AUSTRIAN
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Green Manufacturing

An essential success factor in a globalized world

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GDP	Gross Domestic Product; is the market value of all officially recognized final products and services produced within a country per year or given time period.
U.S. or US	United States (of America)
EU	European Union
WTE	Waste to heat
OECD	Organization for Economic Co-operation and Development
kW	Kilo Watt x hours, kilo equals 10^3, or one thousand
MW	Mega Watt x hours, Mega equals 10^6, or one million
Wh	Watt x hours, a common unit in the SI-system for (electric) energy
kWh	kilo Watt x hours
MWh	Mega Watt x hours
TWh	Terra Watt x hours
UNFCCC	United Nations Framework Convention on Climate Change
EPM	Engineering and Production Management, master degree program at FH JOANNEUM, University of Applied Sciences Graz, Austria
OECD	Organization for Economic Co-operation and Development

1. Introduction

Did you ever think of the power plant running next to your home which provides the power to keep the light bulbs shining, the natural gas that keeps the house warm in the winter or what heated the hot water that's coming out of the sprinkler when taking a shower? By enjoying the comforts of daily life people start forgetting to think about the consequences of using energy. Are gas prices still too low? Or did the engineers a great job in hiding all the negative aspects of energy consumption within their products?

The conscious use of energy can be seen as the beginning of human civilization; when prehistoric human mastered the targeted use of fire for heating and cooking, the human civilization began to rise and evolved to reach the age of steam engines, the automobile, airplanes, nuclear power, and the personal computer. Eventually the human society has come to the point where the consumption of energy is necessary for its functioning, and also the survival of our civilization [cf. 4].

The easy access to energy was enabled by finding coal and crude oil as a great provider. Coal is the most plentiful fuel in the family of fossil fuels and it probably has the longest history. The substance has been used for heating since the cave man era. As a fact, archeologists have found evidence that coal was used it in the second and third centuries by the Romans in England. However, it was the overwhelming need for energy to run new technologies invented during the Industrial Revolution that provided the essential opportunity for coal to fill its role as the dominant worldwide supplier of energy [cf. 2].

The human race today has established itself as a society of production and consumption, performance excellence is required and delivered in all sectors of the market. But driven by the profits and price pressure one important fact was forgotten – the care of our nature and the finite amount of fossil energy sources. Some centuries ago mankind was an expert of green manufacturing; producing waste and using more than needed equaled utopia. By getting the highest possible harvests, as well as the best possible utilization of its products, farmers ensured the survival of their families over the year. And if the farmer was smart he did that in a sustainable way, so that he kept his animals and fields healthy, in order to gain at least the same harvests in the next season. People had no supermarkets where they could buy cooled or frozen foods when needed and put them into their refrigerator at home.

Having all that technology now, two thousand years later, the human race is again learning to be energy- and resource-efficient in producing new goods, calling this Green Manufacturing. Today's manufactured products have to meet a significantly growing amount of requirements providing environmental, societal and economic benefits while protecting environment and human health over their entire life cycle, starting at the extraction of the raw materials and going down to the final disposal or recycling procedure [cf. 3].

All these industrial, economic and social aspects are directly connected to energy consumption. The demand of energy in the entire world has exponentially grown over the last decades and has reached highest levels. Experts claim that further rise cannot be sustained in the near future. At the same time the limited supply of fossil fuels and their effects on the global environment indicate the only long-term solution of the energy challenge - a significant increase in the use of alternative energy sources. Over the last years the most popular and profitable alternative technologies for producing electrical energy were biomass, geothermal energy, hydrogen power, waste-to-heat systems, wind power, sea power, and solar power. Many technologies and products have already left their infancy but yet have not reached enough market share and profits. Without governmental aids and sponsorships it would have been even harder for these new innovations to rise out of the state of an idea on the paper. Beside that it is easy to imagine that there are also people and businesses that would not benefit when others, competitive products gain their market shares, whether environmentally friendly or not. Saving energy and resources has to become an overall goal of the industry and society to maintain the technological and sociological growth of our world.

With the claim “a nation that can't control its energy sources can't control its future” [cf. 1], Mr. Barack Obama, President of the United States of America, pointed out a statement which globally meets the sense of this paper; energy became the global driver number one by delivering the essential power of modern society’s needs. Hence, the future world’s economic leader will have the world’s most energy efficient industry.

So how do we get there? - Considering the increasing economic and environmental relevance of energy and resource consumption, strategies to improve the efficiency and effectiveness of their usage in manufacturing environments still need to be fostered together with the premises of a sustainable development. However, focusing only on research or industrial application is a rather short-term-thinking process. In order to get the best benefit in Green Manufacturing for the future on a long-term perspective, the integration of this issue into the education of today’s and tomorrow’s engineers is the key element [cf. 4].

2. Green Manufacturing and Sustainability

2.1. Definition of Green Manufacturing and Sustainability

2.1.1. What is green?

The word "green" generally describes a specific color spectrum of visible light. It is most commonly related to terms like nature, spring, hope or envy in most societies. Today we also describe things and products that are recyclable, biodegradable or non-polluting as being „green“, meaning they do no or less harm to the nature than conventional substitutes. And this is the same meaning in the context of Green Manufacturing. Hence, the aim of Green Manufacturing is to produce the same goods at the same quality level with less or no damage to the environment, including nature, people, and society. Knowing what green in this context means, one may say that Green Manufacturing was simply another term for „Sustainable Manufacturing“. Is there a difference?

2.1.2. What is sustainable?

There are a number of various definitions of sustainable out in the world. Different descriptions of sustainability are useful for different situations and purposes; however, the following one provides a general view to it: "Sustainability encompasses the simple principle of taking from the earth only what it can provide indefinitely, thus leaving future generations no less than we have access to ourselves [cf. 5].
Hence, a sustainable process is providing least damage to its environment, by paying attention to society and provides economic profit at the same time. Reflecting these definitions, a sustainable manufacturing system or process has to be further associated with the so called "triple bottom line"-thinking, also known as the three pillars of sustainability, shown in figure 1.

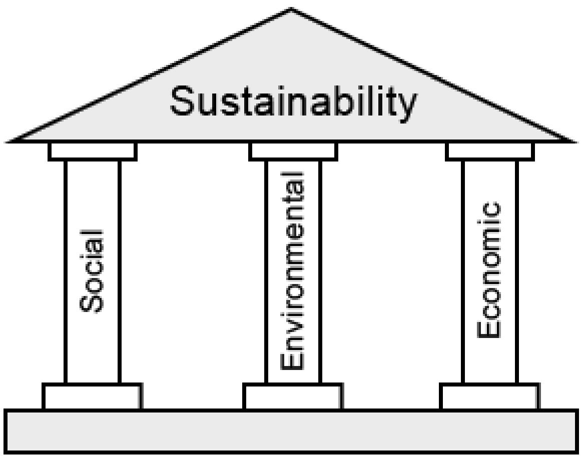


Figure 1: The three pillars of sustainability [cf. 6]

Sustainable manufacturing has to know and control its impacts on society, environment, and economy requirements, in order to minimize negative damage and ensure the best conditions for future generations. The "triple bottom line" often substitutes these terms of social, environmental, economic aspect with people, planet, and profit, respectively, being called "the three Ps".

2.2. Green vs. Sustainable vs. Lean Manufacturing

When talking about "Green" and "Sustainable Manufacturing", also the term "Lean Manufacturing" shows up very often and mixes up meanings and words, as a consequence. For a clear differentiation between the notions, as they are used within this work, figure 2 shows the interceptions of the three critical factors, representing "the three pillars" of sustainability (or "tripe bottom line", or "the three Ps"), that describe each term, it was inspired by [6].

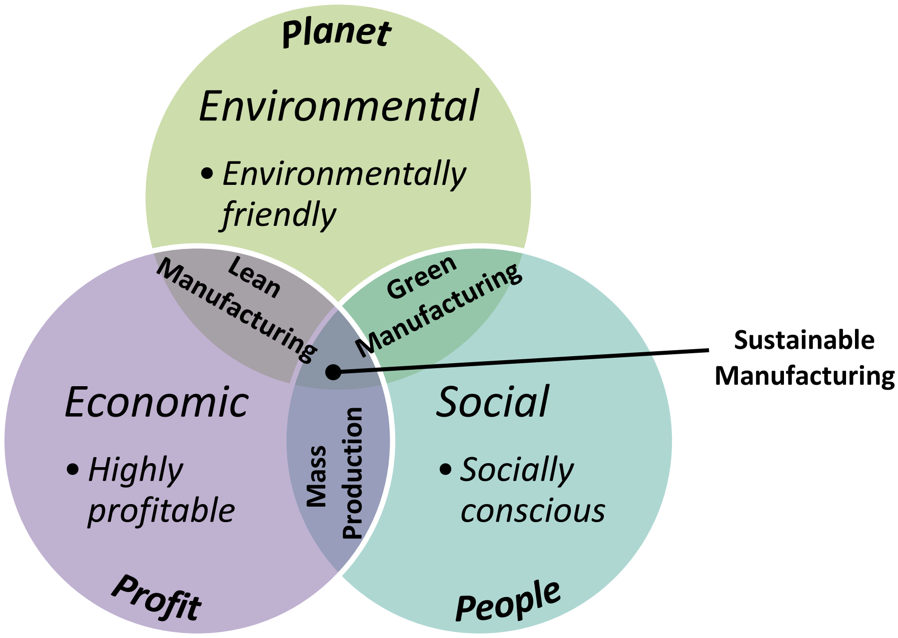


Figure 2: Different approaches to sustainable manufacturing

The Environmental cycle represents the approach of a manufacturing system to be environmentally friendly and minimize the negative impact on the nature by minimizing the use of resources and maximize the energy efficiencies at the same time. But on the other side a company cannot last if it was not breaking even and make profit out of its businesses, this is what the Economic cycle stands for. In contrast, the Social circle, probably the most difficult to define, addresses to the social impacts of Manufacturing issues like job relations, employee retention, salaries and wages, fair-trade regulations, as well as child labor and many other aspects.
Within this coexistence the main focus of Green Manufacturing is represented by the interception of environmental, in first instance, and social aspects whereas the relation to the economic effect is rather small, yet not unimportant.

Lean Manufacturing, on the other hand, occurs in the interception area of the environmental and economic aspects. It usually refers to practices for identifying and evaluating the use of resources only for adding value to the product in a consumer perspective. Moreover it defines certain uses as wasteful and tries to eliminate them. Hence, lean manufacturing concepts include many useful aspects for making manufacturing processes green but they may not consider the same elements [cf. 7]. The focus is therefore shifted from the environmental to the customer or economic values. According to figure 2, Sustainable Manufacturing is the state of equilibrium, where all three pillars share the same level of importance. Generally, this can be seen as the ideal type of manufacturing. Typical companies achieve two out of the three factors. Achieving success in all three factors simultaneously, though, is very difficult. The extent to which companies are achieving the triple bottom line is often reflected in their corporate sustainability reports and published on their Web sites [cf. 7].

3. Current situation

3.1. Waste Generation

The manufacturing industries generate waste mainly in form of solid-waste, waste water, and exhaust emissions which cause significant environmental impacts. Solid-waste gets the highest attention because its impact is seen for the longest time, for example on landfills, dumpsides or uncontrolled waste in the oceans. But not only manufacturing, moreover the consumption of the manufactured products and the continuous increase of the demand for products drives the waste production higher. According to [17], solid-waste-generation rates are a function of both population and economic boom, but data are lacking or questionable for many countries. This results in high uncertainties for greenhouse gas emissions estimates, especially from developing countries. Figure 3 below illustrates 1971–2002 trends for regional solid-waste generation using UNFCCC (United Nations Framework Convention on Climate Change) reported values for each country.

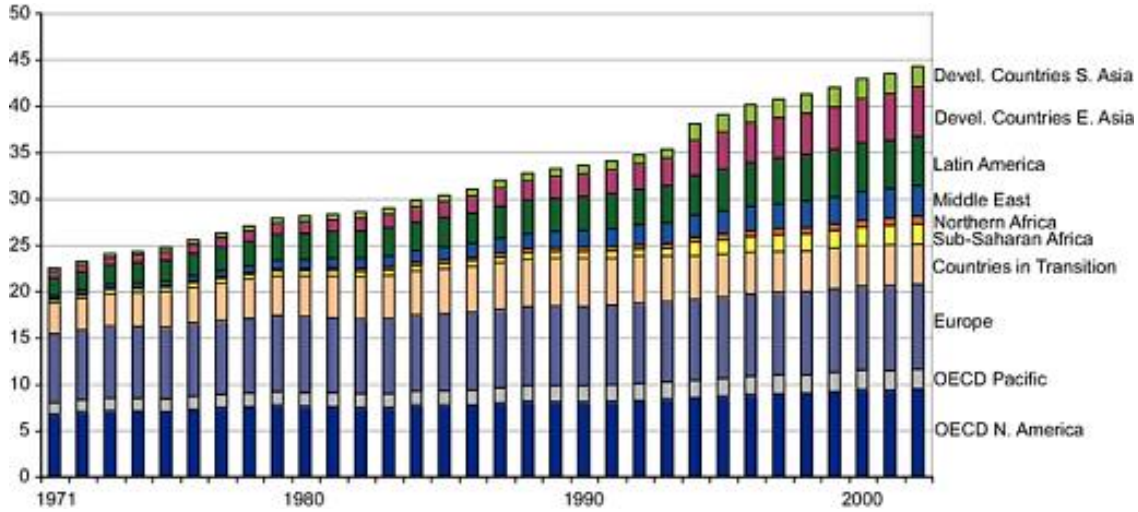


Figure 3: Solid-waste generation [cf. 17]

The fact of the significant environmental problems as a consequence of increasing production and consumption behavior cannot be ignored. Hence, reducing the waste generation from the manufacturing industry to reduce its environmental impact is one of the major objectives of Green Manufacturing practices.

The prevention of overall waste is also a key to reduce environmental impacts during all stages of the material life-cycle. But in contrast to a cut-down of waste generation within the production, which mainly focusses of technological and procedural change and improvement, waste prevention has to take place in people's head and result in a change of the consumption behavior.

Waste recycling, on the other hand, is closely linked to material consumption. Like written in [16], on average 16 tons of materials are used annually per person in the European Union, and a lot of it gets directly transferred into waste. About 33% of this amount comes from construction and demolition activities, 25% from mining and quarrying, 13% from manufacturing and 8% from households. Mainly the increases in overall use of resources and waste generation in the European Union are caused by the economic growth and the rising demand for products of all kind. The EU is, as well as the rest of the world, using more and more raw materials. However, direct links between the use of resources and waste generation are fairly difficult to quantify with current indicators due to differences in accounting and a lack of long-term evaluated data.

3.2. Energy Consumption

The worldwide energy consumption is at its highest level and is at the same time increasing faster than ever. Experts say that by the year of 2030 the energy demand per head will double. The reason will be the growth of the developing countries, and their compensation of living standard. About 85% of all energy is generated by fossil fuels at the moment, but the total consumption is still expected to increase in the next decades. Without a doubt crude oil and its derivate will remain as a main source of energy in this century. Because fossil fuels are limited and the upcoming future demand for energy, organizations all over the planet come up with subsidies and developing projects for alternative energy sources [cf. 21].

As a fact both the environmental impact of manufacturing and the steadily increasing use of natural resources need enormous amounts of energy. In the U.S. for example the manufacturing industry consumes about 23% of total energy in the United States. The energy consumption of manufacturing is second to transportation but larger than residential and commercial sectors [cf. 7].
Due to the complex supply chains a clear differentiation between transportation and manufacturing, where transportation is a major issue for manufacturing in general, cannot be made. But on the other hand some sectors show comparable percentages of energy consumption in the European Union, as seen in figures 4 and 5.

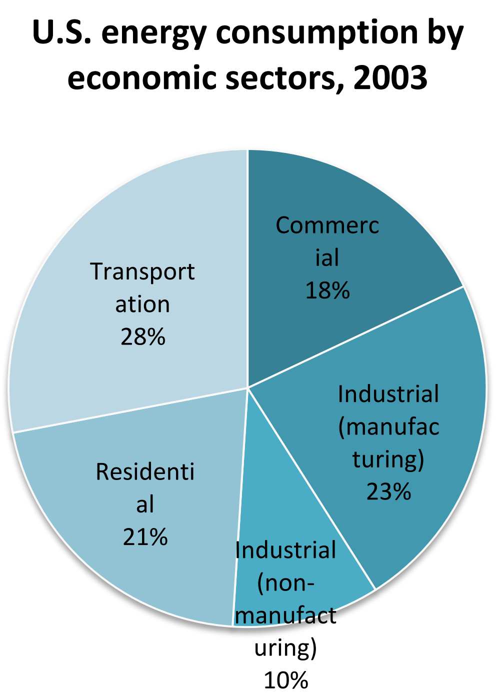


Figure 5: U.S. energy consumption [cf. 7]

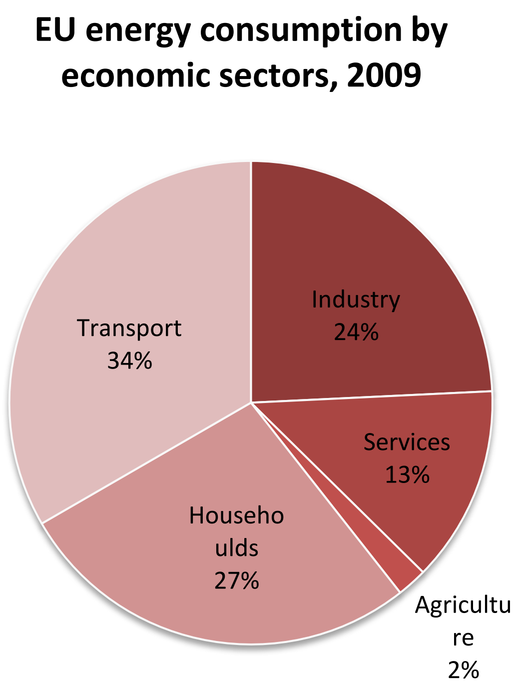


Figure 4: EU energy consumption [cf. 20]

The tremendous importance of transportation as an energy consumer clearly points out in both charts. But counting together the segments with industrial relevance manufacturing as a system seems to have the biggest need for energy.

In order to make the distribution from the pie charts more meaningful figure 6 gives an overview of the energy consumption and disposition of its sources of four important world economies, containing the U.S and the EU.

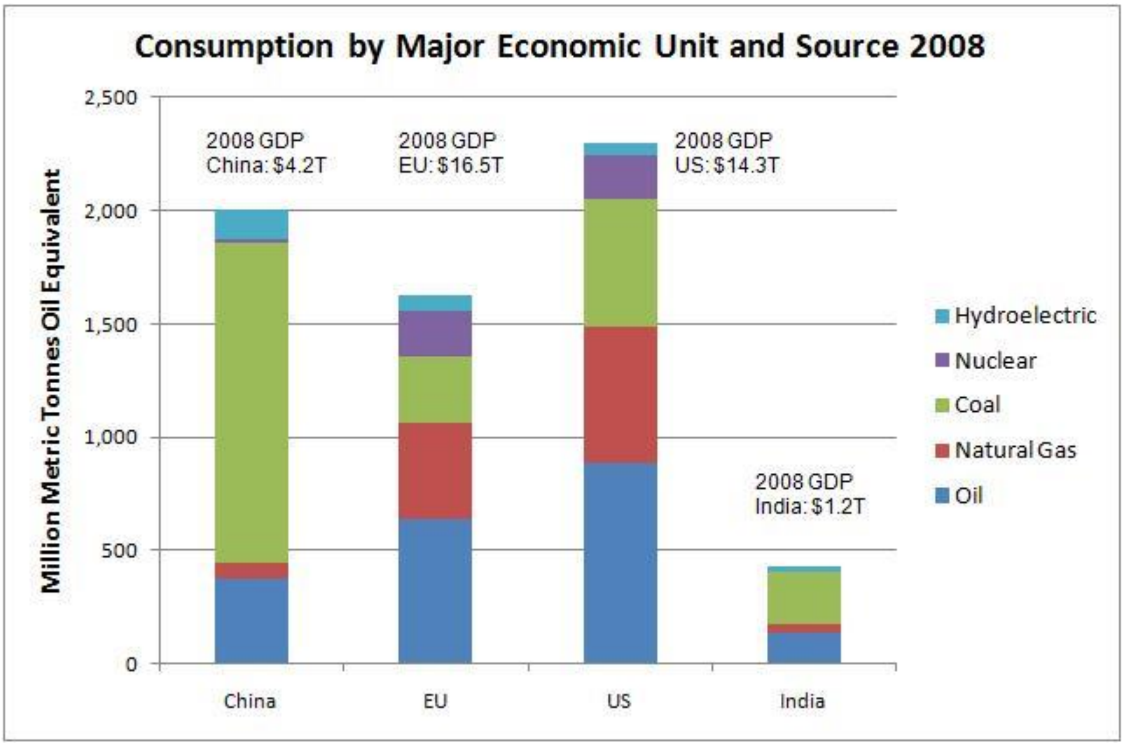


Figure 6: Consumption by major economic unit and source 2008 [cf. 19]

Based on the 2008 GDP of the different countries the US shows the overall highest consumption of energy. The scarcity of coal and fossil fuels in the EU made the Union to become the world leader in so called renewable energy technologies and resulted in a constant decrease of coal use. The lack of technological development as well as the good availability of coal in Northern America and China created a big gap in the overall energy consumption in comparison to Europe. As energy prices now have also risen in the U.S. and Asia these countries are now trying to close up with the European standards in order to reduce their energy costs and increase its efficiencies.

The comparison of economic unit energy consumption 2008 by source shows that European trades increased nuclear for less coal use. Figure 6 covers the usage in the EU, and excludes Russia [cf. 19].

3.3. The aim of Sustainable Manufacturing

Understanding now with the previous chapters what Green Manufacturing is about and what impacts Manufacturing has on society and environment it is now important to define what the aim of sustainability and therefore Green Manufacturing is. Figure 7, inspired by [cf. 7], figure 1.2, visualizes the true aim of sustainability. The red line indicates the expected consumption rate in the future, and the fictive border of sustainability represents a fictive, mathematical line of a consumption rate where the human race consumes only what they need or already have and not using new fossil resources or mined materials.

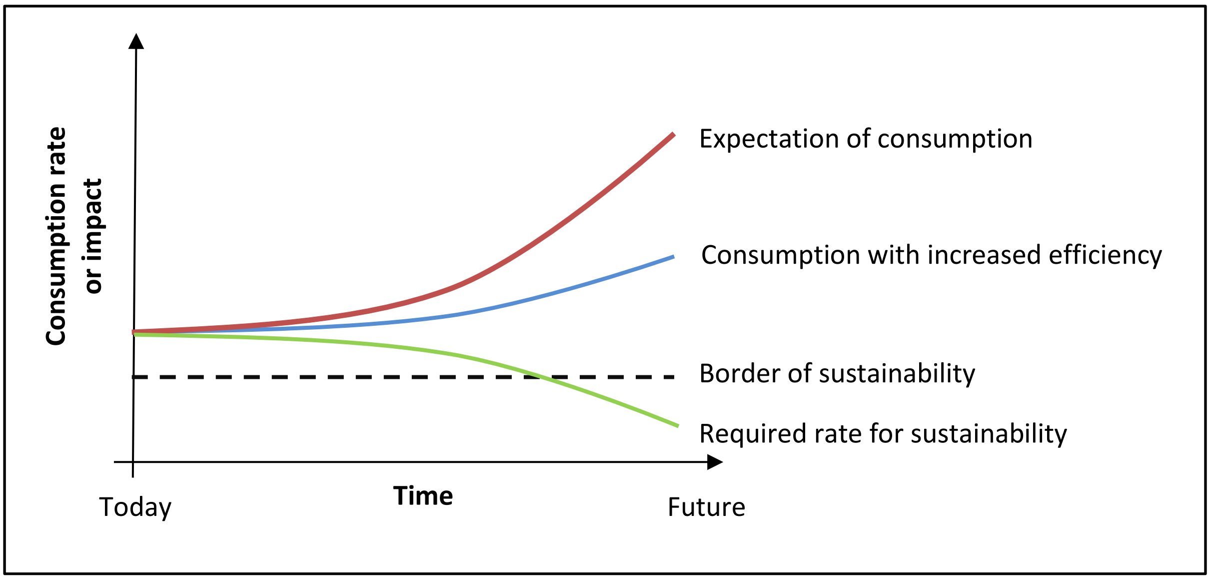


Figure 7: The aim of sustainability

Besides the description in 2.1.2., in forestry the word "sustainability" is often described as simple as this: "you don't fall more trees than you plant" [cf. 5]. Converting to manufacturing this would mean to consume and produce less than what we did yesterday or to reduce the global energy consumption so we don't need to build another power plant. We find out that some aspects of sustainability rival with economic viewpoints of reaching higher profit. But we all know that mankind is far away from a sustainable situation and that the rate of consumption and energy demand of today's society are steadily rising.

Hence, we know that Green Manufacturing on its own is not the yellow of the egg, it is more finding itself within the blue line in figure 7, representing the increase of efficiency or the technological development aspect of it. On the other hand sustainability requires an attitude towards its goal, trying to ensure future generations the same possibilities of development with the same resources and environmental conditions by reducing its own needs and impacts to the limited natural resources and environment. And this requires an everyday-thinking, meaning that sustainability does not start tomorrow or started yesterday, but happens now, every day.

3.4. Motivators and barriers of Green Manufacturing

3.4.1. Motivators

Why Green? – This is the main argument for economic leaders to be answered. More and more CEOs and entrepreneurs eventually discovered the concept of the overall rethinking of manufacturing for themselves and started implementing them. Yet there is still a lot to do, the game has just started. The following headings represent the key indicators for sustainable manufacturing approaches and follow the model of [cf. 8].

3.4.1.1. Continuous improvement

Improve constantly and forever – one of Dr. W. Edward Deming's 14 points in what he called "the system of profound knowledge". He claims that improvements are necessary in both design and operations. Improved design of goods and services comes from understanding customer needs and continual market surveys and other sources of feedback, and from understanding the manufacturing and service delivery process. By reducing the causes and impacts of variation, and engaging employees to being innovative to make their jobs more efficiently and effectively additional improvements in operations can be achieved. When quality improves, productivity improves and costs decrease, as the Deming chain reaction suggests [cf. 12].
Traditionally continuous improvement was not a common business practice, but today it is distinguished as a necessity of global, competitive business environment. Therefore Practices and strategies of Green Manufacturing are likely integrated to the main idea of a quality system's approach to continuous improvement.

3.4.1.2. Competition

Another driver is the competitive advantages a company that is able to obtain in the market through implementation of sustainable manufacturing strategies. The main indicator therefore is the consumer himself. Due to the public's awareness and concerns, implementing green manufacturing principles can enhance a company's image in the society and also can generate higher revenues, and increase market share, as a consequence. As society is becoming more aware of the environmental issues of manufacturing there may not be a company that is isolated from the shifting market or the consumers demand for "greener' products.
According to [7] recent analysis of over 4,000 manufacturing facilities in seven OECD countries found that there is a positive correlation between environmental performance and commercial success. With such economic incentives, Green Manufacturing has been emerging as the one competitive requirement to achieve differentiation in the market.

3.4.1.3. Pressure from government

This can be visualized by terms like regulations, as well as penalties, tax benefits or sponsorships are main drivers. One of the highest impacts is caused by the generally increasing energy costs which lead to an overall rethinking and new approaches. The European Union, for example, has been very proactive here; In December 2008, the EU Parliament decided on a regulation to reduce the carbon dioxide emissions of new passenger cars; in April 2009, the regulation was formally adopted. The purpose is to reduce CO_2 - emissions to an average of 95 grams per kilometer of the entire fleet by the year 2020. The European guidelines are long-term helping to maintain and increase competitiveness of the European automotive industry for the future demand of fuel-efficient vehicles, both in Europe and worldwide [cf. 9].
In 2012 the U.S. backed up with a similar regulation to passenger cars, light-duty trucks, and medium-duty passenger vehicles. The final standards are projected to result in an average industry fleet-wide level of 163 grams per mile of carbon dioxide by the year 2025 [cf.10].
As an Asian pendant to Western countries, China is also working hard on new regulations for both domestic industries. According to [11], by adopting its 12th Five-Year Plan in March 2011, covering 2011-2015, China signaled that addressing climate change would be a top priority. While the country has so far resisted adopting an absolute goal on greenhouse gas emissions, the plan set ambitious targets for reducing both energy intensity and CO_2 emissions by 2015 and for increasing the share of non-fossil fuel energy.

3.4.1.4. Pressure from society/consumers/customers

Within the last decades, there has fortunately been a societal shift towards sustainability in western civilizations, and lately all over the planet, where people developed a thinking and caring for future generations. Not everyone agrees on what the best goals for a better future are, or how to obtain them, but current evidences as, for example, shown by the climate change claim that a new approach to energy and resource consumption overall and especially in manufacturing is necessary – and customer is King. For not understanding the need for change many companies have been criticized - for social issues associated with their products, its supply chains, not only including environmental damages, but also a lack of health care and safety standards, and impacts of poverty have been pressures for many global players to change their perspectives and practices [cf. 7].
The contribution, support of local goods and charities are not all there is to manufacturer's responsibility to society, to the people who are its employees and customers and the communities in which the companies do their business. People are realizing their power to influence the level of sustainability within the supply chain and become a main driver of green manufacturing in various industries.

3.4.1.5. Scarcity of resources and its risks

Infinite economic growth cannot be performed in a finite world, but humans have been quite smart at finding solutions for the problem of scarcity in natural resources. Many manufacturing companies are faced with problems concerning the acquisition of raw materials. Next to fossil fuels, as a classic, some of the recent issues are related to metals, uranium, noble earths, and also fresh water. Faced with the scarcity and the coexisting price pressure, the gap for new technologies and industries came up, dealing with the recycling of materials and alternative, more environmentally friendly mining technologies.
An interesting term of urban mining, for example, describes the fact that an urban area like a big city can be viewed as a big mine of various resource materials. It mainly focusses on secondary raw materials or parts in electronic products that contain gold or other metals. Generally the technological progress in the consistently growing recycling industries is the most logical consequence of today's waste producing society. Most important results can be achieved in recycling of glass, paper and plastics [cf. 13]. The future society will have to develop further approaches of overall product consumption and waste production, in order to reach a sufficient level of sustainability.

3.4.2. Barriers

Green Manufacturing is driven by a number of positive factors, though the manufacturing industry is still faced with some barriers hindering "green" applications to be implemented into practice. The concepts for the following models and headings were inspired by [7], [14], and [15], whereas some literatures moreover categorize the barriers economic, technological, and managerial issues.

3.4.2.1. Risk of business

As in every business there is a basic risk to the implementation and success of Green Manufacturing practices. The recent change in the overall thinking, as well as the recent trend of "greener" products does not promise to maintain consistent success over a long period of time. Unforeseeable cultural or social events, like wars for example, can tremendously change the demands and needs of a country's civilization. But facing the current economic trend, a decrease of interest in sustainable manufacturing is not expected to happen.

3.4.2.2. Technological development pressure

Staying on the top of the business in most cases means to be the technological leader, or to be at least at the state of the art. Since green business is here to stay, keeping ahead of the competitors in green technologies and strategies can be very challenging, both from a managerial and financial point of view. The natural selection takes place like in every free market situation and further shows that a specialization into certain technologies or products and systems is the current trend for businesses over the globe. Moreover, competition is one of the main drivers for prices; the lower the prices are, the more people will buy the product. There will be businesses failing off or miss to jump the train for progress to maintain competitive. Hence, every company has to keep an eye on the three pillars of sustainable manufacturing as described in part 2.1.2.

3.4.2.3. Complexity

Staying with the triple-bottom-line, the main focus of many companies is often oriented to profit and causes a lack of attention to the other two aspects of a sustainable manufacturing system. But for true green businesses it's important not to focus on being profitable, they also have to take responsibility of the impact their business has on people and the planet. Profit should be the consequence of the other two issues.
As a result of profit-based decision making, companies lack in scientifically-based tools for achieving effective implementation of Green Manufacturing strategies. There is an obvious need for appropriate analytical tools to help benchmarking the impacts of their specific manufacturing processes and systems in order to support the decision-making process. While manufacturing is a very complicated system generic decision tools are difficult to use for the whole manufacturing industry as each company has its own specifications and requirements to it [cf. 7].

3.4.2.4. Lack of top management commitment

Leadership is one of the most important drivers for a green approach to manufacturing, but top management positions, like others, contain a certain amount of subjectivity in decision making. However, most business owners are traditional thinkers and therefore conservative, but a top manager rarely has both, conservative and environmentally-focused approach to manufacturing at the same time. Fulfilling both requirements at once is no guarantor for success but definitely is a great fundament.

3.4.2.5. High investment costs

It can be seen that the highest barrier to Green Manufacturing initiatives perceived by the industry is too high investment costs and a longer amortization time compared to conventional solutions. It is a most common barrier in implementing new concepts. Cost is and was always the most important issue for businesses leaders when considering the implementation of an improvement in their existing processes. In most cases the longer amortization is the knock-out factor.
The purpose for early exemplifications of implementing green manufacturing was the reduction of emissions and waste management. But as Green Manufacturing thinking is developing from so-called “end-of-the-pipe” emission control to frontline pollution prevention and the parallel increase of waste disposal costs and environmental

emissions requirements let this barrier gradually fade into the background for the manufacturing industry.

3.4.2.6. Lack of vision and knowledge

As figured out before, top management and CEOs must give their full commitment in terms of supporting infrastructure and providing resources that are needed for successful implementation of Green Manufacturing practices. The vision and guiding of a green statement has to be carried throughout the entire company, down to the line workers to achieve highest participation and motivation in order to enable long term success.

For maintaining an innovative and critical society, as a basis for Green Manufacturing within a company, employees as well as managers need to have a similar level of knowledge that is necessary to be truly sustainable. With the knowledge of what a company can improve and why this is important for everyone the basement for a green attitude is set.

4. Alternative energy sources

4.1. Biomass

The term biomass includes all organic material as well as organic waste derived from plants, humans or animals. Basically all living substances store solar energy in the form of chemical energy in its cells. Plants, for example, use solar energy to convert atmospheric carbon dioxide and water into the complex molecules of glucose and fructose. At the beginning of the twenty-first century the use of biomass as a resource for generating energy widely differed among different countries. While in most OECD countries the use of biomass for energy production is less than 3%, on the other hand Cuba produces more than 35% of its electricity from sugar cane; and Brazil uses sugar cane and corn for the production of biofuels and electricity to satisfy more than 25% of its total energy needs [cf. 4].

4.1.1. Methods of biomass Utilization

Due to biomass as a subject is very diverse and widespread, the following methods of how biomass is used for producing electricity and biofuels have been taken from [4], chapter 10.1.2.

4.1.1.1. Direct combustion

This method is used for cooking, space heating, e.g. in fire places or boilers, process heat in industrial plants, and steam generation for the production of electricity. Because biomass usually has a high percentage of humidity, temperatures achieved in biomass-only burners are significantly lower than conventional fossil fuel burners. Considering the energy spent in the transportation, the efficiency of power plants that only use biomass is in the range 15–20%, roughly half of the conventional fossil fuel plants.

4.1.1.2. Co-firing

The term describes the combustion of a small percentage (2–10%) of locally produced biomass and coal. Because coal is the principal fuel in a co-firing burner, steam may be produced at high temperatures in the boiler and the efficiency of the power plant does not suffer.

4.1.1.3. Gasification in air

The gasification product is a mixture of hydrocarbons, which are used for process heat, e.g. crop drying; running stationary engines in the immediate vicinity of the gasifier; space and water heating; and small electric power producing plants.

4.1.1.4. Pyrolysis

Pyrolysis produces combustible gaseous and liquid products, such as methane, ethane and methanol, which may be used in gas turbines, space and water heating as well as in transportation fuels.

4.1.1.5. Hydrolysis and fermentation

Liquid fuels, such as methanol and ethanol are produced. They are commonly used in mobile and stationary engines, gas turbines, generation of steam, and as gasoline or diesel additives.

4.1.1.6. Anaerobic decomposition

Anaerobic decomposition naturally occurs in municipal and agricultural waste sites, and in animal waste plants. The decomposition produces a gas that is rich in methane, carbon monoxide and carbon dioxide. This artificial combustible gas has a low heating value, but may, nevertheless, be mixed with other fuels to be used in gas turbines or steam power plants.

4.1.2 Negative aspects and future of biomass

It is obvious that the use of food crops for energy production, whether this is electricity or biofuels, is disadvantageous to the environment, and is at the same time less economically efficient than conventional technologies. The direct competition of energy and food production as well as food availability in developing countries maintains the main arguments for biomass opponents. Another issue is the production of greenhouse gases that get into the atmosphere because of leakages causing further damage to the ozone layer. Hence, it is believed that the future production of biomass from energy crops will be regulated, while the biomass from waste products will increase significantly. Technological advances that will lead to increased production of aquatic biomass will materialize when faster and less energy consuming processes are invented, or when more suitable organisms for fuel production are developed [cf. 4].

4.2. Geothermal energy

Geothermal energy is core energy of planet Earth, mainly indicated by nuclear reactions. The magma brings some of this energy to the crust of the planet, where some heat is taken by the water of deep reservoirs to the surface.
Worldwide 11.4 GW of geothermal power in the top 24 countries in 2012 have been delivered. An additional 28 GW of direct geothermal heating capacity is installed for district heating, space heating, spas, industrial processes, desalination and agricultural applications in 2010. Generally geothermal power is said to be cost effective, reliable, and environmentally friendly, but has historically been limited to areas closely to tectonic plate boundaries or areas with volcanic activity. Today's

technologies have drastically widened the range, especially for applications such as home heating. Geothermal wells release greenhouse gases trapped deep within the earth, but these emissions are much lower per energy unit than those of fossil fuels. Hence, geothermal power has potential to reduce greenhouse gases if widely deployed in place of fossil fuels [cf. 22].

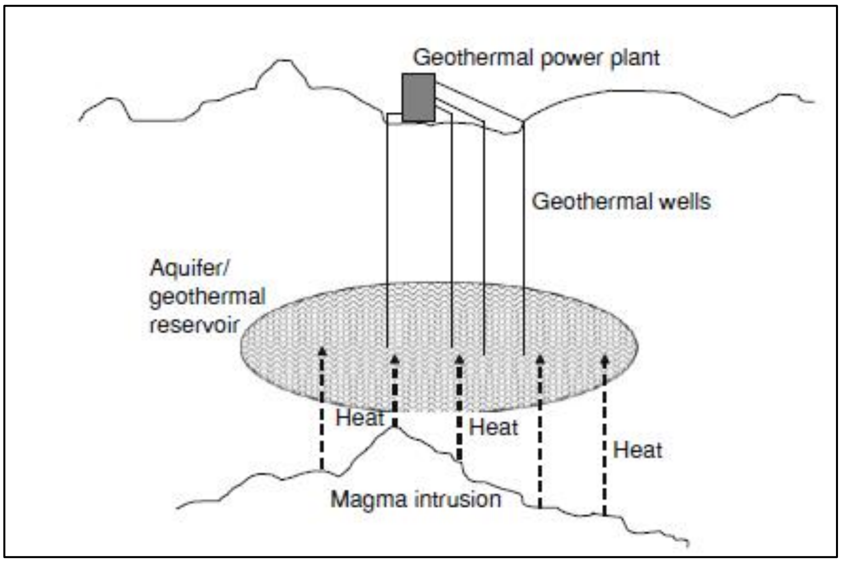


Figure 8: Schematic geothermal power plant [cf. 22]

Looking at table 1, the current leader in using geothermal energy is the U.S. followed by the Philippines and Indonesia, where the Philippines have almost 30% of their entire energy demand covered with it.

Iceland, on seventh position, is the world leader in direct applications. Some 92.5% of its homes are heated with geothermal energy, saving over $100 million of oil imports every year. Reykjavík, Iceland's capital city has the world's biggest district heating system. Once known as the most polluted city in the world, it is now one of the cleanest [cf. 22].

Country	Capacity (MW) 2007	Capacity (MW) 2010	Percent. of nat. electr. energy	Percent. of global geoth. energy
United States	2687	3086	0.3	29
Philippines	1969.7	1904	27	18
Indonesia	992	1197	3.7	11
Mexico	953	958	3	9
Italy	810.5	843	1.5	8
New Zealand	471.6	628	10	6
Iceland	421.2	575	30	5
Japan	535.2	536	0.1	5

Table 1: Top eight countries using geothermal energy [cf. 22]

Geothermal energy is primarily utilized by extracting dry steam or high-temperature liquid water from an aquifer and by using the steam or the vapor of another liquid for the production of power with a steam turbine. The geothermal electric power plants are generally simpler than fossil or nuclear power plants, they simply have fewer components. Because the geothermal fluid carries along other substances, including solids and non-condensable gases, the design of the equipment of a geothermal power plant has to meet several challenges, such as the avoidance of scale in the well and flashing chambers, and the removal of non-condensable gases from the condenser [cf. 4].

The near future of geothermal energy depends on its demand, supply and its competitiveness among other energy sources. The basic trend to “greener” and cleaner energy is given and moreover governmental support is also provided for establishing new technologies and geothermal projects. The fact that the entire amount of geothermal energy is fairly bigger than that of all fossil sources together makes it essential for future use. Further technological research and development effort will make the plants more efficient and the energy more affordable to the customers [cf. 23].

4.3. Hydrogen power

Water as an energy source might be one of the oldest forms of energy used by human civilizations for driving their machineries thousands of years ago. And even today we use the same power of liquid water and its potential and kinetic energy transformed into electrical or mechanical power. But the availability of Hydropower strongly depends on the region and its consistency of water supply. In areas of mountains and big rivers, turbine driven power plants are most frequently being used. These systems are already widely established.
A different type of hydropower plants are tidal power plants who are using the energy that is in the water of the seas or oceans. The 240 MW plant in La Rance, France, for example, has shown that there are reliable systems operating today. Generally tidal power plants in prime locations in England, Norway, USA, Canada and other parts of the world have the capability to produce most of the electricity demand in several coastal countries or areas. In addition there are also several wave power systems that have been invented in the last half of the twentieth century, and are now in the testing or pilot-plant phases. If successful, the widespread use of wave power has the potential to produce more than 50% of the electric demand in Island and other coastal countries in the world. There is also the idea of combining wave power systems and offshore wind power plants for higher overall efficiencies and outputs. Also interesting for coastal communities is the Ocean Thermal Energy Conversion Cycle (OTEC). These systems use the temperature difference of relatively warm surface water and relatively cold water from deeper regions to drive heat pump systems, but they need significantly more research and development effort to reliably and economically meet their promise. All these electric power sources have certain scientific potential, especially the ocean based system are forward looking to provide affordable, and environmentally friendly energy [cf. 4].

Hydroelectric power is essentially is said to be a "clean" energy source. However, the construction of the power plants, especially dams of very large scale cause environmental problems, such as the destruction of the initial environment, flooding of a large area behind the dam, and damages to the fish population and other animals in the food chain. Experts say that almost all of the future expansion of hydroelectric power will occur in developing countries. In other countries that have already utilized most of their large-scale resources, the construction of small (< 30 MW) or micro (< 1 MW) hydro plants as a regional solution for serving small communities or single households, is a feasible way to utilize a higher percentage of the water resources for generating electric power. [cf. 4].

4.4. Solar energy

Solar energy was the main and original energy source for our planet ever since. The overall continuously received solar power, which is called incident solar radiation measures more than 100 million times the total energy used by earthlings in a year. Theoretically, the sunlight might seem as an ideal energy source, as it is free, virtually limitless, and almost uniformly distributed and available to most areas this planet. Today only a very small percentage of the incident solar radiation is used by civilization. Basically solar energy refers primarily to the use of solar radiation for practical ends [cf. 4].
Solar technologies are broadly characterized as either passive or active depending on the way they capture and convert the energy from the sun. Active solar techniques use photovoltaic panels, pumps, and other components to convert sunlight into usable energy output. Passive techniques deal with materials that have favorable thermal properties, for designing places, buildings and entire processes that are only driven by solar power. Active technologies, on the other hand, increase the supply of energy and are considered to supply side technologies [cf. 24].

The technical use of solar energy has strongly increased its popularity within the last decades and became one of the main promising for covering the world's energy demand. The following lists shows the currently most important industrially used solar technologies which are going to lead into the solar energy future:

- Solar panels (photo thermal)
- Solar cells (photovoltaic)
- Thermal power plants; generating electric power by producing steam with solar energy
- Solar updraft tower technology; generating hot air, which is lead through a chimney tower and transformed into electric power

Electricity Generation from Solar		
Year	**Energy (TWh)**	**% of Total**
2005	3.7	0.02%
2006	5.0	0.03%
2007	6.7	0.03%
2008	11.2	0.06%
2009	19.1	0.09%
2010	30.4	0.14%
2011	58.7	0.27%
2012	93.0	0.41%

Table 2: Electricity generation from solar energy in the world [cf. 25]

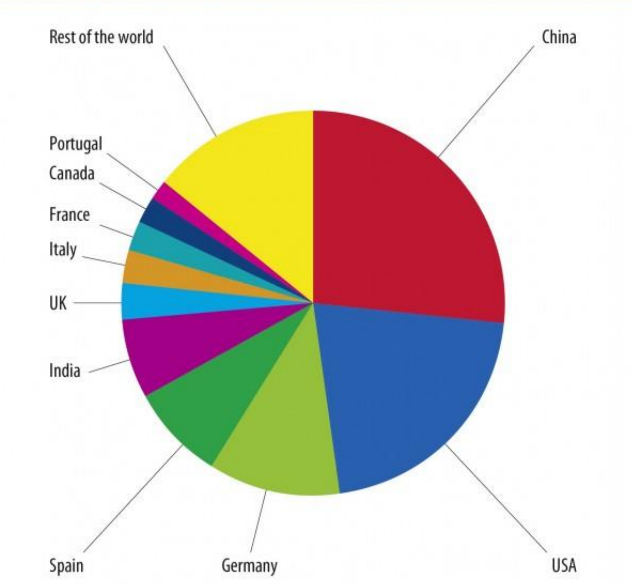
The trend that can be seen in Table 2 shows the significant increase in importance of solar energy in a global percentage. The International Energy Agency (IEA) claimed in 2011 that solar energy technologies such as photovoltaic, solar water heating, and solar power stations, built with mirrors, could provide up to 30% of the world's energy demand by the year 2060. Hence, solar energy could be the key solution for a greenhouse gas-free energy supply in global economy. The main positive aspect to all solar technologies are the incredible variety and flexibility of applications, from small to big scale that ensures its future applications [cf. 24, and 25].

4.5. Wind energy

Wind is, next to solar and water power, also a form of energy which was discovered and used very early in human history for sailboats, windmills, or flying objects. In its latest technological development level wind has been increasingly used for generating electric power. As a fact, the production of electricity from wind power worldwide has increased by a factor of eight. Driven by solar energy from the sun, wind is, same like hydro and solar power, free and available in almost every region on this planet, although the energy density is not very high. Currently, the most economical way of generating wind energy is by using wind turbines of big size, measuring up to 140m with a rotor diameter of about 100m, standing next to each other and being called a wind park. In contrast to conventional gas-fired, or steam powered turbines, wind turbines have are designed to operate within a wide range of condition, with different air velocities, climates, and other local requirements. Hence, wind turbines possess significantly lower efficiencies than other types of turbines; typically in the range of 20 to a current maximum of 45% [cf. 4].

Wind is also, because it's caused by solar radiation, probably one of the most environmentally friendliest energy sources. Experts claim that about two percent of the solar energy is transferred into wind. Theoretically, this is the capacity to satisfy today's total energy demand of the human civilization, but its main disadvantage is its unsteadiness. Hence, practical wind power applications are limited in its widespread use, unless suitable energy storage systems are developed which could store energy that is produced during windy periods - the wind simply cannot be controlled by human.

TOP 10 CUMULATIVE CAPACITY DEC 2012



Country	MW	% SHARE
PR China**	75,564	26.8
USA	60,007	21.2
Germany	31,332	11.1
Spain	22,796	8.1
India	18,421	6.5
UK	8,445	3.0
Italy	8,144	2.9
France**	7,196	2.5
Canada	6,200	2.2
Portugal	4,525	1.6
Rest of the world	39,853	14.1
Total TOP 10	**242,630**	**85.9**
World Total	**282,482**	**100.0**

*** Provisional Figure*

Figure 9: Wind power capacities, 2012 [cf. 26]

According to figure 13, retrieved from [26], the U.S. generates 60 GW of its electric power with 45,000 wind turbines in the grid. A multiplication factor of 1/3 (or 33%) is used due to wind fluctuations. Hence, the averaged output is equal to 20 GW of constant supply. Since the typical nuclear reactor in the U.S. delivers about one GW, the total amount of wind power generated is equivalent to 20 nuclear reactors, which is a tremendous number. Wind power represents 3% of the entire U.S. power.

China took over the lead and is with 76 GW, the world's number one wind power producer. By 2020 Chinese want to deliver between 200-300 GW.

In Europe the German "Energiewende", a governmental program of subsidizing alternative energy sources, became the main driver for so called "renewable" energies, and Germany now is the leading European wind energy provider, with a number of 31 GW.

The world total of 282 GW equals an average power of 94 GW (remember the factor of 33% or 1/3), about the same amount of energy, delivered from 90 nuclear reactors [cf. 4] [cf. 26].

At the current technological status, the unpredictability of wind and its intensity makes wind turbines unable to satisfy the entire electric power demand at a certain time. Therefore, wind energy will be an alternative source whenever it is available, being a backup system to other power plants, which continuously produce electricity. The necessity of these backups and the associated costs are the critical aspects against an expansion of wind power. Again, the development of new electricity storage technologies can lead to a crucial breakthrough with the issue of alternative energy sources.

4.6. Waste-to-energy

The Waste-to-energy principal or WTE as a common abbreviation, is a smart idea to generate usable energy by removing all recyclables and compostables before disposing the waste at landfills. Most WTE processes generate electricity together with heat, or heat only that is being used for heating households or a pre-heating process in manufacturing, directly through combustion. Some processes even use waste to produce a combustible fuel, such as methane or synthetic fuels [cf. 18]. For a comparison between the U.S. and Europe the following graph, like shown in [18], gives an overview of how the different nations concentrate on recycling and WTE.

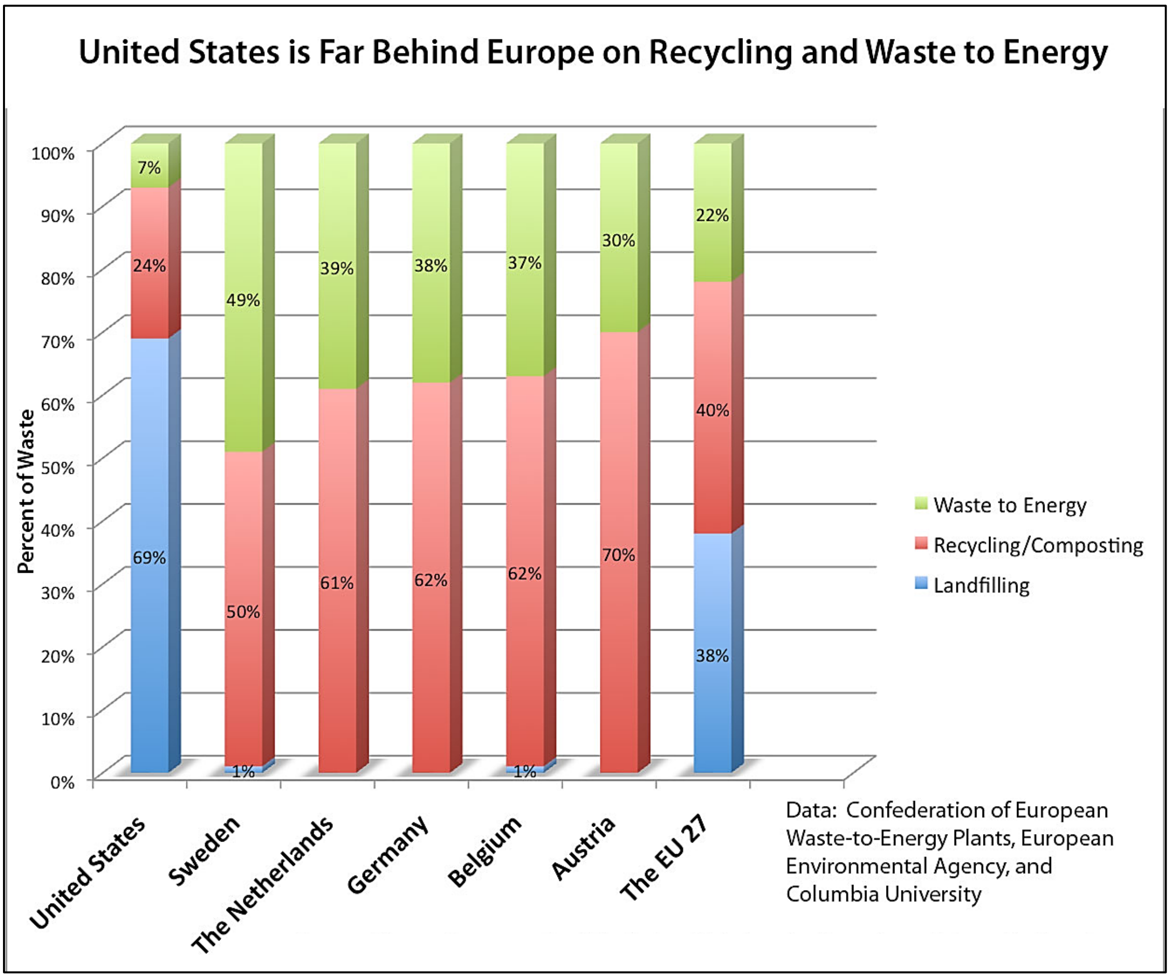


Figure 10: Recycling and WTE overview [cf. 18]

The five European nations with the highest recycling rates - Germany, the Netherlands, Austria, Belgium, and Sweden - also have among the highest WTE usage, reduced landfill use to less than one percent of their waste. Sweden is even importing waste to drive their power plants. While this is questionably desirable, it does not appear to have reduced their recycling effort, which is higher than the twenty two other European nations. In the U.S. by contrast, where environmental groups frequently portray issues as an either/or choice between recycling and WTEs, both rates are tremendously lower than in the European average. As in Europe, the trend of increased recycling rates in communities that use WTE also holds in the US, where communities that have a WTE plant show higher recycling rates than the national average. But also WTE itself is not without waste. For example, the recycling of mixed paper leaves 15 percent of its initial weight that needs to be disposed. Clearly WTE can and do go hand-in-hand with recycling in a responsible waste management, and is a preferable alternative to landfilling [cf. 18].

4.7. Future energy

4.7.1. Technological trends

It is seen as the most probably scenario that in the next decades a shift from fossil energy sources to cleaner and “greener” ones will happen in OECD countries. Assuming that fossil fuels remain dominant until 2050, more fuel efficient fossil technologies will be the essential role of near future energy mixes. Current rising technologies like wind, biomass, and solar energy will need to become affordable to the broad population, sun power in particular needs further technological improvements for its feasibility in future applications to become more competitive. Also future fluctuations in fossil fuel prices, due to its demand, as well as conflict-based issues, could change this image drastically. And against current movements and regulations, nuclear power could be a significant contributor to sustainable energy mixes, providing further research and development with regard to its acceptability, as well as handling nuclear waste in a sustainable way. Fuel cells are also an example of promising technologies, using simple hydrogen as a fuel. When used in cars, fuel cells already provide higher efficiency and lower maintenance effort in comparison to combustion engines. The main rejection of a fuel cell is pure water, mainly in form of steam. But today the hydrogen production itself is the barrier to this technology, due to its process is very energy consuming. Another aspect is that water steam as emission could bring more heat into the atmosphere, causing a stronger increase in temperature than emissions from a conventional fossil fuel-powered car. Besides the use in cars fuel cells are also considered to be operating in buildings in future, where the hot water they reject could save costs for heating and cooling services. Anyway, experts predict a trend towards more flexible fuels, combined with a move towards more differentiated energy services [cf. 4] [cf. 26].

4.7.2. Behavioral changes

At least same important as technological change, also the behavior in energy consumption has to change in order to ensure future energy demand and population growth. Future consumer behavior patterns, mainly driven by new governmental regulations, will be the drivers behind these changes, controlling and strengthen technological improvements for all sectors, from transport to households, and industry. In many economic areas, new and innovative technologies are already available: hybrid engine cars, fuel cells, high-tech insulation and efficient heating systems, energy-saving electronics, and many more [cf. 27].

But their higher investment costs and missing infrastructure (in many cases) make people stick with conventional substitutes. Hence, it will also be the world's governments aim to generate knowledge and public awareness for responsibly using natural sources and energies with a sustainable attitude.

5. Improvements in the product life cycle

As discussed in the previous chapter, alternative energy sources can contribute to reduce harmful emissions to our environment. But not only to protect our nature, also the fact, that fossil energy sources are gradually running out must let us to change our way of energy production in future.

Furthermore to energy production processes there is a great potential in the total product life-cycle to minimize negative environmental impacts, conserve natural resources, increase energy efficiency and pay more attention to lastingly ensure the safety of employees, consumer and surroundings.

The most appropriate way of evaluating alternatives is a systematic approach in which the total product life-cycle is split in sub-processes shown in figure 11. In each step of the life-cycle, the 6R factors (reduce, reuse, recycle, recover, redesign and remanufacture) must be considered as a basis to increase the sustainability [cf. 33]. A closed-loop material flow must be the ultimate goal in order to reduce impacts on the environment. This idea is also known as the concept of Life Cycle Engineering (LCE) – an engineering assessment concept for products that combines environmental impacts and economic impacts from the product's cradle to its grave.

Figure 11: Total product life-cycle [cf. 32]

This chapter deals with diverse approaches, instruments and examples how to improve the current situation beginning from development and design, purchasing, manufacturing processes and facilities, packaging and distribution, sales and services up to use to end and recycling opportunities. The focus is on manufacturing peripheral equipment and innovative technologies.

5.1. Development/Design

The first phase of generating and commercializing a new product is always the development and design phase which involves idea generation, product design and detail engineering as well as market research and marketing analysis [cf. 35].
This planning stage is pioneering for the complete product life-time, because the further the progress the more difficult and costly are changes in the concept (see figure 12). Research has found that 80 % of economic costs, social and environmental impacts are determined in the product development stage [cf. 37].

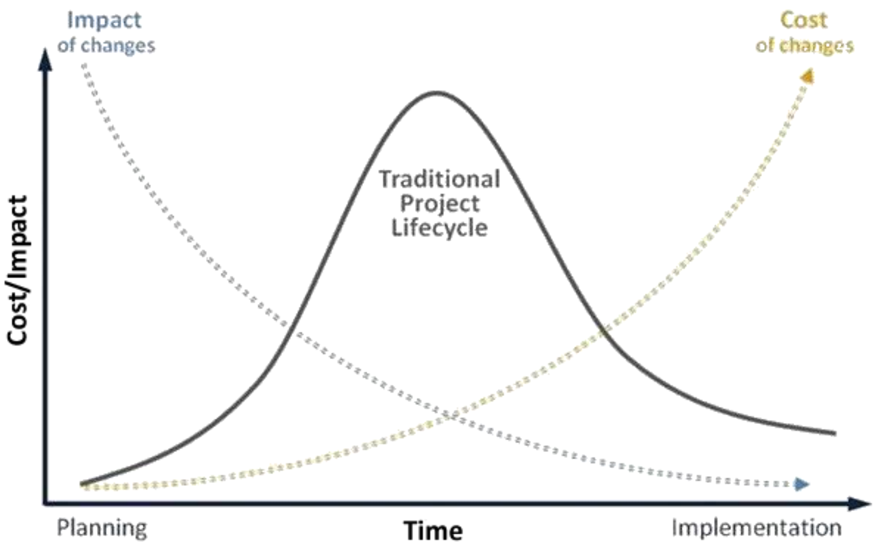


Figure 12: Cost-impact comparison of changes in the development phase [cf. 34]

That’s why also from the green perspective, the development and design process is the most important step. Since on the one hand this process contains the greatest potential to implement environmental principles, on the other hand it also defines several boundaries. Boundaries are for instance used materials which require highly energy-intensive raw material extractions (e.g. aluminum) or products which require toxic and hazardous substances in production processes which endanger employees and the environment (e.g. ammonia, acids).

5.1.1. Employee motivation and trainings

Employees who are part of the development and design team have to think about how their newly developed products can affect our environment during the entire life-cycle. There are two different options how to qualify engineers to generate novel ideas and make right decisions (see figure 13).

The Bottom-Up approach deals with the awareness of engineers to develop sustainable products and how to influence his/her consciousness. Influence options are literature, media, training/teaching and especially the working environment for engineers and decision makers.

The Top-Down approach is mainly driven by external forces (legislation, standards, and guidelines) and economic attractiveness of sustainable products. This approach leads more likely to use methodologies and tools such as Life Cycle Assessment or Life Cycle Costing. The negative aspect of the Top-Down approach is that engineers only adapt their products as much as necessary to market needs so that they will never push themselves to the limit of possibility in terms of developing sustainable products [cf. 42].

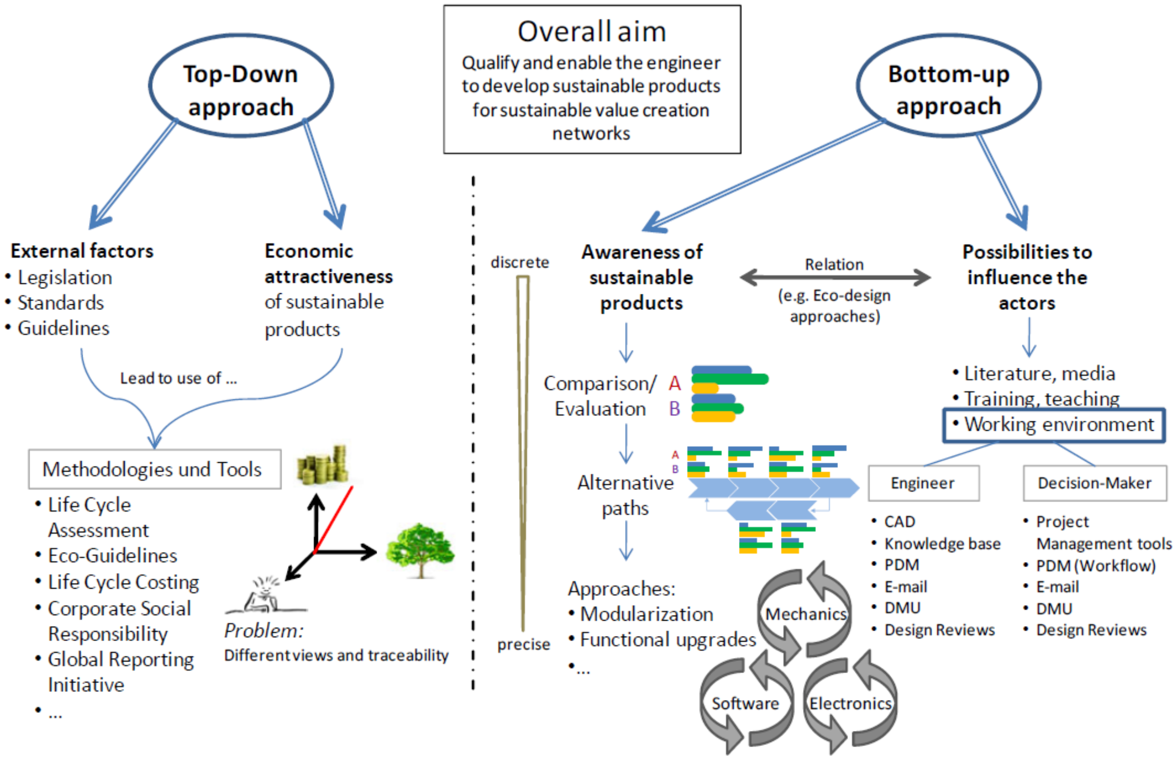


Figure 13: Engineer qualification approaches to develop sustainable products [cf. 42]

In a real work environment with complex relationships and dependencies, both approaches cannot be completely split. Nevertheless, whether a Top-Down or a Bottom-Up approach, employees must always have in their mind why greener products can lead to a win-win situation. If and only if designers are convinced about that fact, big changes and innovations are possible.

5.1.2. Approaches and tools

If the phase of collecting ideas and concept development is finished, there are several methodologies and tools which assist designers to assess the degree of sustainability of their products.

One of them is called “Design for X” (DFX). This term refers to approaches such as Design for Manufacturability (DFM), Design for Assembly (DFA) or Design for Recycling (DFR). DFR can be used as a design assessment tool to determine the feasibility of end-of-life options by assessing design attributes from recycling, disassembly or serviceability. The negative aspect of DFX approaches is that they largely overlook aspects of social sustainability while emphasizing the economic view on a product. [cf. 42].
Another upcoming approach is known as Eco-Design. In the past, principles have been reactive and considered effects rather than root causes. Nowadays Eco-Design strategies are encouraging proactive approaches which are focusing on impacts from the whole product life-cycle. While traditional design guidelines are mostly based on the Life Cycle Assessment (LCA) for assessing ecological aspects of a product, Eco-Design with its 15 tools builds a foundation for the development of approaches that also include economic and social aspects [cf. 37] [cf. 42].
The benefit of these assessment tools is that they give feedback on the current status and help to develop alternative and more environmentally friendly solutions.

5.1.3. Future Materials

As already mentioned, in the development and design phase there are some fundamental opportunities to make our future greener.
For instance, there is a significant future potential in the used materials which are crucial for the environmental impact during the production, use and after use of products.

Interesting materials are for example mushroom materials. They consist out of agriculture waste and fungal mycelium which is a natural, self-assembling glue and a digesting crop waste. Mushroom materials are meant to serve as a cost-competitive, high-performance and sustainable replacement for plastic foams insulation, packaging materials, as well as a material for automotive applications. Another conceivable field of business for this special kind of material is the furniture industry. Conventionally formaldehyde, a known carcinogen, can be compensated with fungal mycelium technology to avoid harmful chemicals. Mycelium acts as a strong, self-adhesive natural glue to bind and finish structural board. No gluing in material manufacturing and product assembly lead to shorter production times and lowered costs [cf. 36].

Other emerging materials are thermoelectric materials. They show the thermoelectric effect in a strong or convenient form. The thermoelectric effect refers to phenomena by which either a temperature difference creates an electric potential and vice versa [cf. 38]. Scientists of the Northwestern University located in Kirkland, Washington, and scientists of the Michigan State University have developed a thermoelectric material which showed the best performance in the World at the end of 2012. If these materials become more efficient in future, there will be an enormous market, because nearly two-thirds of energy input in several processes is lost as waste heat. Hence thermoelectric materials represent great energy efficiency potentials, because waste heat can be used to generate electrical energy. Possible areas of application include the automotive industry (much of gasoline's energy goes out a vehicles tailpipe), heavy manufacturing industries (such a glass and brick making, refineries, coal- and gas-fired power plants) and places where large combustion engines operate continuously (for instance ships and tankers) [cf. 39].

The increasing oil-shortages, rising oil prices and emissions of greenhouse gases lead to an enhanced preoccupation with the future of our oil-based economy. Oil-based products have to be substituted with regrowing bio-based products in order to keep these products available. Attractive options to oil-based plastic products are fully renewable bio-composites which can be processed using current technologies like injection molding, extrusion, thermoforming, rapid prototyping etc.
Bio-composites consist of natural fibers in conjunction with biodegradable, renewable sourced or less toxic matrices. The benefits of these composites are that they are light, strong, but also cheap and more environmentally friendly than carbon- or glass-fiber composites. In addition bio-composites are less toxic in manufacturing and in use while popular composites present a health risk for employees and for consumers [cf. 41]. The challenge is that these bio-composites need to be on the same technological level as oil-based materials and must have similar manufacturing characteristics in order to fully replace them. A small amount of bio-composites has already entered the market leaving a good impression for the future [cf. 40].

Recyclability and reusability are going to play a decisive role to avoid waste which can only be burned in a waste incineration plant or end in a waste disposal site. Also downsizing and reducing weight is becoming more and more important to save costs and increase efficiencies in all sectors of today's economy. The development phase is also the phase where we have to seek ways to replace materials which are prohibited by laws and local requirements.
The overall focus should be on designing products which make it possible to use recyclable or reusable as well as biodegradable materials. Furthermore designing more energy efficient products and minimizing health risks for employees, society and customers are challenges for the future.

5.2. Purchasing

Due to the increasing globalization in the past, many companies had to change their direction and to re-orientate themselves in order to stay on the market. Most of them specialized on tasks they did best. This specialization is the reason why today's supply chains are getting larger and a professional supply chain management is essential in order to be able to place finish products at competing prices on the market. The selection of suppliers is nowadays no longer only the responsibility of the purchasing department; it is also part of the strategic management decision process.

Traditional objectives in this selection process have been product cost, lead time, product quality and service level. Companies paid a lot attention to low cost material and low cost logistics to enhance competiveness. But there are also some risk factors for the global search for suppliers to get low product prices. Increasing transportation costs, enlarged lead times, uncertainty in currency exchange rates, instability in economics and politics as well as changes in governmental regulations lead to a rethink. In addition to economic factors, environmental factors have increasingly been considered due to the considerably deteriorated environment, regulatory requirements and consumer pressures [cf. 43].

5.2.1. Environmentally Preferable Purchasing (EPP)

Green purchasing, also known as Environmentally Preferable Purchasing (EPP), is the sustainable way of selecting and purchasing products and services in a modern supply chain. The goal is clear – the minimization of environmental impacts. Departments with a green focus add environmental aspects to quality, cost and delivery aspects to achieve this objective. In order to evaluate impacts of purchased products, an assessment of environmental consequences is required. It's very important that these assessments include all stages of the product life-cycle.
Environmental management certificates such as ISO 14001 can make it easier to select right partners.
Also software solutions like SAP Environmental, Health and Safety Management can be used to support companies to improve their supply chain efficiencies.
Cooperation and knowledge exchange regarding environmental issues are playing a key role in green supply chains. Joint settings and coordination of targets during early design phases are also essential success factors for prospective enterprises.

Many companies and governments have already implemented policies which emphasize their focus on conserving energy and natural resources, reducing pollution and eliminating waste. Against widespread presumptions that green products are always more expensive than conventional products, lower operating costs are able to quickly compensate possible higher acquisition costs.
Green purchasing principles are not highly scientific; there are some simple guidelines which can help to improve the supply chain's performance in terms of going green.

Buying from local companies is one good example which can lead to many advantages. Logical consequences of shorter transportation ways are lower logistics costs. But also the uncertainty of global logistics operations can be reduced by preferring local businesses.
The general public as well as the companies themselves benefit from buying local.
The remaining money in the region supports the process of creating new workplaces and leads to an economic upturn from which the companies can profit again.

Other important issues that have to be considered are the transportation method and the packaging of the purchased products. Details to these topics can be found in the packaging and distribution section (chapter 5.4) of this work, because same rules can be applied for sending and receiving of products.
All in all, green purchasing is not only a goodwill of companies. The selection of suppliers with a green perspective can result in big benefits over a longer term. In addition to a well to market green image, there are also some cost reduction factors. Avoiding hazardous waste which is very expensive to dispose and preferring short transportation ways which reduce shipping costs are only some of them.

Very important is the fact, that green purchasing is a top-level decision and must be an integrated part of the company's culture. If companies sell themselves as green and sustainable companies to the public, they must also buy their needed products from a green point of view in order to be credible in regard to their statements.

5.3. Manufacturing

The goals of Green Manufacturing are broadly diversified. Minimizing waste and unwanted outputs, increasing material-, resources-, an eco-efficiency, reducing pollution, assuring the safety of employees, achieving cleaner production and ensuring a problem-free supply chain integration are only some of them [cf. 45].
There are a lot of possibilities in production processes to implement green manufacturing approaches to reduce environmental impacts on the one hand and achieve economic goals on the other hand. But not only production processes, also facilities and energy systems of production plants have to be considered. One the basis of examples and state of the art technologies, some opportunities are listed and evaluated.

5.3.1. Principles

Some principles have to be abided before effective improvements can be achieved. These fundamentals are partially adopted from [cf. 7].

First of all, it is absolutely necessary to follow a comprehensive systems approach to evaluate and analyze manufacturing processes from a green perspective. Various factors can influence each other and planned outputs can show completely deviated and unexpected values. David Dornfeld used a standard machining process shown in figure 14 to explain these possible behaviors of systems. For example, reducing the amount of cutting fluid provides environmental benefit. But this decision may also result in greater compressed air use or increased electricity consumption due to the increased cutting forces. In addition, increased human health risks and other environmental aspects because of the vaporized cutting fluid in the air can be consequences. That's why production processes must be seen as a whole when improvements activities are intended.

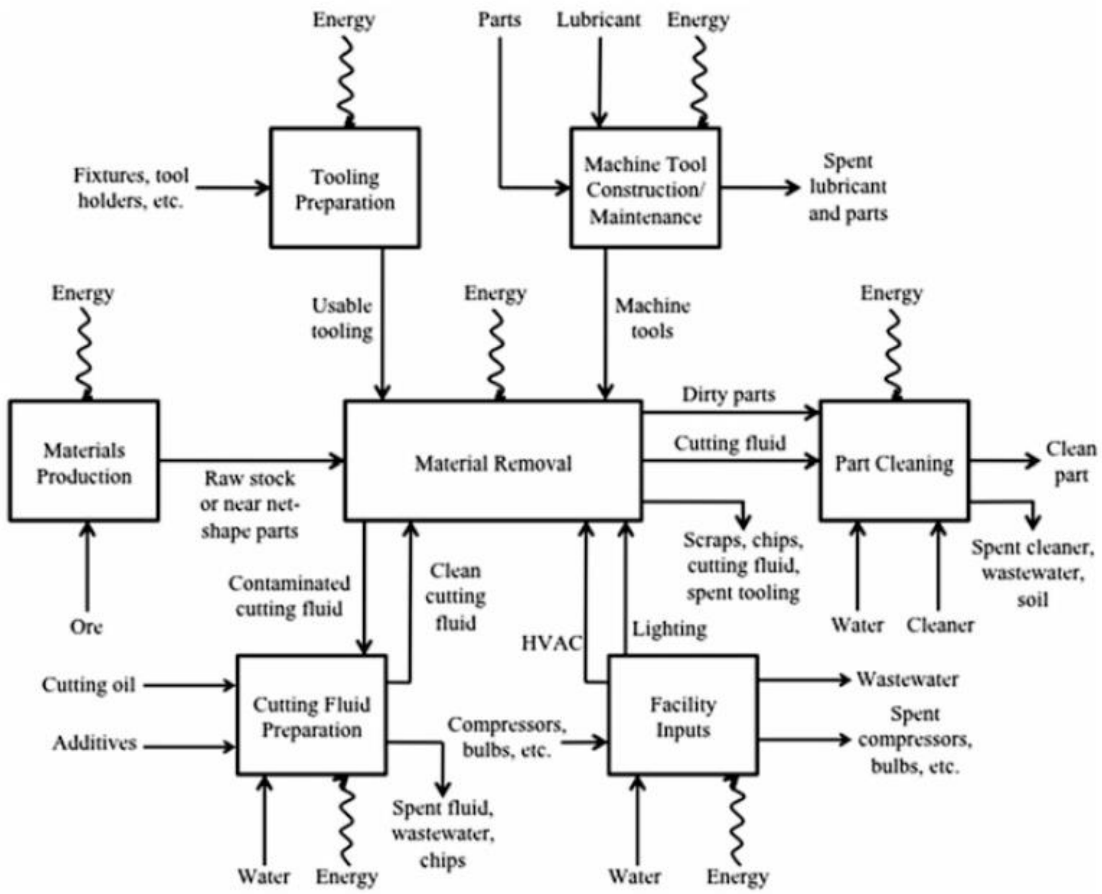


Figure 14: Comprehensive systems view of a standard machining process [cf. 7]

In addition to the comprehensive approach, the system should be viewed in vertical and horizontal directions.
Vertical means in this connection the levels of detail from enterprise down to the process level. While the energy consumption of a single machine tool may seem negligibly small, the energy consumption at the factory level may be quite large due to the number of machines.
In contrast to vertical, horizontal refers to considering the system at any one level of detail. Air is usually compressed using only a small number of compressors shared by all machines and processes. So the entire machine level of detail should be considered when analyzing compressed air usage.

5.3.2. Introduction

A large potential for improving is in energy recovery systems. Energy recovery systems are used in several applications with an aim to reduce emitted energy to the environment. Most systems directly exchange thermal energy from output flows to input flows, but also storage systems are forms of these. The benefit is that energy inputs and installed power capacities can be dramatically reduced so that operating costs for consisting and investment costs for new equipment decreases. Due to the less needed energy, the efficiency of the overall system increases.

Besides of saved money, also environmental impacts decline. For instance, CO_2 emissions can be reduced if fossil energy sources are used for heating up the input flows.

Innovative heat pumps/refrigeration systems are also very economical solutions if waste heat would be discharged to the surroundings without use. They can provide higher temperature levels than the waste heat as well as coldness for air conditioning and other cooling applications. Refrigeration via heat in combination with solar thermal systems is an emerging and promising technology for the future.

There is another great energy saving potential in using state of the art lighting technology, because electric lighting is still a major energy consumer. Besides minimizing energy consumption, energy efficient equipment reduces also heat gain which result in air-conditioning savings. In addition, electric lighting design affects visual performance and visual comfort by aiming to maintain adequate and appropriate illumination.

Compressed air generation accounts for 10 % of industrial electrical usage in the EU, so focusing on improvement is an essential effort in order to develop more sustainable manufacturing processes [cf. 55].

5.3.3. Heat recovery systems

One kind of energy recovery systems are heat recovery systems. The heat content of waste heat flows of fluids or gases emitted by diverse processes is passed to input flows. The central parts of most of these systems are heat exchangers which are available in different designs for various applications. Decisive factors for the transferred heat in heat exchangers are the so-called heat transition coefficient, the surface area where the substances are passed by and the temperature difference between the substances. The heat transition coefficient is affected by the thickness and the properties of the used material (heat conduction, heat capacity) as well as by flow conditions (grad of turbulence, flow velocity). Also the flow directions inside the heat exchanger affect the transferred heat (concurrent flow or countercurrent flow). All these factors have to be considered when heat exchangers are used [cf. 46].
Basically there are two main types of heat recovery systems – recuperative systems and regenerative systems. Regenerative systems are mostly used for gas/gas heat transfer applications. Frequently used regenerative systems are rotation heat exchangers, combined circulation systems and heat pipes.

Recuperative systems are “standard” heat exchanger systems which use static exchange areas to transfer heat. Examples are shell and tube heat exchangers for fluids and plate heat exchangers for fluids or for gas flows.
Plate heat exchangers for air to air applications use a lot of plates (aluminum or plastics) which are soldered, welded or screwed together. Screwed forms have the

advantage of easy dismantling and cleaning. Plate heat exchangers have a high efficiency at small dimensions. Furthermore they are cheap, because they are produced in great quantities.
One special feature of recuperative systems is that there is no exchange of substances between the flows. This characteristic can be essential if ingredients like harmful particles, odors, dust, germs etc. are undesired in the input flows.

Rotation heat exchangers enable a heat transfer between parallel flows with a rotating regenerator. This regenerator consists out of thin foils (aluminum, ceramics or stainless steel with or without coatings) and stores the heat intermediately during the turns [cf. 47]. In consequence of the alternations of the flows, a self-purification effect occurs. A rotation heat exchanger is very efficient and can also be used for small temperature differences. The negative aspect is that the operating life is shorter due to wear and tear. An exchange of substances is possible. This recovering of humidity is the reason why they are often used for air-conditioning applications [cf. 46].

In combined circulation systems, water/glycol – gas heat exchangers are located in input and output flows and connected by pipes. A pump supplies the storage medium which is heated up by the exhaust flows to the supply flow where heat transfer occurs to the supply flow. The input and output flows are separate so that no exchange of substances is possible. The big advantage of combined circulation systems is that multiple flows can be integrated within the system and different temperature levels of output flows can be used. Clever positioning of the individual heat exchangers lead that the input flow can be heated up to a higher temperature level than the mixing temperature of the output flows (as for instance with plate heat exchangers) [cf. 48].
Combined circulation system can not only be used within a single system; it can also be used to warm up the supply air for the whole plant with waste heat from diverse processes (welding suctions, washing plants, dryer etc.).

Heat pipes use evacuated ribbed type pipes to transfer the heat. Within the pipes, there is a fluid, mostly a refrigerant, which evaporates at one side and condenses at the other side. The fluid gains the heat for evaporating at the bottom, rises to the top and condenses with head dissipation. Hence, the temperature range is limited by evaporating and condensing fluid properties. The benefit is that no external power is required for the circulation of the fluid in contrast to combined circulation systems.
Because of the simple design, heat pipes are often used for small applications [cf. 46].

Integrated air preheating for industrial burners is another application of heat recovery systems to save considerable amounts of primary energy. Parts of the heat content of the exhaust gases are transferred to the combustion chamber supply air. The result of the preheating process is that less fuel is required which decreases also the needed supply air volume. Hand in hand with the fuel reduction, also the emissions to the environment decline. The potential of saved energy depends mainly on the temperature level of the exhaust gases. Recuperation burner and regeneration burner are examples how the principle of preheating is used in real-world applications [cf. 46].

There are opportunities in Michigan and in Austria to get financial support for heat recovery systems. Pure Michigan (Michigan Economic Development Corporation) and the food ministry of Austria managed by Kommunalkredit Public Consulting are examples of funding bodies for both nations [cf. 49] [cf. 50].

5.3.4. Thermal storage systems [cf. 46]

Heat recovery systems, as discussed before, immediately use waste heat for warming up other flows. If the heat production and the heat demand differ in time, thermal storage systems are required. The efficiency of a thermal storage system depends on the loading and unloading time, the storage capacity and the rate of heat loss. Also the storage time and the maximum possible number of usage cycles must be considered if different systems are analyzed.

Thermal storage systems can be classified into three categories:

- Sensible storage systems: They change their temperature during the loading and unloading process. The storage capacity depends on the heat capacity of the storage medium and on the temperature difference between the heat source and the storage medium.

- Latent storage systems: They use the phenomenon of a phase change, where the temperature of the storage medium remains constant. The maximum storage capacity is limited by the needed energy for completely changing the storage medium's phase.

- Thermo-chemical storage systems: They store heat by endothermic and reject heat by exothermic chemical reactions.

These three types of storage systems are applied in different real-world applications.

Common thermal storage systems are buffer storage systems which belong to the group of sensible systems. They usually use water as storage medium which limit the maximal temperature to about 95 ºC. Under pressure or with thermal oil this temperature barrier can be higher. The advantages of buffer storage systems are that they are cheap and flexible in use. They are frequently used in heating systems to integrate solar systems.
Also storage systems for coldness can be realized with buffer systems. For this application, a water-based antifreeze mixture is used as storage medium.

Gravel/water storage systems belong also to the group of sensible storage systems. They are mostly used for long-term heat storing as a supplementary heating system. The storage medium is a pit filled with gravel and water which can be warmed up directly (changing the water) or indirectly (heat input with plastic pipes). The unloading process works identically. The heat limit is about 90 °C. The big benefit of this system is that it is statically loadable. So roads or parking lots can be built above these systems.

Crushed rock storage systems are similar to gravel/water systems. The storage medium is crushed rock where air is alternately flowed through. These storage systems are rectangular shaped with air distribution systems which allow air to get in or out (see figure 15).
In summer, warm outside air passes through the thermal storage system rejecting heat and giving off humidity during the day to the crushed rock. The cooled and dehydrated air can be used afterwards for air-conditioning. Cooler air at night is used for regenerating the storage system.
In winter, cold ambient air is warmed up at night for heating applications. During the day, waste heat can regenerate the storage system.
90 % of the required cooling quantity in summer and 15 % of the needed heating energy in winter can be reduced with these systems.

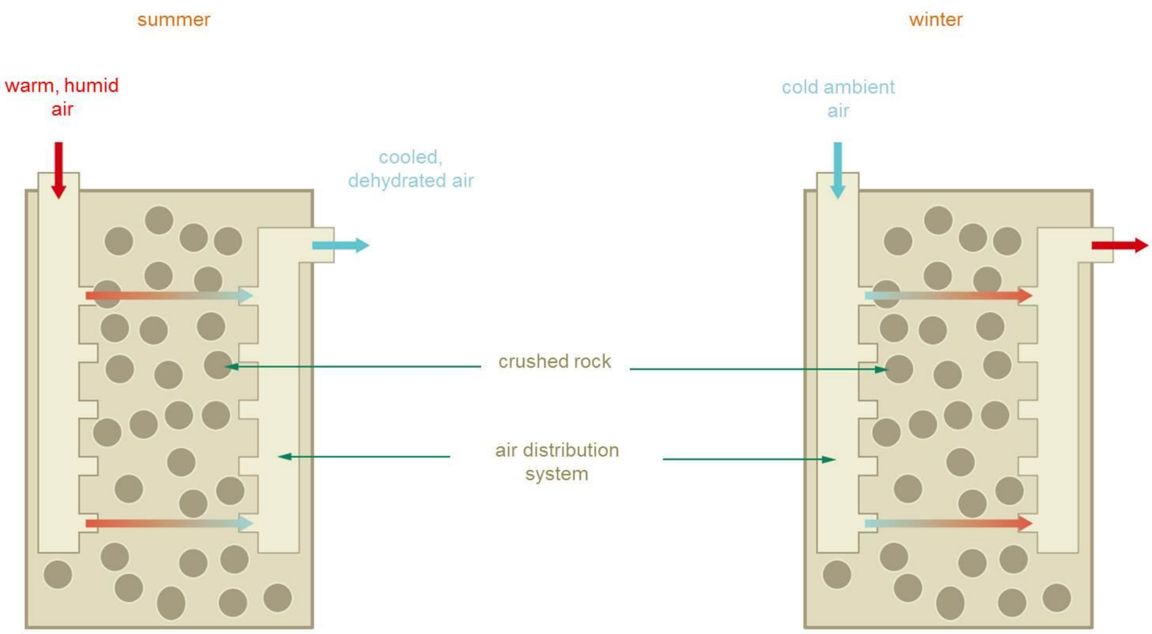


Figure 15: Crushed rock storage system [cf. 46]

Other sensible thermal storage systems are earth probe systems. The technology has been derived from earth probe heat pump systems. There are a lot of earth probes which store the heat in the ground. A water/glycol mixture circulates through these probes to load and unload them. The efficiency of earth probe systems is mainly influenced by the drilling costs. That's why these systems are profitable if the ground is easy to drill.

Latent heat storage systems use special phase change materials as storage media. These materials, mostly salts or paraffin, take advantage of reversible phase change processes for storing the heat. During these processes, the temperature of the storage medium doesn't vary. So also for unstable loading temperatures, the unloading temperature remains constant which is a big benefit in comparison to sensible storage systems. Most latent heat storage systems use the transition from solid to liquid. Different material properties allow temperature ranges from -30 °C – 1000 °C as heat dissipation temperature. In addition to this flexibility, the storage density is very high too.

Thermo-chemical storage systems, also known as sorption storage systems, can store heat via reversible chemical reactions. The storage density of these systems is 4 – 5 times higher compared to conventional hot water storage systems. Thermo-chemical storage systems use either an absorption process or an adsorption process which are more closely described in chapter 5.3.5. They are still in the development phase and will be available on the market in future.

Some thermal storage systems have been used for a long time while new storage technologies are tested and improved in pilot tries.
In Gleisdorf (Austria) for instance, a high energy density sorption heat storage system for solar space heating was built in 2001 by AEE INTEC [cf. 51].
Also Michigan is pushing energy storage systems and invested $6 billion in this field. In less than three years Michigan has become the North American center for the development and commercialization of advanced energy storage systems with 16 companies establishing new research and production facilities [cf. 52].

5.3.5. Heat pumps and refrigeration systems [cf. 46] [cf. 53]

The objective of a heat pump is to maintain the temperature within a dwelling or other building above the temperature of the surroundings or to provide a heat transfer for certain industrial processes that occur at elevated temperatures. The purpose of a refrigeration system is to maintain a cold region at a temperature below the temperature of its surroundings. The basic design and the components of heat pumps and refrigeration systems are equal.
Energy is needed in the form of electrical energy in compression heat pumps/refrigeration systems or in form of heat in sorption heat pumps/refrigeration systems.

Compression heat pumps/refrigeration systems have a simple design and are widely used systems. They consist of four parts which form a thermodynamic cycle: evaporator, compressor, condenser and an expansion valve (see figure 16).

A refrigerant enters the evaporator as a two phase liquid-vapor mixture at state 4. In the evaporator, the refrigerant changes phase from liquid/vapor to saturated or superheated vapor as a result of heat transfer from the region at lower temperature to the refrigerant.
After the evaporator, the refrigerant is compressed from state 1 to superheated state 2. During this process the pressure and the temperature of the refrigerant increase.
Then the refrigerant enters the condenser where heat transfer occurs from the refrigerant to the hot thermal reservoir. The refrigerant changes phase from superheated vapor to saturated or subcooled liquid at state 3 in this process.
The last process of the cycle is a throttling valve to reduce the pressure of the refrigerant to its initial state 4.
As the heat source at the lower temperature level, geothermal energy or waste heat in form of water or air are mostly used. It should be noted that the efficiency of compression heat pumps/refrigeration systems depends a lot on the temperature difference between the hot and cold thermal reservoir. The smaller the temperature difference, the higher the efficiency.

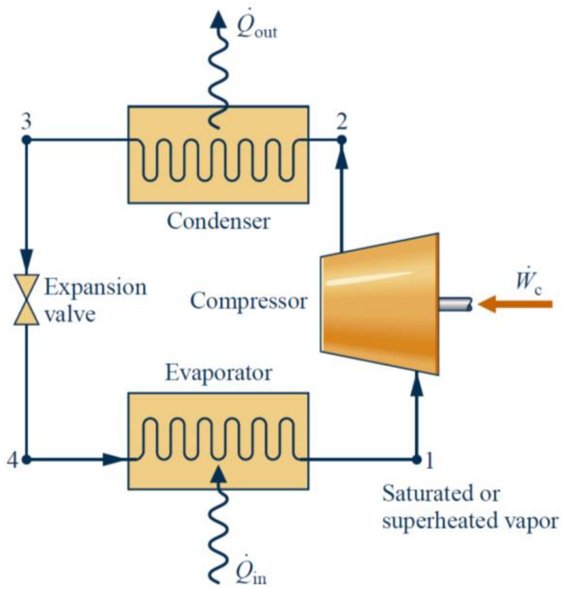


Figure 16: Sketch compression heat pump/refrigeration system [cf. 53]

Absorption heat pumps/refrigeration systems have some features in common with compression heat pumps/refrigeration systems, but they differ in two aspects:

- Instead of compressing a vapor between the evaporator and the condenser, the refrigerant of an absorption system is absorbed by a secondary substance (absorbent) to form a liquid solution. The formation of this liquid solution is exothermic so that heat transfer from the system occurs. The liquid solution is then pumped to a higher pressure which requires much less work than pumping vapor.

- In the generator, heat transfer from a high-temperature source is required in order to retrieve the refrigerant vapor from the liquid solution before it enters the condenser. The remaining weak solution flows back to the absorber through a valve.

The required drive energy for absorption heat pumps is mostly provided by burning fossil fuels as natural gas and oil as well as by waste heat from various processes.
Absorption refrigeration systems need smaller temperature levels at the generator so that solar energy or waste heat with lower temperature often meets the requirements.

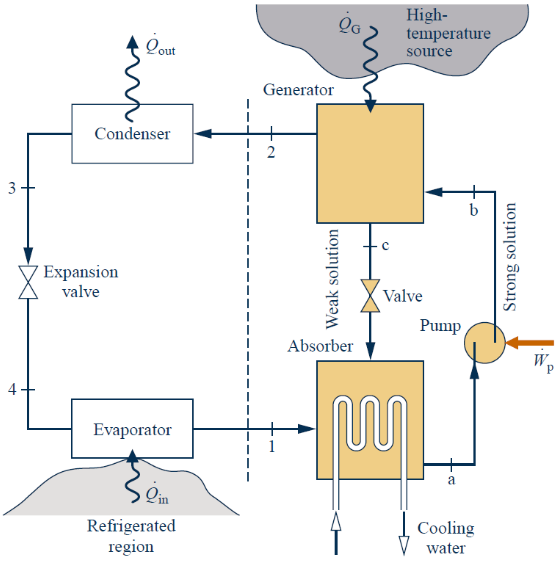


Figure 17: Sketch absorption heat pump/refrigeration system [cf. 53]

The third heat pump/refrigeration technology is based on an adsorption process. The functionality is shown in figure 18.
Adsorptions systems have two chambers which are filled with adsorption medium. These two chambers are alternating in the adsorption and desorption process so that a cyclical process can be achieved by switching.
In the first phase (desorption phase), the surface area of the adsorber is covered with molecules of the refrigerant [1]. Heat transfer occurs at a high temperature level to the heat exchanger where the adsorber is placed [2] so that the adsorbed refrigerant evaporates. The steam enters a second heat exchanger (condenser) where the refrigerant condenses and condensation heat is rejected [3].
In the second phase (absorption phase), the refrigerant evaporates again due to heat transfer to the system [4]. The required heat quantity can be provided by heat at a low temperature level (for instance geothermal energy or waste heat). In refrigeration systems the coldness is generated in this process. The evaporated refrigerant flows to the adsorber where adsorption occurs. Heat resulted from the adsorption process is rejected and can be used for heating applications.

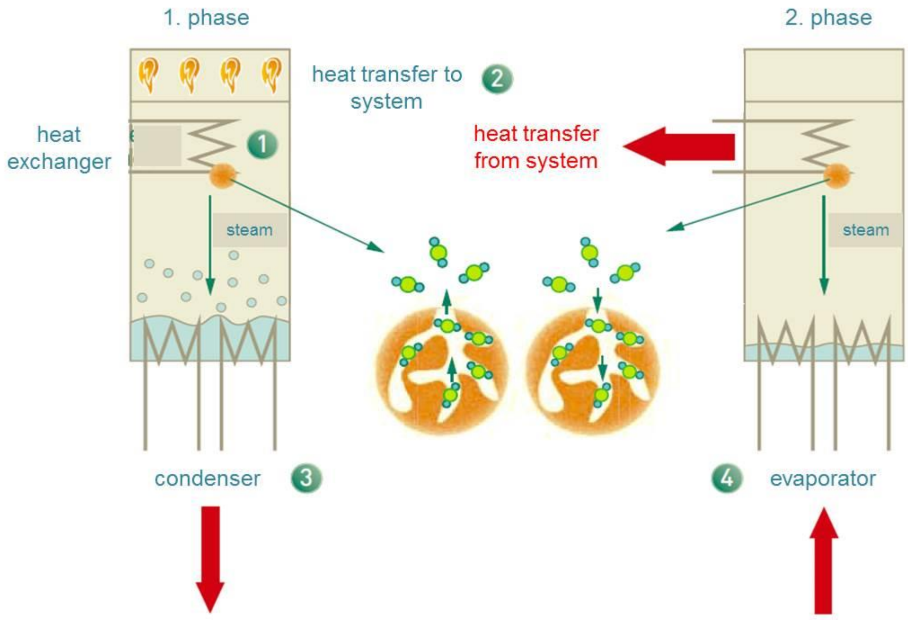


Figure 18: Sketch adsorption heat pump/refrigeration system [cf. 46]

5.3.6. Lighting [cf. 54]

One energy-saving opportunity is to replace incandescent light bulbs by compact fluorescent lamps, also called energy-saving light, or by LED systems. It's very important to compare the light output (lumens) instead of watts which refers to the amount of energy used and not the amount of light emitted. LED technology can be a good investment for companies, because prices have fallen sharply in the last years. The same applies also for linear lighting systems.

Lighting control equipment such as occupancy/motion sensors or photo sensors and time clocks represent also a big saving potential.
Occupancy/motion sensors allow the lights to turn on whenever someone is within the area being scanned and to shut off when motion can no longer be detected. Passive infrared sensors which react to changes in heat or ultrasonic sensors are different technologies with the same goal.
Photo sensors monitor daylight conditions and allow fixtures to turn on only when needed. They can be used indoor and outdoor to detect the actual light quantity and to adjust the light accordingly.
Time clocks save energy by reducing lighting time through preprogrammed scheduling. They are very simple, cheap and one of the most efficient energy management devices.

High intensity discharge (HID) lighting is also much more efficient in comparison to incandescent, quartz-halogen and most fluorescent light fixtures. HID types include mercury vapor, metal halide or high pressure sodium. Mercury vapor is seldom used because of the environmental impact.

The lighting industry is booming and worldwide competition affects prices of diverse systems. That's why it is very important to compare the performance, investment costs and operating costs of various systems during the decision-making process.

5.3.7. Compressed air systems [cf. 56]

Pneumatic systems are widely used in production and material handling applications. A major criticism of such systems is their low energy efficiency.
The main causes of wasted energy are leaks, pressure drops, over pressurization, misuse of jets and poor compressor management.

Leakage is the major source of energy loss in pneumatic systems. Air leaks don't make a mess like oil leaks – so they are on the one hand hard to find and on the other hand easy to ignore because of higher noise levels from machinery.
Planned maintenance activities can reduce losses which are up to 30% in typical plants. Leaks often occur in aging pipelines, flange connectors, fittings, coupling etc.
Ultrasonic technology or microphone array technique can be used to find leaks.
Simple shut-off valves or electrically operated soft start dump valves are cost effective, interim solutions to isolate leaky systems when unavoidable leaks occur.

Pressure drops are caused by localized restriction and general friction in pipes and components. The working velocities should be kept low and gentle sweeping bends should be used to reduce these losses.

Compressed air systems and components have an optimum operating pressure and flow for their applications. So both, under and over pressurization, will slow down production rates or increase costs for additional air consumed.
Most double acting cylinders are applied to give a power stroke in one direction, but simple return the piston in the other direction. Reducing return stroke pressures by using pressure regulators can increase efficiencies especially if large bore, long stroke or multiple cylinder systems are used.

Jets of air are frequently used for carrying out processes such as dusting, cooling or separating. These jets are often left permanently running also when production processes are at a halt. Automatic controlled valves and sensors can avoid these unnecessary costs.

Modern compressor management systems can help large compressor as well as simple compressor installations with intermittent use to avoid overproduction.
They use the expected consumption rate, storage volume and the required pressure to calculate the optimal running times to meet needs in an effective way.

5.3.8. Conclusion

The increasing prices for energy and governmental funding opportunities lead that energy efficient technologies getting more and more interesting and financial lucrative for new and for existing plants. There is a great potential in heat recovery systems, thermal storage systems, modern heat pumps and refrigeration systems. State of the art lighting technologies and sophisticated pneumatic systems can also contribute to increase the overall efficiency of production plants.

Also rising prices for waste and global competitive pressure are causes why companies have to minimize waste in order to be efficient and to maintain and expand their market shares.
In addition to economic factors, environmental regulations for emissions are going to be stricter and stricter. So there is no way around for companies to take care and to think about how to produce efficiently in future.

5.4. Packaging and Distribution

After the production process, finished goods have to be packed and shipped to customers.

Green packaging principles include using as less as possible materials (reduced packaging, lower masses, lower volumes) as well as recyclable and reusable materials (glass, biodegradable materials etc.). Many industries are already using standardized load carriers such as pallets, lattice boxes or collapsible containers which are interchangeable and easy to coordinate with warehouse systems. They avoid waste and save money and time simultaneously for customer and supplier without any disadvantages.

In addition to packaging, the mode of transportation must be considered. Figure 19 compares CO_2 – emissions of truck and train transportations.
The bar chart shows that transports via trains are always less CO_2 intensive than transports via trucks. Moreover the utilization level of the trucks is essential for the emissions.
Well-coordinated quantities lead to fully-utilized trucks and trains so that the costs and the emissions calculated for one unit get to the lowest possible level.
A global statement is despite to this chart not possible, because the data is based on several assumptions. For shorter distances, transportations via trucks can also be more environmentally friendly.

The key massage is that the transportation method is not the only important aspect with regard to reduce emissions, also the batch sizes of the shipment should be well deliberated with the selected means of transport.

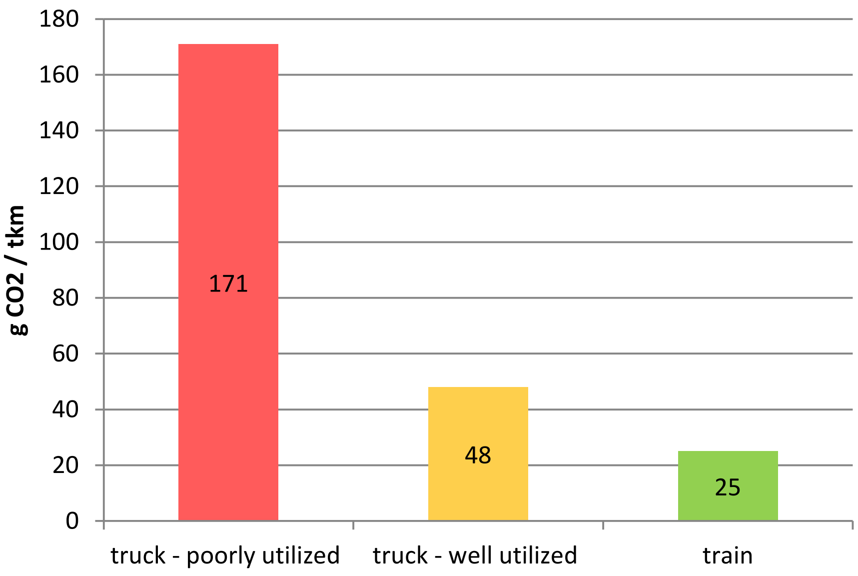


Figure 19: Comparison CO_2 – emissions of transportation methods [cf. 44]

5.5. Sales and Service

Sales and service chances are already defined in the development phase. From a green perspective, products should be simple and service-friendly designed to guarantee a long lifetime.
In the last years, newspapers, magazines and TV documentations have mentioned one special word very often: planned obsolescence.
Planned obsolescence in industrial design is a policy of planning or designing a product with a limited useful life (obsolete – that is, unfashionable or no longer usable) which has potential benefits for producers [cf. 57].

A classic case of planned obsolescence was the nylon stocking. The inevitable “laddering” of stockings made consumers buy new ones and for years discouraged manufacturers from looking for a fiber that did not ladder.
Also the computer industry uses the strategy of planned obsolescence. New software for instance can read all the files of older versions, but not the other way round. There are also some persistent rumors that motherboards are produced with planned, specific lifetimes [cf. 58].
Planned obsolescence is often difficult to prove, but it’s very important that consumer know about this possibility when they are evaluating products.

5.6. Use to end (in-use)

The in-use phase is usually the longest time period of each product. Hence, most negative environmental impacts to our environment are determined in this phase.

Reliable and low consumable goods can cause a significant reduction in emissions. High-quality products have often higher investment costs, but they are also more durable as comparable low-standard options. Not only investment costs, also operating costs and expected lifetimes should play a decisive role in buying products. The focus must also be in using products with low energy requirements which result in low energy costs for the consumer. New motor technology for instance reduces emissions by cutting fuel consumptions while providing the same comfort standard of mobility. Consumer must keep themselves up to date, because energy efficient products are booming and worldwide competition drives forward the technical progress too.

Energy performance certificates make electrical devises easily comparable and facilitate buying decisions. There are different energy labels in the US and EU [cf. 59]:

- US Energy Star: Denote high efficient products.
- US Energy Guide Label: Provide quantified energy and cost saving information.
- EU Energy Label: Denote product’s energy efficiency rating and energy consumption information to assist consumers in product selection.

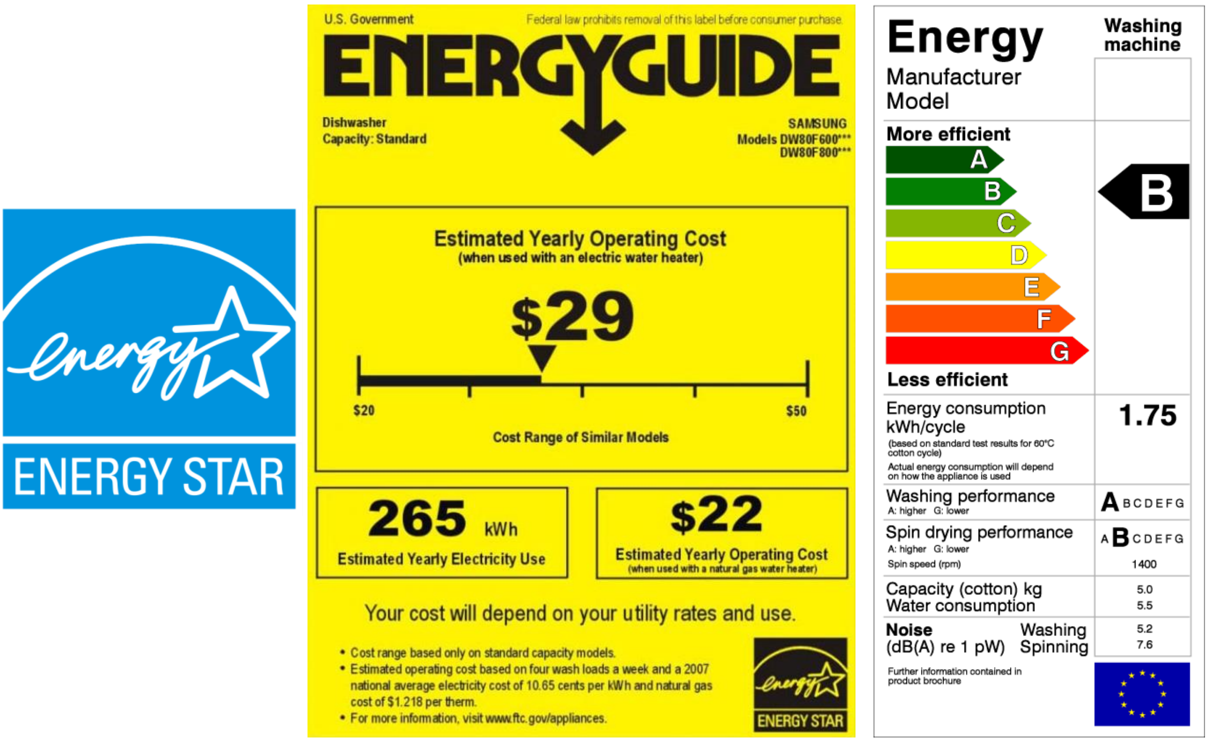


Figure 20: Comparison US/EU energy labels [cf. 60] [cf. 61] [cf. 62]

5.7. **End-of-life** [cf. 64] [cf. 65] [cf. 67]

The end-of-life phase is the last process of a product's life-cycle. Reusing and recycling are great opportunities instead of storing all products at a waste disposal site for infinite time.

To reuse is to use an item again after it has been used. This includes conventional reuse where the item is used for the same function again and new-life reuse where it is used for a different function.
Reusing has certain positive advantages as reduced disposal costs for end-users and cost savings for new consumers, because used parts are always cheaper than new parts. Furthermore, energy and raw material savings are consequences of reusing processes.

Reusing of individual parts as spare parts for related products, also known as remanufacturing, is another approach for products at the end of their lives. The company Caterpillar for instance is one of the world's leading company in this field. They return products to same-as-new conditions and help to reduce owning and operating costs by providing their customers same-as-new quality at a fraction of the cost of a new part [cf.63].
Other examples for reusing are second hand shops, deposit, refilling, regiving (regifting) and repurposing programs.

Recycling is the breaking down of the used item into raw materials which are used to make new items. Cost-effectiveness in comparison to new production, recovery of valuable materials, reduction of disposal costs and governmental regulations can be reasons for recycling. Particularly for poor biologically biodegradable materials, recycling is very important to protect our planet. Most types of glasses, metals and papers are easy to recycle and help to save energy and reduce waste.

Good examples for recycling because of precious metals are catalysts of exhaust gas purification systems. Catalysts contain platinum, palladium and rhodium which are seldom on Earth and very expensive [cf. 66].

Correctly sorting of waste is very important for plastic recycling processes. Most homogenous plastics can be recycled by conventional plastic processing processes like extrusion, injection molding or sinter pressing. Mixed plastic waste has to be separated by different dry or wet processes previously.
If separated fractions cannot be used in conventional processing processes, their polymer chains can be decomposed by gasification, cracking and hydrogenation so that they can be used as a feedstock for new materials.
For a small percentage, there are technical, economic and ecological reasons why they cannot be further used. Most of them are used for energy recovery processes in incinerating plants. The remaining parts have to be deposited.

Plastic waste is a big global environmental problem. The amount of plastic waste in our oceans is growing all the time and the demand for plastics is rising strongly. Approximately 53 % of the worldwide's plastic waste is not recycled or used otherwise. Plastic degrades very slowly, only water and sunlight are able to partially break down plastics in nature. That's the next problem of ocean dumping, because very small plastic parts are eaten by fishes and can enter the human food chain in this way. Also a large number of seabirds die every year in consequence of these small plastic parts.

Figure 21: Plastic waste in oceans and seabirds [cf. 67] [cf. 68]

6. Best practice projects

This chapter deals with several best practice projects in Austria and in the United States especially in Michigan. The goal of these example projects is to show directions of today's research and industry efforts in terms of green and sustainable technologies and compare them to each other. Energy efficiency projects as well as new, innovative production processes and optimization projects are documented.

6.1. Austria

6.1.1. Heat recovery system for a paint shop [cf. 70]

MAGNA STEYR Fuel Tec in Sinabelkirchen, Steiermark, is a supplier company in the automotive industry with about 260 employees and develops and produces fuel tanks for different cars. Today's customers are BMW, AUDI, Maserati, Lamborghini and Daimler.

The production focus is on the assembling of components. All tanks, with the exception of plastic fuel tanks, have to pass through a washing plant and are varnished at the end of the production process.
An energy efficiency initiative pointed out that there is a great potential in the exhaust air flows of the different process steps of the washing plant and the paint shop for further use. For this purpose, various heat recovery systems and refrigeration systems which could use the waste heat had been compared and analyzed.

Heat recovery systems transfer the heat of the exhaust air flows to the supply air flow for the paint shop. It turned out that a plate heat exchanger will be the best solution for this specific application. For the generation of coldness, the exhaust air flows must have higher temperature levels. That's why only a plant for the generation of coldness as well as a combination of a heat recovery system in winter and a coldness generation in summer are not possible.

The investment of 162,275 € for the plate heat exchanger system will have been amortized within 2.95 years in a 2-shift operation if a 30 % funding is considered.
The gas consumption of heating will be reduced by 505,785 kWh and the CO_2 emissions will be reduced by 146,678 kg per year. The heat recovery system went into operation in February, 2014.

This heat recovery system is a good example that energy efficiency efforts can lead to a win-win situation for the company and for the environment. The governmental funding opportunities up to 30 % lead to shorter payback periods which make energy efficient solutions to interesting investment options also for fast-moving industries as for instance the automotive industry.

Figure 22: Heat recovery system MAGNA STEYR Fuel Tec Sinabelkirchen [cf. 74]

6.1.2. Development of a continuous hydrogen-carbon nanofibers production line [cf. 69]

The project “Development of a continuous hydrogen-carbon nanofibers production line” is a subproject of the program “Fabrik der Zukunft” (factories for the future).
This program was started as a part of the R&D area “Sustainable Management” of the Austrian Federal Ministry of traffic, innovation and technologies in 2000. The goal of this program is the initiation and realization of sustainable technologies in companies to give new impetus for this field of business.

The head of this project was the company Elecrovac AG in cooperation with Heat GmbH and the University of Leoben. The final project report was published in July, 2010.

Today, hydrogen represents the future base of an energy system, which is potentially envisaged to become independent from conventional energy resources. The key-technologies in that system are linked to the production, the storage, the transport and the use of hydrogen.
Hydrogen can be produced on a laboratory scale by electrolysis of water or by influencing of diluted acids on zinc or iron.
Large scale industrially, hydrogen is produced by burning hydrocarbons with a following water gas reaction. The problem is that big amounts of CO_2 are emitted.
Innovative CVD (chemical vapor deposition) processes can produce hydrogen without any harmful emissions to the environment. The only by-products are carbon nanotubes and carbon nanofibers which have enormous potential because of their physical and chemical properties. High-performance composites, microelectronics, batteries, supercapacitors and fuel cells are some possible application areas.

The objective of the project was to plan and implement a thermo-catalytic process to split hydrocarbons, preferably Methane, into hydrogen and carbon nanotubes.
The economic benefit of this process, compared to state of the art methods, was demonstrated through the commercial exploitation of the carbon nanotubes inherently produced. In addition, the usage of natural gas from biologic origin was discussed.

To proof the concept a pilot facility was designed and realized allowing continuous processing, however, with strict regard to valid safety regulations in terms of machine operations and exposure of workers. The productivity of this novel reactor was demonstrated to exceed the original calculated capacity of carbon nanotubes and hydrogen.

This technology opens the door for hydrogen as a serious future energy source. Because of the emerging nanotechnology with its demand for carbon nanotubes and carbon nanofibers, this continuous production process will get more economical efficient in the next years. Also the fact, that two technically demanding materials are won with biogas as base material makes this process to a highly promising technology for the future.

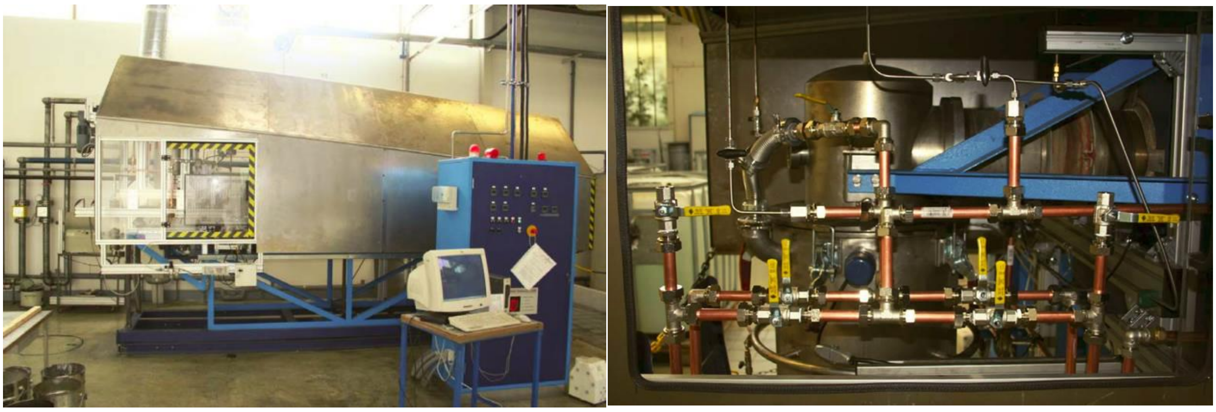


Figure 23: Continuous hydrogen-carbon nanofibers production line [cf. 69]

6.1.3. High efficient combination of solar thermal and heat pump systems [cf. 71]

The client of this research project was “Klima und Energiefonds” located in Vienna. The contractor, AEE – Institute for Sustainable Technologies located in Gleisdorf, was founded in 1988 as an independent research association and is one of the leading institutes for applied research in the fields of solar thermal energy, low-energy and zero energy buildings as well as in energy efficiency industry. In cooperation with the project partners University of Technology Graz, SOLution – Greiner Renewable Energy GmbH and the company Ochsner Wärmepumpen GmbH, different system concepts using a combination of solar thermal systems and heat pumps have been documented and analyzed. The project was completed in July, 2013.

First, AEE INTEC conducted a market analysis in order to obtain an overview about available solar thermal and heat pump combination systems on the Austrian market. These combination systems can be split into four categories: parallel, serial, regenerative and complex systems whereby parallel systems with 61 % are dominating.

The analysis of field test plants has shown that an implementation of solar thermal systems improved the coefficient of performance of the overall systems (between 13 % and 65 %). Another interesting result is that heat pumps are very sensible to small design and installation errors like sensor positions and storage connections. Also hydraulic and control schemes of the storage system affect the efficiency of the hybrid system a lot. In addition there is room for improvement in the dynamic power control of heat pump compressors especially in variable speed control and inverter technologies. Coordinated systems with a high degree of standardization have great benefits concerning system efficiency (heat losses, hydraulic, control) in comparison to individual systems.

AEE INTEC also point out that it will be necessary to have a standard evaluation scheme for combination systems in future. Various system boundaries and different detail levels of key performance indicators make it difficult for end customers to compare several combination options.

Solar thermal systems in combination with heat pump systems help to reduce electrical power requirements which save money for consumers. Another consequence of lower electrical power needs is that it relieves the Austrian electricity grid which is on the maximum load level right now.

Research projects like this are very important for finding the best way of energy supply in future. Thought out and well-tested hybrid and combination systems will play a pioneering role in the next generation of alternative energy sources.

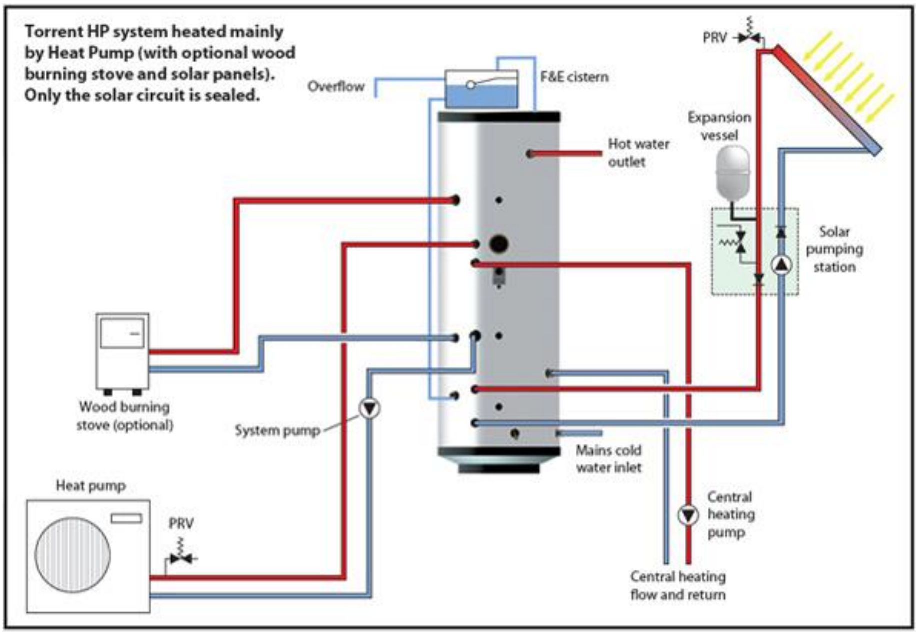


Figure 24: Solar thermal and heat pump system combination [cf. 72]

6.1.4. Demonstration plant Green Biorefinery [cf. 73] [cf. 76] [cf. 77]

The project “Demonstration plant Green Biorefinery” is another subproject of the program “Fabrik der Zukunft” (factories for the future). This demonstration plant is located in Utzenaich, Upper Austria.

In Austria, there is a lot of grassland which will be unused in the coming decades. The reason is that for today’s animal husbandry, the need for grass is declining.
Farmer and scientists look for solutions how to preserve this cultural landscape on the one hand and how to use the harvested biomass efficiently on the other hand.

The concept of a “Green Biorefinery” was elected as a so-called light-horse project for developing renewable technologies. The feedstock grass should be utilized to generate a variety of products beginning from lactic acid, amino acids up to biogas.

A main procedural step is the mechanical separation of grass into a solid fraction (press cake) and a liquid fraction (silage juice).
Silage juice is then further processed using ultra-nano-filtration units, ion-exchanger, electro dialyses and reverse osmosis to separate and purify lactic acid and amino acid to marketable quality standards.
The press cake which consists mainly out of fibers can be used to produce heat and electricity in a biogas plant or can be further processed to insulation materials, special animal feeds or building slabs.

The Green Biorefinery demonstration plant was put into operation in May, 2009 to test laboratory experiments on a larger scale.

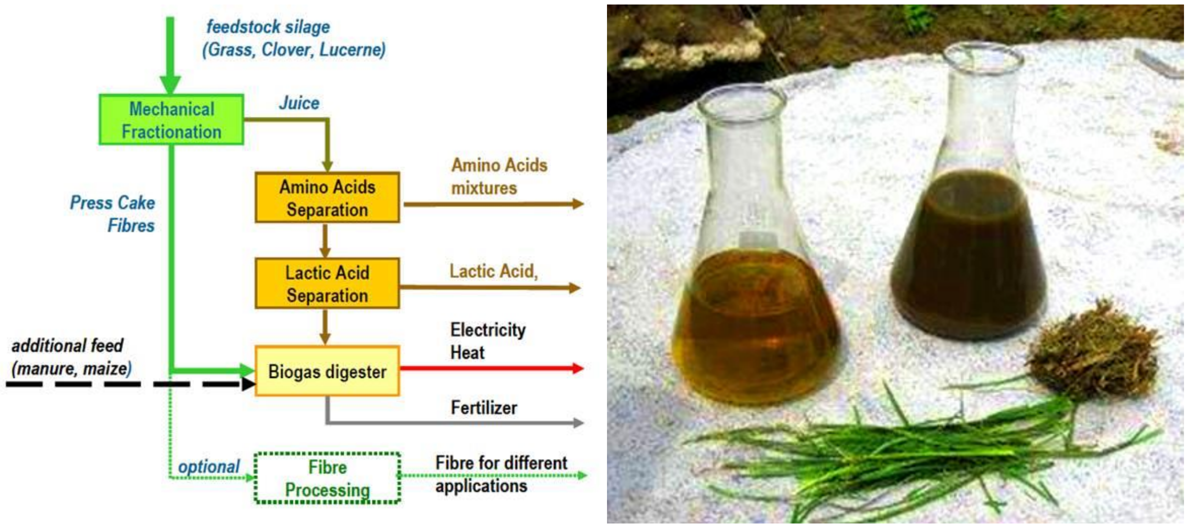


Figure 25: Green Biorefinery Demo Plant [cf. 73] [cf. 75]

6.1.1. Biomass thermal power station Güssing [cf. 78] [cf. 79]

Decentralized, regional adapted power plants will play a leading role for the production of heat and electricity in future.
In Güssing, Burgenland, a new type of power plant for wood gasification was realized in 2001. The cogeneration power plant has an electrical power output of 2 MW and a thermal power output of 4,5 MW by an investment of 10.9 million euros. The total efficiency of the power plant is 81.3 %
Members of the project development team were the plant manufacturer REPOTEC, EVN, RENET and scientists of the Vienna University of Technology.

The core of the plant is formed by two inter-connected fluidized bed systems of the fluidized bed steam gasifier (reactor).
In the gasification zone the cut-down biomass is whirled up and gasified at approximately 850 °C in the shortest time possible by introducing steam. The product gas is nitrogen-rich and low in tar. Then the products gas is cooled, purified and subsequently used in a gas engine to produce electrical energy. The waste heat is fed into the district heating grid.
Resulting flue gases are derived separately and the heat is also fed into the local heating grid.
The used bed material (olivine sand) has the function of a heat transfer medium and provides a stable temperature in the reactor.

Due to interesting properties of the product gas, other application areas used as a syngas are possible. Current research projects deal with various opportunities:

- Fisher-Tropsch synthesis for producing synthetic diesel.
- Generation of hydrogen-rich gas.

- Generation of natural gas by methanization.
- Optimization of the thermal power station: Catalytic cracking of tars, additives and bed materials to increase the quality of the product gas.
- Becoming energy central in terms of converting biogenic materials and wastes to heat, electricity, SNG and liquid fuels.
- Utilization of the gas in high-temperature fuel cells.

The biomass thermal power station is another flagship project of the region to become energy self-sufficient with local produced goods such as wood.
Other intended uses of the product gas (synthetic diesel, natural gas, etc.) contribute to enhance the profitability and to increase the flexibility of these plants. Being able to react quickly to market changes will be one important success factor for future businesses.
Pilot plants like this plant in Güssing are very important to gain knowledge about strengths and weaknesses of innovative ideas. Not only one technology will enable a turnaround of today's energy policy, a clever combination of renewable energy sources will be the foundation of the new energy age.

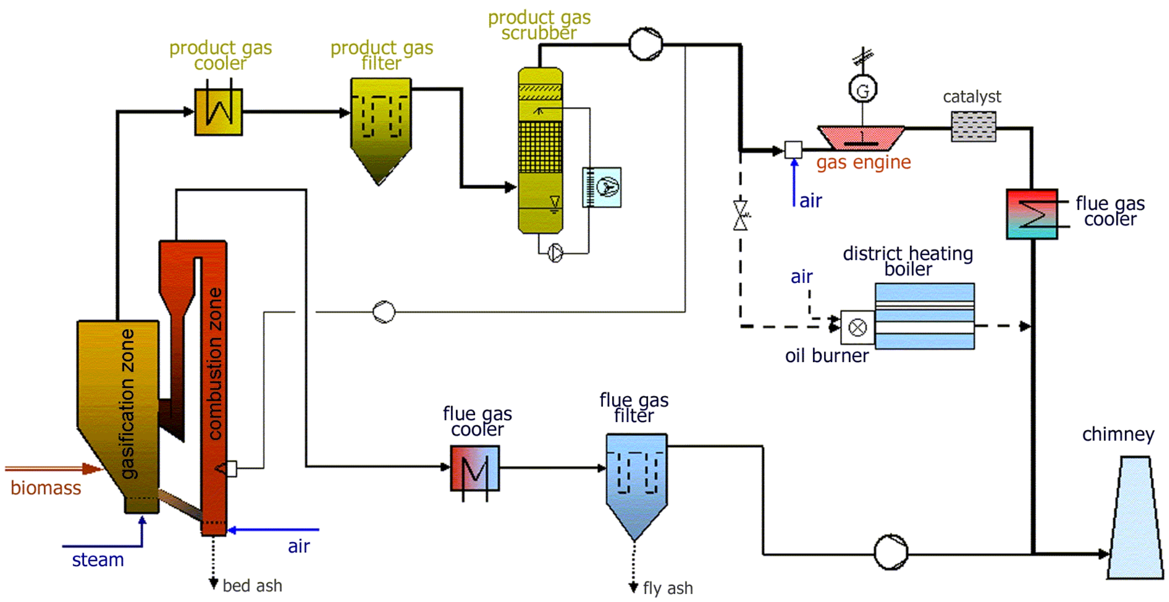


Figure 26: Biomass thermal power station Güssing [cf. 78]

6.2. USA

6.2.1. Lake Michigan Offshore Wind Assessment Project [cf. 28]

Grand Valley State University and its Michigan Alternative and Renewable Energy Center (MAREC) are working in partnership with GVSU's Padnos College of Engineering and Computing, the University of Michigan and its Michigan Memorial Phoenix Energy Institute, and the Michigan Natural Features Inventory of Michigan State University Extension on secured funding for the Lake Michigan Offshore Wind Assessment Project. The aim of this project is to develop an understanding for offshore wind resources as well as other conditions on Lake Michigan and the rest of the Great Lakes, for a future development progress of offshore wind energy technology in the U.S.

Figure 27: Lake Michigan offshore wind assessment project [cf. 28]

The project received $1.4 Million in initial funding support from the U.S. Department of Energy through a congressional allocation. Required local match funding support was obtained from the Michigan Public Service Commission with a $1.33 Million grant award. Additional project funding in the amount of $260,084 is being provided by the University of Michigan.

The project will deploy an extended season offshore wind assessment research buoy that will feature the use of LIDAR (Light Detection and Ranging) laser light pulse technology as an alternative to traditional cup anemometer wind measurement instrumentation. The project will conduct correlation studies, in part, by using near-shore MET tower locations in conjunction with the State of Michigan Tall Towers project and other shore based towers.
The GVSU buoy will be deployed in multiple locations over the life of the project, including the mid-lake plateau region of Lake Michigan. In addition to the

measurement of wind, the GVSU buoy includes equipment to assess water quality, conduct aquatic studies, as well as avian activity. The project will follow-up on the work and study results of GLOW, the Great Lakes Offshore Wind Council, appointed in January of 2009. The GLOW Council and other recent Great Lakes studies have identified the need for additional research of year-round wind conditions and related environmental factors critical to future development of off-shore wind energy technology on the Great Lakes.

Identified as a rich and promising source of wind energy, the Great Lakes are presently being considered as a potential source for meeting a significant portion of our renewable energy needs in the Great Lakes region in the decades to come. The Offshore Wind Assessment Project hopes to contribute to a greater understanding of this significant renewable energy resource.

6.2.2. Copper Mountain Solar 1 [cf. 29]

The Copper Mountain Solar 1 photovoltaic solar power plant is located in Boulder City, Nevada. The 48 MW plant is the largest utility-scale photovoltaic power plant in the U.S. Generating electricity demand for about 14,000 households, all emission-free. It was built at a cost of $141,000,000. The plant was officially dedicated in March 2011 by the Nevada Governor, Boulder City Mayor and the president and chief executive officer of Sempra Generation.

Figure 28: Copper Mountain Solar 1 [cf. 29]

The Copper Mountain Solar 1 plant is located on a **320,000** m² desert site in Boulder City. The construction of the 48 MW plant started in January 2010 and was completed and went online in December 2010.

At first Copper Mountain 1 delivered electricity to the power grid after installation of 8 MW in June 2010. The project thus achieved a major milestone within five months of construction. A total of 103,000 steel posts were erected to hold 775,000 solar panels. And in order to ensure the alignment to the sun, the steel units were installed using lasers and a global positioning system.

Sempra Generation has planned to expand its existing facility by more than 200MW. In August 2011, the company announced it was to build Copper Mountain Solar 2, an expansion of Copper Mountain Solar 1. When completed in 2015, the 150MW plant will become the largest photovoltaic power plant in North America and produce emission-free energy, powering about 45,000 households, measuring **4,450,000 m² of solar panels.**

6.2.3. Alta Wind Energy Center, California [cf. 30]

Figure 29: Alta Wind Energy Center [cf. 30]

Alta Wind Energy Center (AWEC), also known as the Mojave Wind Farm, is the second largest onshore wind energy project in the world. It is owned by Terra-Gen Power, an affiliate of Arclight Capital Partners and Global Infrastructure Partners. The project will supply 1,550 MW of clean energy for more than 25 years under a 3,000 MW wind power development initiative upon its completion.

The incredible area of 13,000,000 m² are lying in the foothills of the Tehachapi Mountains in Kern County, AWEC is located just two miles from the Tehachapi wind resource area, which consists of wind farms constructed in the 1970s and 1980s. The turbines have been installed at altitudes ranging from 3,000ft to 6,000ft above sea level. The first phase of AWEC began in July 2010 and consisted of units I to V, which were completed in April 2011. Construction of units VI and VIII began in early 2011 and building of the additional units VII and IX started in April 2012.

Terra-Gen took over the Alta project from Australian infrastructure fund Allco Finance Group after the company discontinued its 'Alta - Oak Creek Mojave' initiative because of bankruptcy in the early 2000s.

Terra-Gen offered $325m to the company for acquiring the project. It will see the installation of up to 600 wind turbines in total, serving the electricity needs of 257,000 California homes upon completion. Construction and installation of some 300 turbines is expected to start in 2015; these will generate around 830MW. Other infrastructure includes communication cables with data input monitored by a SCADA system, meteorological towers, a lightning protection system and other operations and maintenance facilities. The transmission line includes a single six-mile long 230kV line, connecting the SCE's Windhub substation. Graders and power haulers are used for transferring the turbines to the project site.

The first phase of AWEC consisting of units I to V became operational in April 2011. Unit I has an installed capacity of 150 MW and was the first unit to be connected to the Windhub substation. Unit I is installed with GE 1.5 MW turbines. Units II to V have installed capacity of 150 MW, 150 MW, 102 MW and 168 MW respectively. Construction of units VI and VIII began in January 2011. The two units will have an installed capacity of 150 MW each. A total of 100 turbines will be installed for the two units, which are expected to be completed during 2012. Units VII and IX also use the same turbine types and the construction work on them started in April 2012. Their completion will increase the generating capacity of the AWEC to 1,320MW.

6.2.4. Agrilectric Power in Louisiana runs "zero waste" biomass facility [cf. 31]

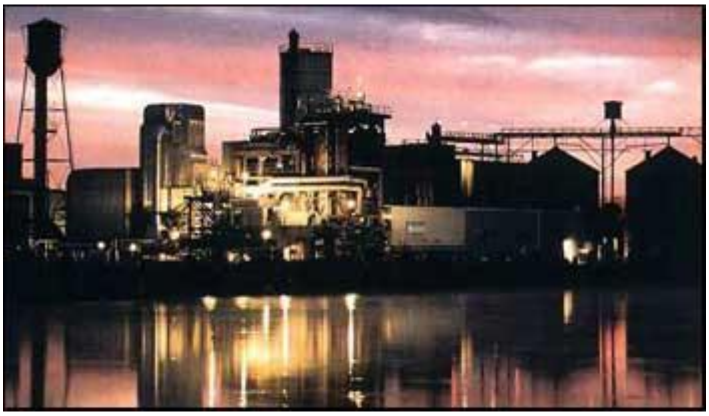


Figure 30: Agrilectric power partners facility [cf. 31]

The Agrilectric Power Partners facility in Lake Charles, Louisiana – part of a rice mill complex owned by the 115-year-old Powell Group – certainly produces renewable energy. Instead of wood, however, its fuel of choice is rice hulls, because Rice is a huge industry in southwestern Louisiana. According to the USA Rice Federation, the rice processing and production account for about $300 million for the state, making it Louisiana's second largest industry. A challenge to rice millers has been how to dispose of rice hulls after the "meat" of the plant has been extracted to sell as a food product for humans and animals. While small in size, a rice hull is made of well over 95% silica – an extremely hard and durable substance that is most typically found in nature as sand or quartz. Silica is a notoriously difficult byproduct to dispose of; it can take decades for discarded rice hulls to completely biodegrade when buried or placed in a landfill.

In the early 1980s, well before ´the boom of biomass began to be used as a viable source of energy in California, Agrilectric came up with a brilliant solution to the problem of rice hull disposal: it would burn the hulls in a boiler to power the rest of its operations. This method was very successful in reducing waste and disposal costs and in saving energy costs for the rice mill. The company sells the excess power from the 12 MW facility to a local utility on the electric grid. It also discovered that the ash produced from burning rice hulls was a sought-after commodity that it could sell for use as an insulator in the steel making industry.

In recent decades, as the biomass industry began to grow and become increasingly regulated, Agrilectric noticed one more benefit to its rice hull disposal method: this form of biomass produces very few emissions, as its moisture content is very low. Additionally, aside from the trucks used to transport the raw rice product to the facility, materials are moved within the facility pneumatically – meaning there are very few transportation-related emissions.

7. Visions for FH JOANNEUM - Engineering and production management

7.1. What defines a good engineer?

Engineers are often compared to artists. A good engineer might be a creative, but also critical person whose mind is full of visions. And in contrast to non-engineers, this person is capable of transforming his or her ideas into reality, using their skills and knowledge. An engineer's aim should not be to simply change the world, but to change the lives of the people and future generations of this world and make it better, filled with more life quality than it was the day before.

7.2. What this means for production engineering

Manufacturing is the main driver for the increasing quality of life of the people on this planet. Mass production means affordable products, and affordable products mean good life quality for the majority – and this is where the true power of manufacturing can be seen. But on the other side, these forces are reliable for all the impacts of the usage of the resources which cause deep impacts and damages to the environment and society. This is what makes manufacturing, as an entire system, very powerful and dangerous at the same time. Hence, mankind would be well advised to grow their future engineers with greatest care, teaching them ecology and macroeconomics, before talking about Pythagoras' theorem. However, focusing only on research and industrial application is rather short term thinking. For a production engineer sustainability is not a vogue word – it should be the key principal in the overall thinking. Consequently, the integration of this issue into the education of engineering students is the key to a long-term perspective.

7.3. EPM Contents

The teaching in Engineering has to integrate methods and tools for the sustainable development into the curriculum. The center of this approach could be the three pillar model from part 2.2., with respect to the interests of each "pillar". The contents in EPM master degree program (Engineering and Production Management) have to effectively connect the students' individual development and excitement, for encouraging their own thoughts and problem solving strategies. Hence, the dual concept of the EPM master degree program, with its cooperative education system and partner companies, offers ideal and unique possibilities for each student.
The educational concept of the single lectures does not only consider Engineering subjects from the traditional perspective, but should moreover be looking at them from an interdisciplinary point of view [cf. 3]. Future graduates should be equipped with the ability to understand both technological processes and the creative arts of managing these, ready for tomorrow's industrial challenges.

7.4. Specific ideas

The following listing represents ideas of lectures that could be an essential knowledge basement for tomorrow's production engineers:

- **Creative Engineering/ Product and Process Innovation**: Being or becoming a creative, innovative, but critical engineer at the same time should be a goal for a modern engineer.
- **Sustainable Manufacturing (Engineering/ Management)**: Every engineer, but especially production engineers should be capable of the knowledge, or at a least have an overview, of Sustainability in every sense.
- **Macroeconomics**: A great addendum to a subject dealing with sustainability, in order to understand economic impacts of produced goods and its importance in the world financial system.
- **Troubleshooting/ Social Management**: Lots of good engineers have a lack of social skills, hence, this could be a way for enhancing the social power and strengthen an engineer's three pillars of sustainability.
- **Engineering Law and Responsibility**: This lecture shall emphasize on laws and attitudes towards threats or risks of being an engineer in a leading position in the industry.
- **Sustainable Supply Chains and Business Strategies**: Another very good add-on to macroeconomic functions and theories.
- **Energy Management and Globalization**: This includes similar contents towards Sustainability, with a greater focus on globalization and the requirements of a world population concerning manufacturing.
- **Socio Technologic Systems**: The coexistence and importance of technology in social systems is a key knowledge in future organizations and companies. Could easily be integrated into most of the previous topics.

8. Conclusion and outlook for the future

Green Manufacturing is booming right now with bright prospects for the future.
The upward trend is based on the fact that fossil energy sources are becoming more and more expensive, because resources are running out and energy demands are increasing. But not only competition pressure also pressure from governments and society/consumers lead to a rethink in terms of reducing harmful emissions to our environment.

There are a lot of alternative energy sources which can contribute to partially substitute fossil energy sources. Geothermal energy, biomass, hydrogen power, solar energy, wind energy and waste-to-energy solutions are promising technologies in this field. In fact there won't be a single energy source in future, well through-out combinations and hybrid systems which use best environmental conditions will solve upcoming energy problems.

In addition to alternative energy sources, negative environmental impacts can also be reduced during the total life-cycle of products. Each sub-process (design, purchasing, manufacturing, packaging and distribution, in-use and end-of life) must be examined and continuous improved to become more environmentally friendly.
For instance, there is a great potential in novel materials. Mushroom materials can replace plastic foams insulation and packaging materials, thermoelectric materials can improve energy efficiency of high-temperature waste-heat processes and regrowing bio-composites are opportunities to compensate oil-based plastic products. Heat recovery systems, thermal storage systems and heat pumps/refrigeration systems help to increase overall efficiencies so that money can be saved and emissions can be drastically reduced. Modern lighting and state-of-the-art compressed air systems are other possibilities to achieve higher energy efficiency levels in the manufacturing area.
At the end of each product life cycle, reusing and recycling are great chances instead of storing all products at waste disposal sites.

Austria as well as the United States of America is pushing projects in the field of renewable energy sources, energy efficiency and innovative production processes.
Besides governmental supported research and development activities, legislative framework conditions and funding opportunities are very important aspects. Fair competition and start-up support for sustainable solutions are necessary to encourage today's economy to invest in a greener future.

Academic programs or integrated academic courses which focus on Green Manufacturing are the foundation for the engineers of tomorrow. The dual master program "Engineering and Production Management" at FH JOANNEUM offers a unique possibility to understand both technological aspects and how to manage innovative approaches. Future graduates should be ready for the new industrial age.

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