	41.62752
10	47.50	416 100	164.7756

Table 22: Energy loose from compressed air leakage (Bremer Energie-Konsens GmbH, 2006)

With the ultrasonic detection device, it was possible to detect two leakage points in the compressed air system. The diameter for the leaks found was 5 mm. By fixing the leaks, the saving is around 210 MWh and approximately 42 tons of CO_2 per year.

5.12. Reduce nitrogen pressure from 8.5 to 8 bar

Another big energy consumer is located in the nitrogen (N_2) pressure system. It is possible to reduce the N_2 pressure supply from currently 9 bar to 8.5 bar. This way 38 880 kWh per year on the compressors are saved.

Table 23 shows the measurement for the energy saving from N_2 compressor system.

Before improvement	After Improvement
One compressor run full load at 9 bar	Pressure of compressor reduce to 8.5 bar
Energy consumption equal: 193 kWh	Energy consumption equal: 188.5 kWh

Table 23: Energy saving from N_2 pressure decrease (own measurement)

The difference in energy consumption leaves a saving of 4.5 kWh. On a yearly base this equals a saving of 39.42 MWh in electricity and 15.6 tons of CO_2.

With the average price for electricity of 1,310.14 VND/kWh, the saving in money is 1,860 EUR per year.

The ROI is zero years as there is no investment require.

A future investment could be to replace the howl nitrogen supply system. Currently the nitrogen is supplied with single speed compressors with a fixed setting of 600 Nm^3/h. The facility is currently only consuming 450 Nm^3/h of the supplied 600 Nm^3/h $N_{2,}$ the rest is dispensed into the surrounding. By applying gas compressors with variable speed drives the energy consumption could be reduced. Because the process owner is the N_2 supplier Airliquid, but the equipment is connected to the Bosch facility electricity grid the investment is on supplier side but the energy saving would be on Bosch side. There would not be much motivation to Airliquit since there is no option for sharing of cost savings and risk of implementation.

6. Conclusion and forecast

The Project for CO_2 reduction at HcP shows how critical the process for energy efficiency is in developing countries like Vietnam is. The energy demand in all sectors is rising. The world is still relying too much on fossil fuels resulting in strong air pollution and increasing share of Greenhouse Gases in the atmosphere. Considering Robert Bosch as international company with international standards it is still hard to push ideas for reducing the CO_2 emission from planning to acting status. The energy price in developing regions like Vietnam is low enough in comparison to developed countries to not be a motivation for energy efficiency. The bad infrastructure with lot of power downs makes the process quality and how to gain a stable energy supply a bigger issue than saving energy. Also, the initial position with no clearly documented energy streams and leak of possibilities to create them show how low the priority for energy efficiency was while planning the facility.

Not only technical and budget issues have to be considered in this case, but how to motivate the employees to contribute to the project with new ideas for saving energy. Especially in developing counties saving energy is not clearly seen as benefit but unnecessary obstacle.

On the other hand, it clearly shows that despites its quiet modern equipments there are a lot of potential to have even more energy efficient facilities. It was possible to determine energy waste by running unnecessary equipment and run the system as and when required only. It is also possible to apply waste heat from one process into process heat for another process like applying the exhaust heat from the furnaces to heating up the water for the washing machines. With bigger budgets and some investment for measurement equipments or, a contracting agreement with an external company, more solutions will be prevailed.

For sure the, project will not stop at this point. The Target for Robert Bosch worldwide to decrease the CO_2 emission by 25% until 2020 is still ongoing and the Ho Chi Minh City plant shows good potential to contribute to this target.

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