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COMPARISON OF AVAILABLE RENEWABLE ENERGY SYSTEM FOR MAGNA CAMPUS

Diploma Thesis

Field of study: Mechanical Engineering and Business Economics – Production Science and Management

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Graz University of Technology
Graz, May 2010

Statutory declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all the material which has been quoted either literally or by content from the used sources.

Graz, May 2010

Sundeep Reddy Shada

Acknowledgement

With the oil price hiking and depleting oil resources has made the world thinking about new technologies for energy. I strongly believe that this is the time for a change, when Mr Bodner offered me this thesis I was really happy and agreed to work on it. As the alternative energies are ecofriendly technologies and do not account to global warming, from the business point of view they are cheap fuels. This makes it interesting and profitable for investing in green technologies. As the governments are pushing money into green projects there would be good funding and maintenance plans from the state.

I would like to sincerely thank Mr. Peter Bodner and Ms. Ines Käeshmayer of Magna international for their dedicated support.

I would like to express my gratefulness to Mr. Georg Premm and Mr. Hannes Fuchs of Graz University of Technology for their informative and beneficial suggestions and support they rendered.

Last but not least I would like to express my thankfulness to my parents and family, who have supported me all long my study period.

Sundeep Reddy Shada

Abstract

The main aim of the thesis was to develop an alternative energy system for two high energy consuming buildings at the magna campus in aurora, which would be able to use the biomass generated in the campus from horses, golf course and from the community.

The environmental conditions of the buildings were the main factors influencing the plans. High priority was given for minimal replacement of the current energy system employed. All the energy needs and the reasons for the energy usage are carefully examined for reaching the goals. Having the above stated considerations as the ground rules all the available alternative energy sources are examined. Considering the environment in the campus and other governing factors scenarios were developed. Three scenarios were developed with technical facts and feasibilities. The economic facts are also stated along with the investments and payback times.

All the results are summarized in form of a comparison between the three scenarios in technical and economic terms. An earnings prediction for the next ten years has also been calculated and stated. Having the results together would make the decision maker to make a judgment easier for the final erection of the plant.

From the prospective of a major electric equipment manufacturer the future electric power generation is not only form power plants but from smart electric grids. These grids are connected to homes, buildings, cars, and power plants, and all take energy from the grid as well as supply energy to the grid. If this is the case then there would be demand for small independent energy systems that would run on renewable energy, as this is the time to realize the future this would be a good time to invest in projects like the one that has been described in this master thesis.

Contents

1 Introduction

Every Industry today is talking about green technologies. So what does green really mean? The answer is to be friendly to nature and environment. According to the United Nations environment program green energy means , energy sources that can be grown, and harvested, similar to other products of the land such as food and fodder[1]. The initial picture when industries heard about it year ago was uneconomical, as it was indirectly stating to invest money in things which would be unprofitable in economic senses, but as time passed things have changed. With the increase in fuel price energy costs have increased to a great extent[2].

Now at this moment of time where every drop of oil is counting industries and individuals start searching for new technologies which are non-depended on fossil fuels. This new search has pushed research into renewable energies, now investing in green energy technologies is making profit. In this thesis investigation is carried out about investing money for an independent heat and power plant system, which would be using renewable forms of energy.

1.1 Magna Group

Magna international is a major automotive supplier listed in Toronto stock exchange as MG and in New York stock exchange as MGA. Having their corporate headquarters located in Aurora in Canada. Magna group at the moment employees approximately 72,500 employees in 238 manufacturing operations and 79 research centers. They have a global presence having centers in 25 countries. Generating turnover of $1100 million in 2007 and a loss of $500million in 2009 this is due to the global turmoil magna group could still survive the losses due to their strong profit position previous years and innovative steering top management[3].

Magna group delivers services in engineering and production from single parts to whole car assemblies to automotive industries unlike their other competitors. This gives magna group a unique position among the competition[4].

The ten division’s in magna group are financially independent but are strongly connected to the head office. The groups show a great diversity within the automotive industry (shown in Figure 1.1).

[1] United Nations (1991),p.4
[2]http://www.ifpaenergyconference.com/Green-Energy.html Retrieved 30.04.2010
[3]http://www.magna.com/magna/de Retrieved 12.04.2010
[4]Weber (2009), p.3

Figure 1.1 Divisions of magna group[5]

1.2 Task description

The idea to have a feasible economical alternative energy plan for magna campus in aurora first as a pilot project and after running the plant and having a successful result, this would turn out to be a new business wing of magna international came from Mr. Frank Stronach himself. As all the companies were talking about going green this would be a good publicity point. At the same time it would be economical in terms of savings after the plant is installed. The task of the project team was to check the environmental condition, to check the economic feasibility of these systems and to develop partnerships with organizations for future. For this Master thesis the tasks were

- To investigate available renewable energy system for buildings 337 and 375 in MAGNA campus
- Compare the economic feasibility of these systems
- Provide investigation for most feasible solution
- Assess economic feasibility of suggested system

[5] By courtesy Magna International

1.3 Methodology

As this was an information gathering stage and a planning phase during the start of the project there was no information available.

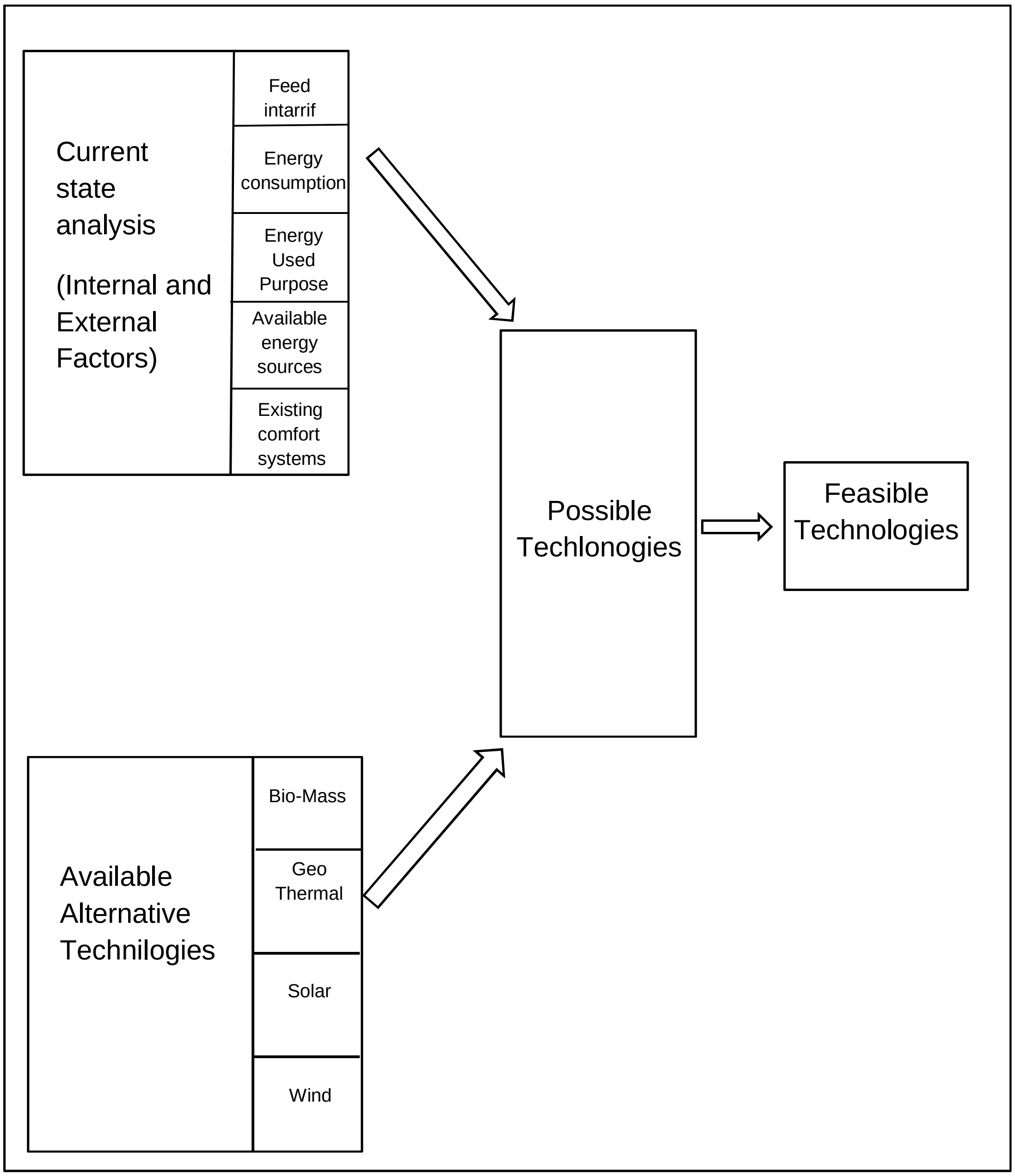

Figure 1.2: Schematic representation of methodology followed for this master thesis

Project group in Canada gathered the historical energy consumption data form the electricity and gas bills from the campus. At this stage information was available about how much energy is needed.

This was the start point of the project. There was an idea to use biomass as the required ground work and research was already made by the group before starting the project. One of the other main intentions was to use the horse manure from the horses in the campus, the chipped grass from the golf course and the bio-waste from the campus. Having these as ground rules the work was started.

As a start internet search was made to find data about subsides and rebates that are available in the region and all the environmental facts such as the quantity of usable biomass that is available from the campus and other were calculated. Then the search of suppliers in form of technology and products was done. As the key business of magna group is not in heating systems partnership opportunities for future business were also made by the working group from the company. From the energy data from the campus and technical data from companies and universities were used to compare and finally scenarios were developed. These are explained in the final chapter. These scenarios not only use bio-mass but use more forms of renewable energies as the research in the ongoing time showed that a mixed approach would lead to better results.

1.4 Structure

In the first chapter a description of the company the task and the methodology that has been followed to achieve the goal has been made. From this section of the thesis an overview of the initial situation of the project and what was to be delivers form the thesis is clearly explained in the first chapter.

In the second chapter the current energy scenario i.e. the energy consumption details, the campus information like the location, buildings, the comfort systems employed in the buildings are discussed. Along with this the rebate and incentive programs from Ontario government are also discussed in this chapter. The information about the bio-mass available in form of horse manure and other forms available in the campus are also stated.

In the third chapter the suitable renewable energy systems are explained in brief. The availability and the method to harness these renewable energy systems are explained. From this chapter one could get an idea of available renewable energy systems. This section of the thesis is not dedicated only to this particular problem but can be used in any situation where there is a need to install or think about renewable energies.

In the fourth chapter the scenarios that are developed from the research are explained. The investments that are to be made and considerations that are made during the calculations and the economic impact of the scenarios, such as the payback time and earnings from these scenarios are given. The comparison of these scenarios in terms of investment, payback time and long term earnings are discussed, the final decision of installing the plant has to be done by the top management of Magna group. As they have to invest and the most interesting scenario for them makes sense in investing.

In the final chapter the future work that has to be done in order to have a successful implementation of these scenarios are stated. The opportunities for new business are also given.

2 Current state analysis

In order to understand the current situation for the research, several aspects have to be thoroughly analysed. Firstly, the Magna Campus which includes the buildings, facilities and surroundings will be firstly discussed.

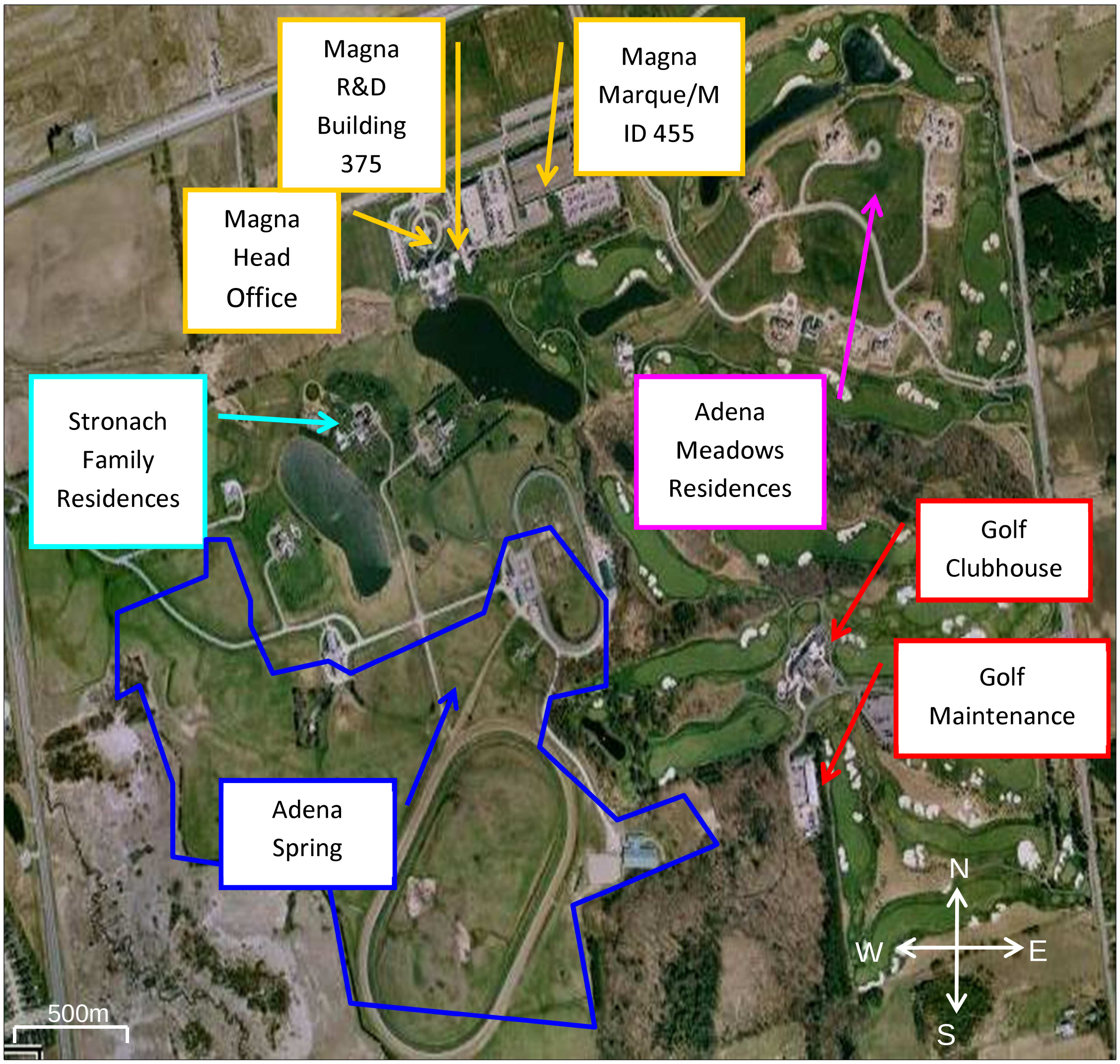

Figure 2.1: Magna campus Aurora, Canada.[6]

[6]http://maps.google.com/maps?oe=UTF-8&gfns=1&q=google%20maps&um=1&ie=UTF-8&sa=N&hl=en&tab=wlRetrieved: 08.04.2010.

This will be followed by the detail description about the heating and cooling systems used. Further issues like environmental analysis, feed in tariffs, and special benefits from the government will also be described. Environmental analyses such as the feed in tariffs, special benefits from government and new business opportunities that are possible from the idea of green energy are also mentioned.

2.1 Area and biomass availability description

The area surrounded by Wellington Street east in the south, east by LenslieStreet, north by VandorfSideroadand west by Bayview Avenue in clockwise direction is referred as Magna campus here after. This area has the following buildings

- Magna Drive 336: Magna head quarters
- Magna Drive 375: Magna R&D building
- Magna Drive 445: Magna marque (e-car facility)
- Magna golf club
- Adena meadow residences

The campus has a total area of twenty five square meters approximately.These buildings are places wide apart as shown in Figure 2.1.This thesis is concentrated on magna drive 336 and 375 buildings as they are place closed and these are major energy consuming buildings. The energy demands, the systems used for heating and cooling and other energy consuming equipment details are given in the next sections.

The Adena meadows residences have 20 houses having and surface area in between 557.5 and 930 square meters. These have an average electrical consumption of 10000kWh and an average gas consumption of 8100 cubic meters. Stronach residences have three large homes from 650-930 square meters and 3 small homes of 111.5 square meters and there are 6 dorms of 465 square meters. In the Adena springs there are 120 Horses and every 1000 Kilograms of horse produces 50 kilogram manure every day which is equivalent to 3000 liters of oil or 30000kWh per year. The grass cut during the maintenance operation in the campus from the golf course and other garden areas can also be a form of biomass. This can be used for useful proposes instead of paying them off for disposal.

The aurora community residences are from 13-34 square feet. There are total of 100 houses in this community and they have an annual average consumption of 8000kWh and annual average gas consumption of 2700 cubic meter. As these are residential houses the bio-waste from these houses can also be used as fuel for a bio-mass energy plant if installed.

2.2 Energy demand and comfort system's employed

As there are records available for buildings 337 and 375 and as these are the most energy consuming buildings the annual electrical and gas consumption data is given in Figure 2.2

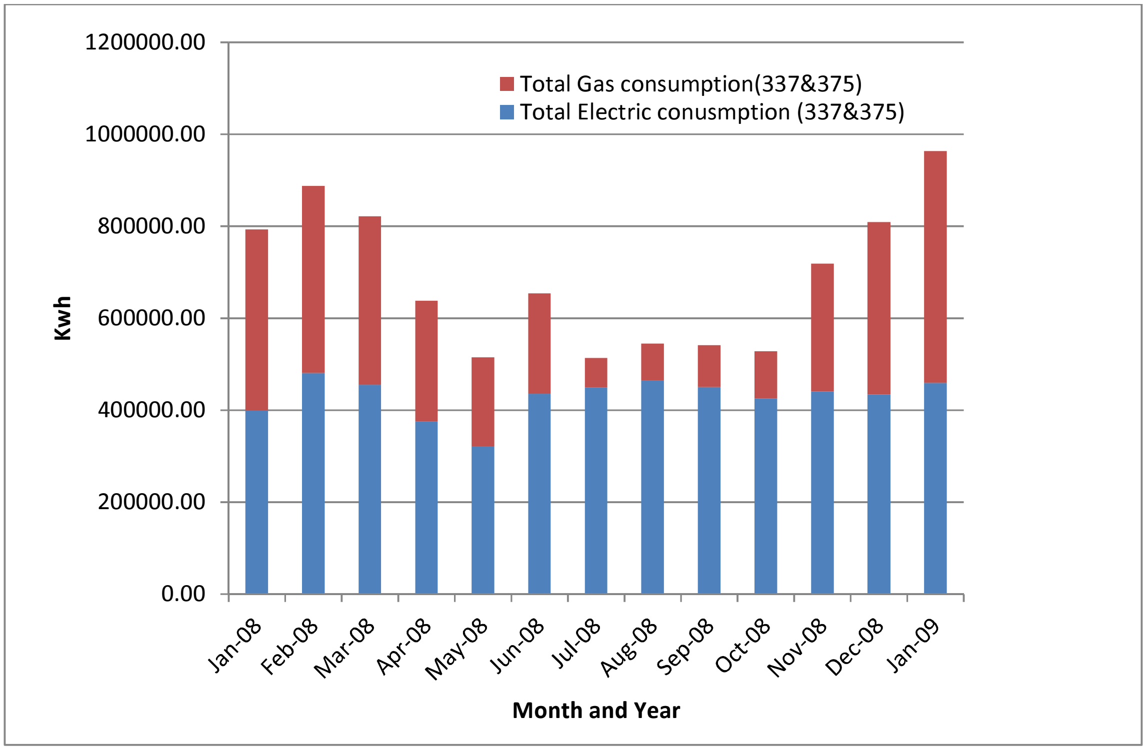

Figure 2.2: Total energy consumption for buildings 337 and 375

From Figure 2.2 could be deciphered that there is a high usage of electricity in the summer months that is from June till September. This could be justified from the use of air-conditioning, as this is electrically power there is an increase in electric demand. The gas demand is more in winter a month that is November till April this is justified by the use of gas for heating the space. But still there is some amount of gas that is used every month; this is used for heating water. The need for hot water is all along the year so there is need for gas along the year. The interesting thing that can be observed from the graph is that there is a high electric need in the winter months also. When a study was done for the high usage of electricity in winter months, the result was use of portable heating systems by the employees under the desk.

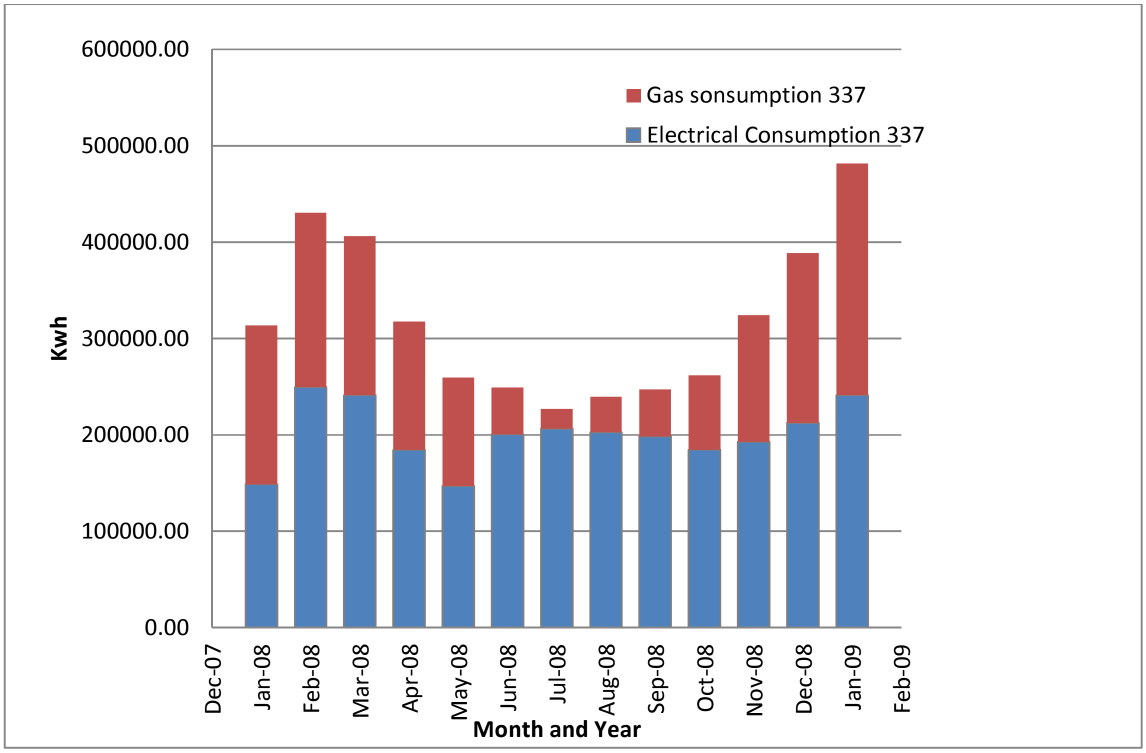

Figure 2.3: Total energy consumption of Building 337

The reason for the use of portable heating systems was in adequate heating temperatures in the offices. One of the important things to think before installing new system would be the size of the existing heating system.

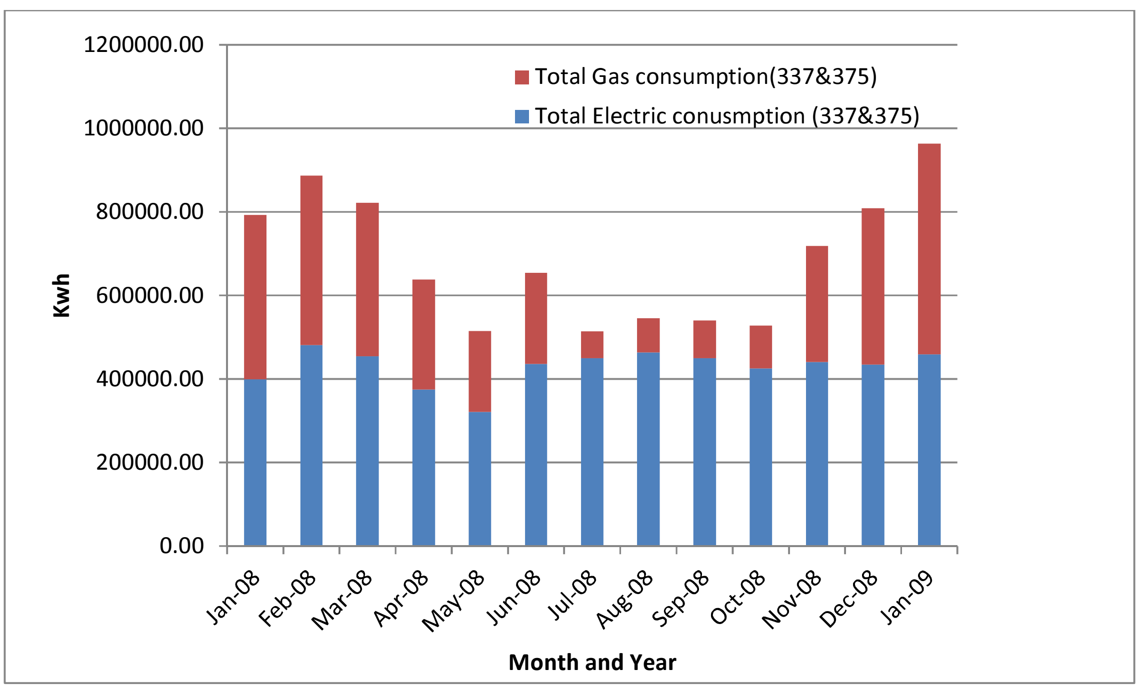

Figure 2.4: Total Energy consumption of Building 337

There is a high electrical need in this building alone also in the winter months. He reason for this is the same as before, this is due to the portable heating systems.

There is the same energy trend even from the building 337. From the Figure 2.4 it is clear that the electrical demand is high in winter due to the electrical cooling system. The usage of the portable heating systems effect is seen even in building 337 and there is a high energy usage in winter months too.

2.3 Heating system

Heating system employed in the campus is combined radiant and forced air heating. Heat is generated in a gas-fired low-pressure boiler which heats a glycol circuit. The circuit passes through radiant heating panels throughout the building and the heat in form of radiation is transferred to the space and objects in the buildings. Additionally, the circuit transfers heat to a ventilation system that distributes forced-air heat through ducts to registers located throughout the building.

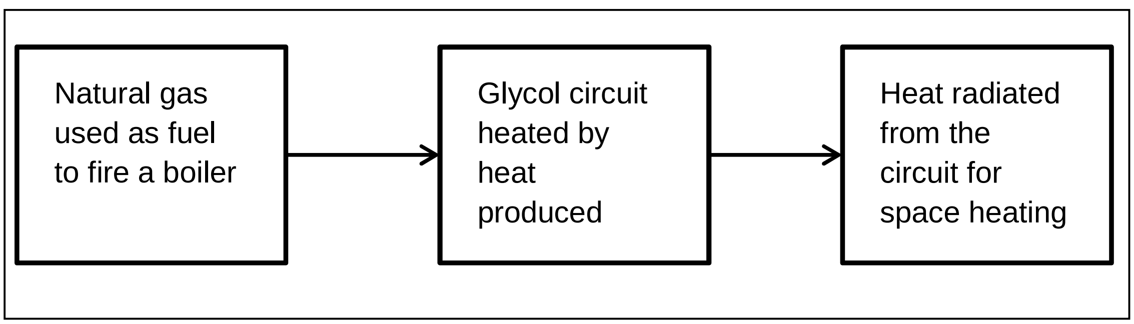

Figure 2.5: Schematic diagram of heating system in magna campus

2.4 Cooling system

The air-conditioning system that is employed in the magna buildings is electric radiant (evaporative) cooling which is explained by a schematic sketch in Figure 2.6 : An electric evaporative water chiller cools a glycol cooling circuit which transfers cooling to a ventilation system that distributes cold air through ducts throughout the building.

Water chiller air-conditioning is used in large and complex HVAC applications. For these applications, the use of chilled water systems is dedicated. This is typical; the chilled water systems are employed in large buildings such as office's laboratories etc. or in multi building campuses where the cooling is supplied from a single central cooling facility.

As shown in Figure 2.6 the water cooled air-conditioning system has three heat transfer loops in loop 1 cold air is blown into the facility or buildings by use of blower which are located in the ducts used for cooling. The air gain heat from natural sources such direct solar radiation through windows and walls through radiation and the internal heat from appliances such as computers lights are other equipment, heat from the humans is also transferred to the air in the buildings. Latent heat gains, the moisture that is added by people and appliances are also absorbed by the cold air which results in increase in its specific humidity.

In the second loop the air is returned to the air handling equipment which is mixed with the outdoor air for ventilation, and this is directed toward a cooling coil which has a supply of chilled water in order to extract heat from the air resulting in lower temperature and moisture air. This is then pumped into the space where cooling is required. In this way the moisture and temperature of the space is maintained. When the extraction of heat from the air is done the chilled water gains heat and the temperature is raised about 5-7ºC. The water is returned to the chilled water supply where the heat is transferred to the refrigerant and the water is cooled to desired temperature. As this is the heat flow work has to be done in order for heat transfer from a cold medium to a hot medium. This work is done by the compressor on the refrigerant for the cooling to occur. As the chillers are refrigerant cooled the compressor heat is added to the building heat and these are rejected thought he condenser

In the third loop the amount of heat that is experienced by the compressor completely depends on the efficiency of the compressor. The amount of heat that must be rejected by the condenser to the heat sink must be added to the heat load on the chiller water loop[7].

[7] W.Stanford/Herbert(2003), p.5 ff

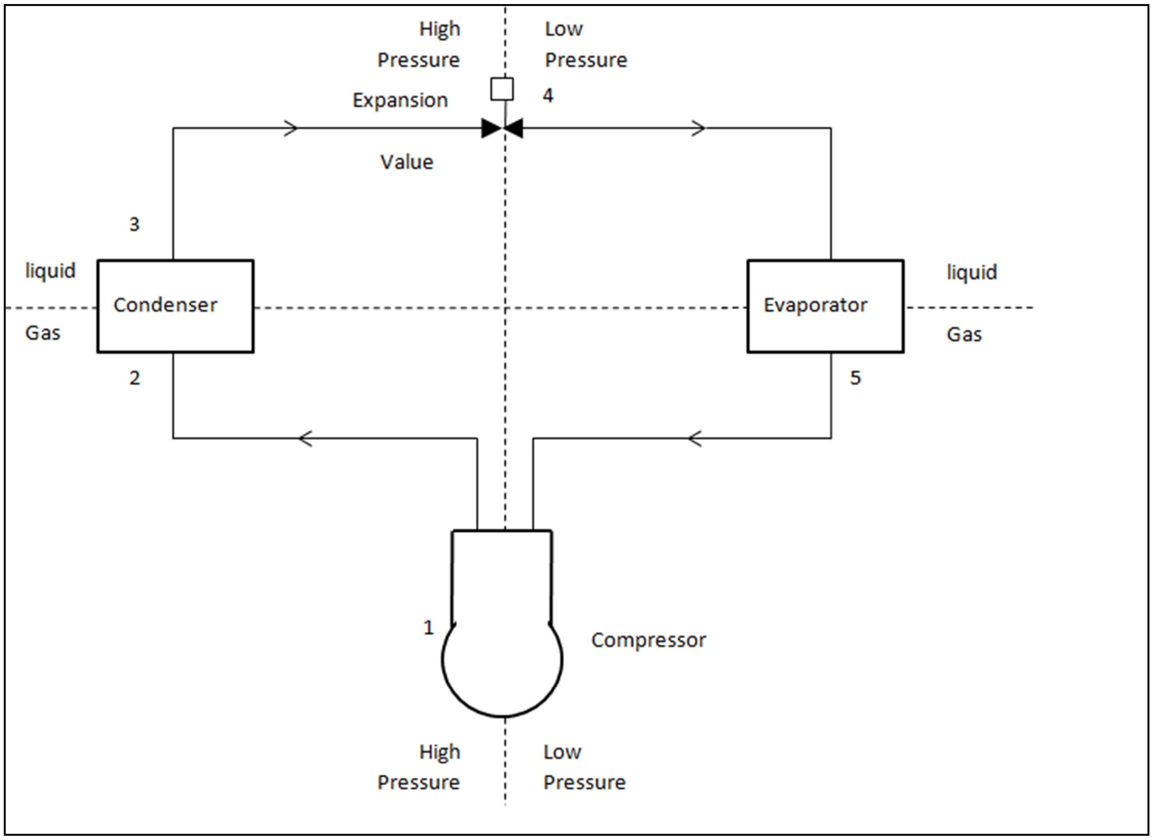

Figure 2.6 : Water cooled HVAC system schematic[8]

2.5 Feed in tariff's and government subsidies

From the website of ministry of energy and infrastructure of Ontario their view says that "The Ontario government is focused on bringing cleaner, green electricity to life"[9].

The Green Energy Act that has been announced recently will provide opportunities for homeowners, farmers, businesses, Aboriginal communities, and community groups throughout Ontario to undertake renewable energy projects of their own.

The green energy act was announced on May 14, 2009. The green energy act will increase the investments in renewable energy projects and help preserving nature, creating jobs and ensuring economic growth to Ontario. The GEA is based on Ontario government's earlier initiatives which including plans to eliminate coal from

[8]W.Stanford/Herbert(2003), p.7
[9] http://www.mei.gov.on.ca/en/energy/renewable/ Retreived:10.05.2010

the power supply. Coal-fired generation is the single largest source of air pollution in Ontario and eliminating it from the supply mix will be the largest climate change initiative in Canada.

A special feed-in tariff program is a guaranteed funding structure that promises competitive prices in a long-term contract basis for energy generated from renewable sources. All the house owners or business owners are eligible for this program if they generate electricity from renewable sources such as wind, water, biomass or biogas, solar and landfill gas. The Ontario power authority would be responsible for the FIT program and the tariffs are given in Table 1[10].

Technology	Size	CAD/kWh
Biomass	<10MW	0.0138
	>10MW	0.013
Biogas		
on farm	<100kW	0.0195
on farm	>100kW < 250kW	0.0185
Biogas	<500Kw	0.016
Biogas	>500kW < 10MW	0.0147
	>10MW	0.0104
Wind		
onshore	Any size	0.0135
offshore	Any size	0.019

Table 1Feed in tariff for renewable energy production[11]

[10]http://www.mei.gov.on.ca/en/energy/renewable/index.php?page=fit Retrieved 09.04.2010
[11] http://www.mei.gov.on.ca/en/energy/renewable/index.php?page=fit Retrieved 09.04.2010

2.6 Energy crisis

The world is now facing its most serious challenge ever. The name of that challenge is peak energy.

If an immediate action is not taken, peak energy could prove to be a crisis worse than world wars, more unruly than plagues, and more dangerous than crop failure. We're talking about a crisis of epic proportions that will change everything. And rest assured that it will not discriminate. That may sound hyperbolic to you now, but bythe end of this section, you will understand why it is said.

Everyone depends on some of the other form of energy for everything. Our entire way of life, and all of our economic projections, is built on the assumption that there will always be more energy when is needed. But the global energy depletion has started already and few have realized it.

The people who have realized the crisis are the lucky ones, challenge of peak energy and developed some solutions early in the game giving us the opportunity to be well - positioned to not only profit from the renewable energy revolution that is already occurring, but to thrive.

By the end of the section one would have a full understanding of what peak energy is, how it affects the future of global economy, and why is it important that this challenge of peak energy is met ahead - on with renewable energy solutions. This will ultimately lead us to profits via the companies that are providing the solutions both in the near -term and as well into the future.

2.7 Peak energy

The production of any finite resource generally follows a bell curve shape. The start is by producing a little, and then increases it over time; then you reach a peak production rate, after which it declines to make the back side of the curve. Between now and 2025, one could see the peak of every single one of our finite fuel resources. But why is the peak important? Because after the peak, there would be rapid decline of these fuels, leaving the world vulnerable to what could amount to the biggest disruption the global economy has ever witnessed. This would be a disruption that could spark an international crisis of epic proportions.

2.7.1 Peak oil

The first resource that will peak is oil, which is also our most important and valuable fuel resource. Here are some simple facts about peak oil:

- The world's largest oil reservoirs are mature.
- Approximately three - quarters of the world's current oil production is from fields that were discovered prior to 1970, which are past their peaks and beginning their declines.
- Much of the remaining quarter comes from fields that are 10 to 15 years old.
- New fields are diminishing in number and size every year, and this trend has held for over a decade[12].

Overall, the oil fields that are used to meet our demand are old, and their production is declining, thereby driving the petroleum industry closer to the peak and our global economy closer to the verge of catastrophe. As when these fields go empty, our life's come to a virtual halt. And unfortunately, as today's oil fields are struggling at this moment to keep pace with demand, new field discoveries are diminishing. Before tapping a reservoir, it must be discovered. Here, too, the picture is clear: The world passed the peak of oil discovery in the early 1960s, and now for every three barrels of oil used only one barrel is found. The fields that are being discovered now are smaller, and in geographically challenging locations, making them far more expensive to produce. And the new oil is of lesser quality: less light sweet crude, and more heavy sour grades. These trends have held firmly for about four decades, despite the latest and greatest technology, and despite increasingly intensive drilling and exploration efforts.

Statistics state that global conventional oil production peaked in 2005. For "all liquids," including unconventional oil, the peak of global production will likely be around 2010. With a little less than half the world ' s total yet to produce, which will increasingly come from ever - smaller reservoirs with less desirable characteristics, peak oil is not about " running out of oil, " but rather running out of cheap oil.

This is a very serious situation, because without enough imports to meet demand, it is hard to function. As our daily life is directly or indirectly linked to oil .daily operations like transporting food, medicine, and clothing; fueling our planes, trains, automobiles, and cargo ships providing heat in the winter and cooling in the summer; and manufacturing plastics and other goods that rely on petroleum as a key ingredient will suffer.

The U.S. Government Accountability Office (GAO) said:

[12] Huges/David (2006), P.10

[T]he consequences of a peak and permanent decline in oil production could be even more prolonged and severe than those of past oil supply shocks. Because the decline would be neither temporary nor reversible, the effects would continue until alternative transportation technologies to displace oil became available in sufficient quantities at comparable costs. (US, Feb 2007)[13]

Even so, peak oil is the beginning of energy crisis that will soon be unleashed. Just after the peak oil, we will have peak gas.

2.7.2 Peak gas

In many ways, the story of natural gas is similar to that of oil. It has a bell -shaped production curve (although compared to oil, it hits a longer production plateau, and drops off much faster on the back side), and the peak occurs at about the halfway point.
Like oil, new gas wells are tapping smaller and less productive resources every year, indicating that the best prospects have already been exploited and now the world is relying on “infill drilling” and unconventional sources, such as tight sands gas, coal bed methane, and resources that are deeper and more remote.

Like oil, the largest deposits of gas are few in number and highly concentrated. Just three countries hold 58 percent of global gas reserves: Russia, Iran, and Qatar. All other gas provinces have 4 percent or less.

Similar to oil, there are quality issues. It appears that the best resources are already used up and cheapest natural gas — the high - energy – content methane that comes out of the ground easily at a high flow rate. We are now moving towards smaller deposits of “stranded gas” and the last dregs of mature gas fields, and producing gas that has lower energy content.

Assuming that world economic growth continues, that estimates of conventional reserves are more or less correct, and that there will not be an unexpected spike in unconventional gas, the world will hit a short gas plateau by 2020, and by around 2025 will go into decline.
Figure 2.7illustrates the peak oil and gas demand for the forthcoming years.

[13] Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil

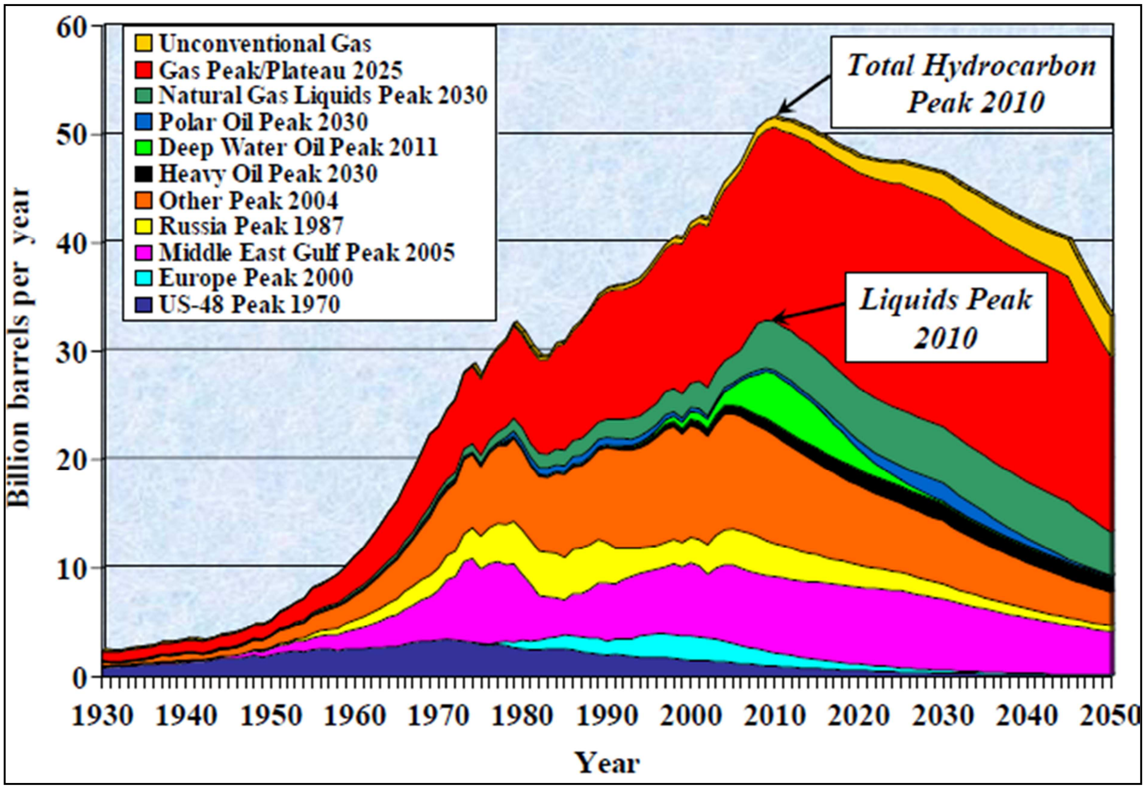

Figure 2.7: Campbell's (2003)Forecast of World Oil and Gas Production[14]

Therefore, the main concern with gas is the domestic production peak. North America has reached its peak of gas production in 2002, and has been declining ever since and is reaching the end of their productive lives. Which is described in Figure 2.8.The onset of the U.S. production peak was in 2001, and production is now declining at the rate of about 1.7 percent per year — far below the projection of the Energy Information Administration.[15]

[14]Huges/David (2006), P.12
[15]Huges/David (2006), P.13

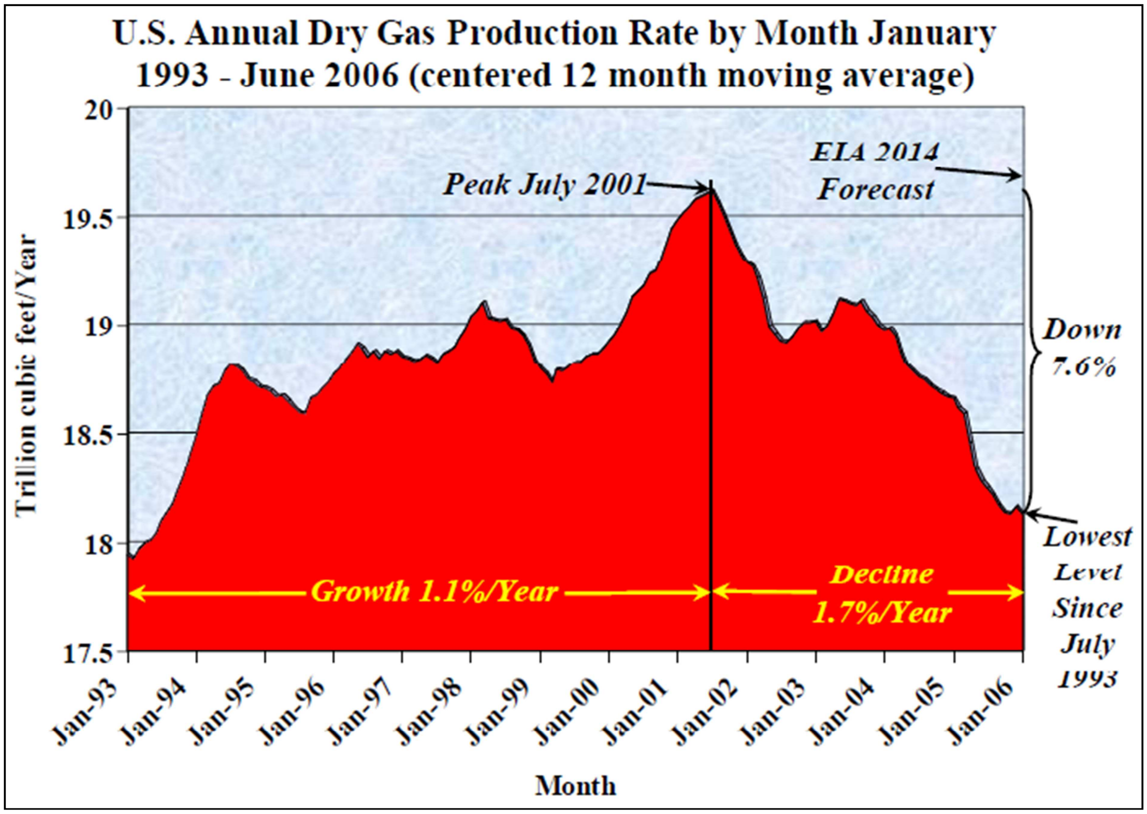

Figure 2.8 Annual gas production of the US by moth[16]

2.7.3 Peak coal

One of the dirtiest forms of fossil fuel used is coal; on the other hand it is the most reliable form and occurring in relative abundance. One quarter of total energy demand s met by coal.40 percent of world's electric production is depended and derived from coal. Two-thirds of the coal industry depends on the coal of high quality that is "black coal. „Similar to oil and gas the coal deposits are highly concentrated. About 90 percent of the deposits are located in just six countries: the United States has 27 percent of world's coal reserving making it the world leader in coal reserves, plus Australia, China, India, Russia, and South Africa.

American coal reserves are estimated to last for 250 years but the estimate was based on USGS study from the 1970s, where assumptions were made that 25 percent of the known coal could be recovered with current technology and at current prices. The National academy of science in 2007 published an alarming study
Stating that after looking into recent updated surveys from the United States Geological Survey (USGS) and determined that some of the old assumptions were

[16]Huges/David (2006), P.13

wrong. “There is probably sufficient coal to meet the nation’s needs for more than 100 years at current rates of consumption,”

As the 100 - year estimate is based on the current consumption rate about 1.1 billion tons a year. Due to the depletion or oil and gas resources and increase in the oil and gas price there would be a rapid switch over from these fuels to coal and thereby decreasing the coal availability. Similarly, a separate study of world coal reserves in March 2007, which was conducted by a German consultancy called the Energy Watch Group (EWG), found that the United States does not have anywhere near its claimed 250 - year supply of coal. 19 Indeed, EWG claims that in terms of energy content, the United States passed its peak of coal production in 1998.

For comparison purposes, EWG translated the energy content of the coal produced into tons of oil equivalent. In terms of volumes of stuff mined, they found that U.S. coal production can continue to grow for about another 10 to 15 years. But in terms of energy, which is the only metric that really matters, U.S. coal production peaked in 1998 at 598 million tons of oil equivalent, and had fallen to 576 million by 2005.[17]

Like the other fossil fuels all the good quality coal has been burnt. The rest available coal is not of superior quality, and will be more expensive to transport as the diesel cost are going to be escalated due to peak oil scenarios. It appears that the global reserve numbers for coal have been vastly overstated. The information given to the world, like the U.S. data, is decades old and unreliable.
Modern reassessments by transparent countries like Germany and the United Kingdom have resulted in 90 percent reductions[18]. The reserve numbers from Asia are suspicious, some dating1960s. China is showing the same reserve numbers from past 15 years, even though it is known that it has produced some 20 percent of its reserves since then. All the major coal producing nations in the 20 years have cut down their reserves and in the past 25 years there has been a 60 percent decline in coal reserves globally.

To summarize Figure 2.9 shows the world coal production and the coal production peaks

[17]Siegel/Nelder/Hodge (2008), p. 13
[18]Siegel/Nelder/Hodge (2008), p. 13

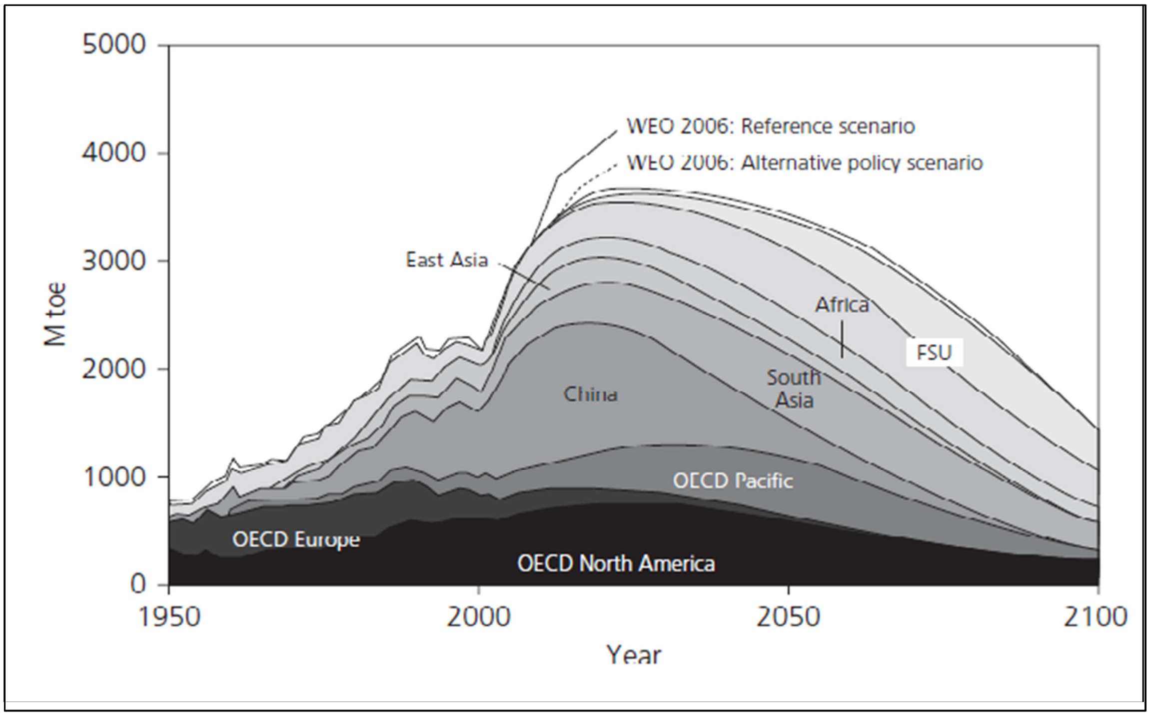

Figure 2.9: World Wide Coal Production[19]

2.8 Summary

Today 80 percent of the world electricity is produced from fossil fuels illustrated in Figure 2.10 which are at their peak production. As stated earlier after the peak there is going to be a steep decrease in their production, which would lead to problems in supply and would make it expensive. As our daily life is directly or indirectly liked to energy and there by linked to fossil fuels, and as it has been noticed that there is going to be a crisis situation this would be a good time to think and develop energy systems that are independent from these energy sources.

[19]Siegel/Nelder/Hodge (2008), p. 15

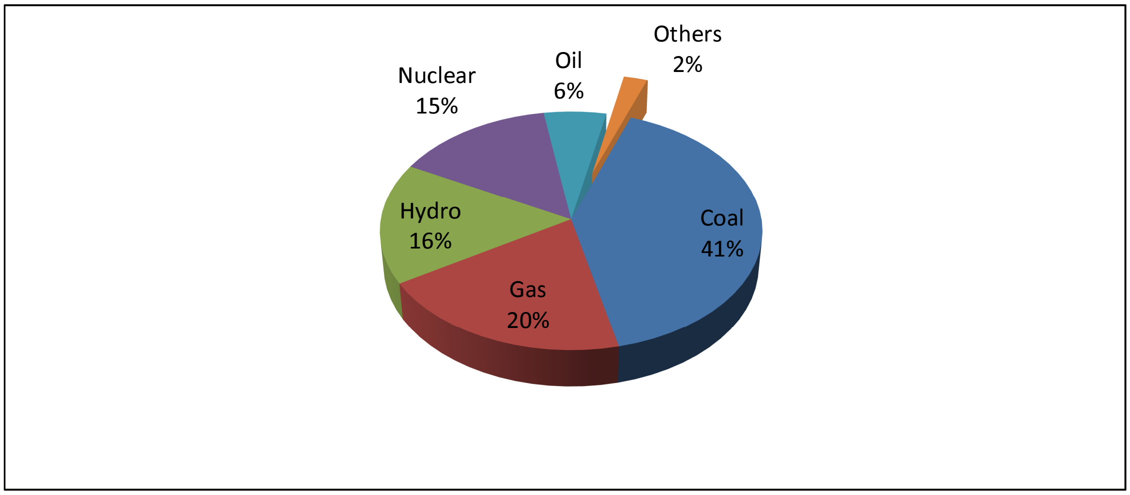

Figure 2.10 : World electric generation scenario [20]

[20] http://www.world-nuclear.org/uploadedImages/org/info/World_Electiricty_Generation%281%29.png Retrieved: 18.04.2010

3 Renewable/Alternative energy sources available

Renewable energy resources are those which can be renewed or natural energy sources. These are direct or indirect application of solar energy. Renewable energy sources that are suitable for utilization in the campus are Biomass, Solar and Wind energy. The available technologies can be used to harness the energy for the three energy resources are explained in this chapter.

3.1 Biomass

Biomass is an indirect form of solar energy. Which is entrapped by plants in the process of photosynthesis in addition to sunlight carbon dioxide is also captured and converted to plant materials in the form of cellulose, hemi-cellulose and lignin. The term biomass therefore covers a range of organic materials that are recently produced from plants, and also the animals that feed on plants. This biomass can be collected and converted into useful bioenergy. this includes crop residues, forest and by products of wood process, animal wastes including human sewage, municipal solid waste (MSW) (excluding plastics and non-organic components), food processing wastes, purpose grown energy crops and short rotation forests.

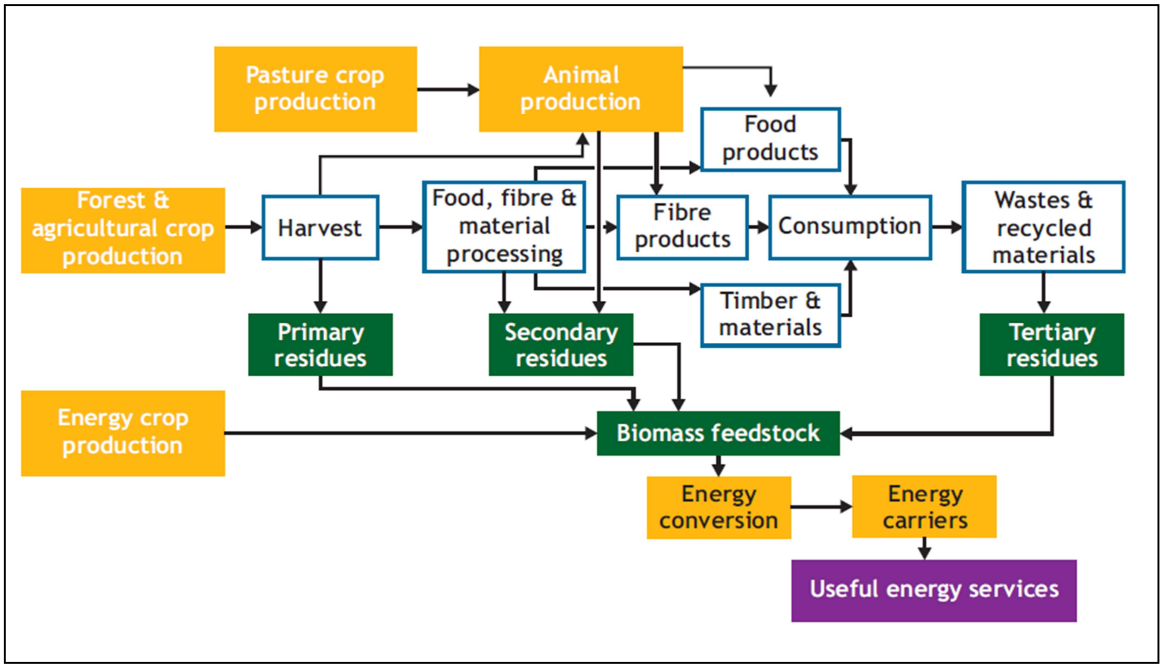

Figure 3.1 : Biomass generation from crops and residues[21]

From ages biomass is known to the world, mainly as fuel wood or dried dung, which has been used for cooking and heating and is still the energy source for one third of

[21] IEA (2007), p. 15

the world's population. From the day agricultural production began, crop cultivation has provided human food, feed for animals, a source of construction materials, fiber for textile and paper production. Harvesting of food and fiber crops to provide the main products by using the industrialized agricultural production methods of today, results in primary residues that are left in the field or forest. *Secondary residues* originate from food, fiber processing and as animal production wastes.

Other waste materials are derived after the main product is used such as leftovers after timber demolition, sewage sludge, and MSW can be classified as tertiary residues. Figure 3.1 illustrates the generation of biomass from crop residues and byproducts of agricultural operations.

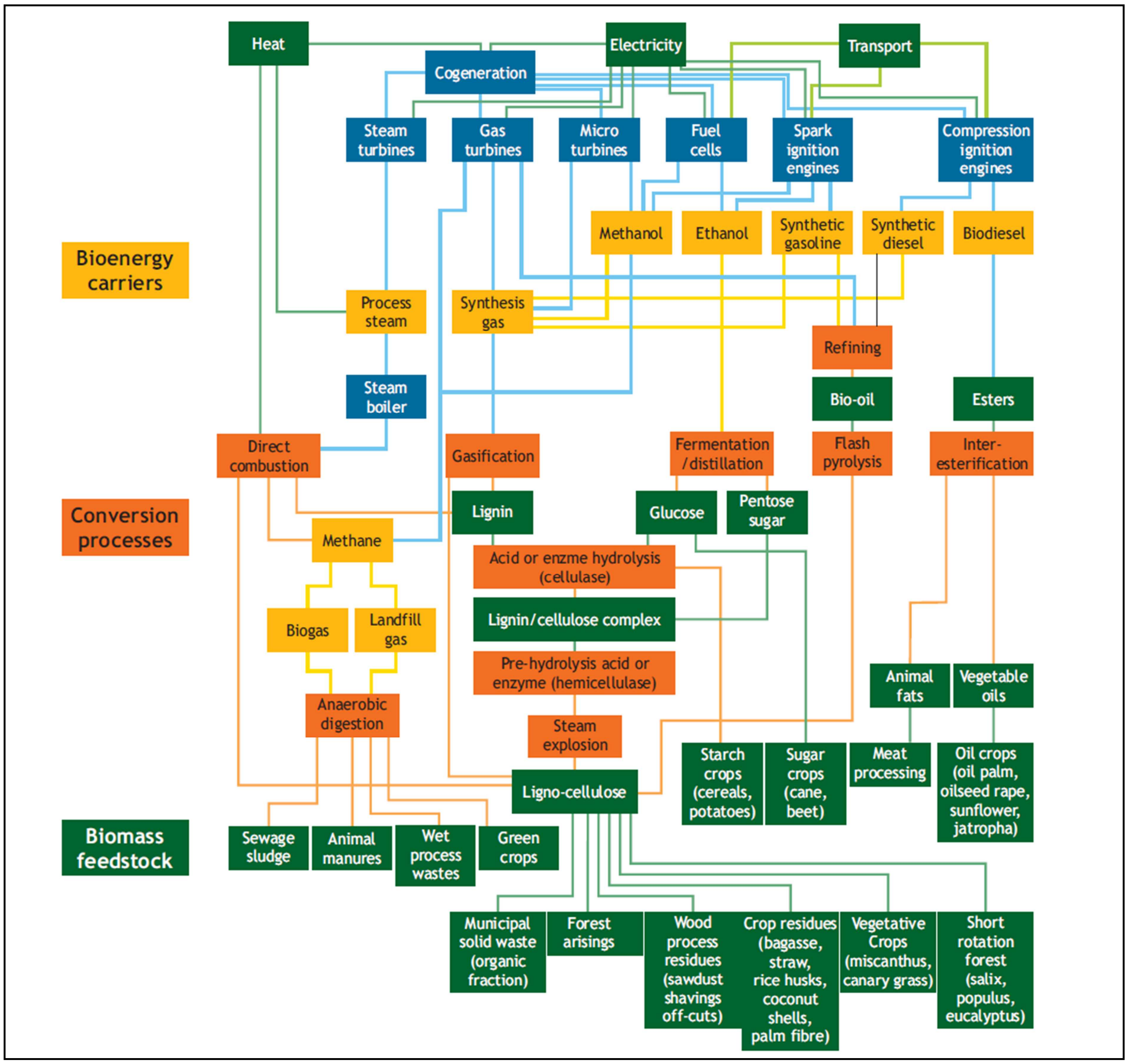

Figure 3.2 : Conversion of biomass to various energy carriers and methods[22]

[22]IEA (2007), p. 16

For more convenience in energy transfer the solid or liquid biomass can be converted into more useful forms by available technologies.

(*E.g.* wood chips, pellets, briquettes), liquid fuels (*e.g.* methanol, ethanol, biodiesel, bio-oil), gaseous fuels (synthesis gas, biogas, hydrogen) or direct heat the schematic representation is given in Figure 3.2.

As the figure depicts these simplified form of bio-mass can be used for purposes like generating heat, Electricity and can even be used as a transportation fuel.

3.1.1 Biomass heating system

When biomass is burned directly in the nature this is an inefficient process. To have an efficient combustion process to acquire the energy from biomass it is needed to burn it in a specialized system. These systems are explained in the following section.

3.1.1.1 Basic Woodchip Heating system

The wood chip heating systems are simple in operation; there is a storage silo or a Hooper for the chips, a boiler and a burner and a fuel screw conveyer for moving the fuel i.e. the biomass. There are many option of store to boiler wood chip heating system which refers to storing the wood in a store house and using it when needed.

This storage can be in a room above below the boiler or even storage a yard away. The only thing that has to satisfy is the place to run the conveyer for transportation of the fuel to the system.

A sketch of a typical biomass heating system is show in Figure 3.3 the conveyer system is designed for pellets, chips and a mixture of chips and sawdust; recently systems are developed for conveying manure and logs also. Practically bio-mass burning systems at the moment can burn anything that is listed as bio-mass the only criteria is the conveying system that has be designed for everything. Layout of the system as another important consideration the Hopper or the silo should be located such a way that a truck is able to move in order to drop the fuel into the storage[23].

[23]A.Bridgewater/G.Bridgewater(2008), p. 108ff

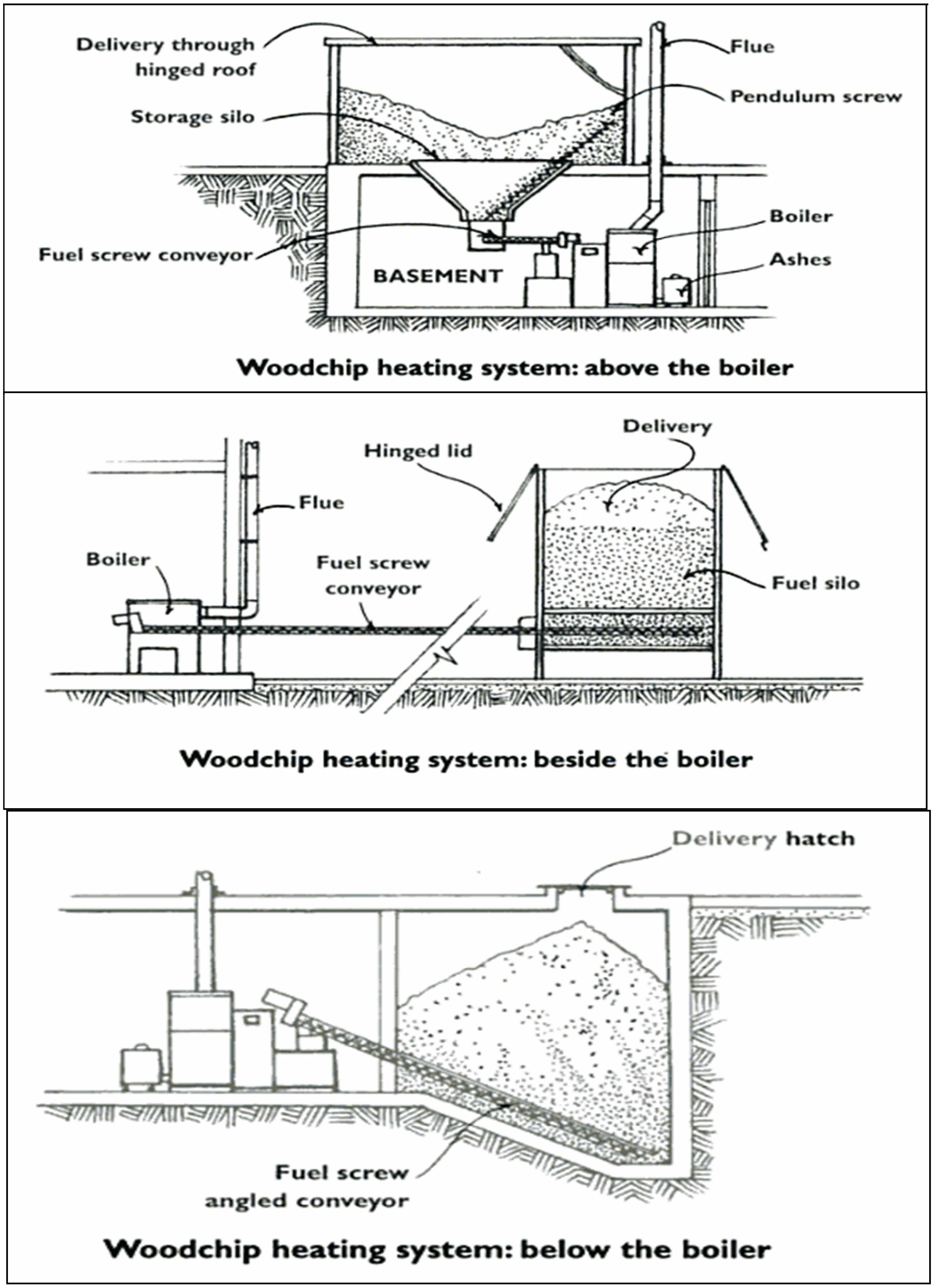

Figure 3.3Woodchip heating system[24]

[24]A.Bridgewater/G.Bridgewater(2008), p. 108

3.1.2 Fixed bed furnaces

For many years the fixed grate combustion systems were the most common ones. In the simplest form of a fixed bed, fixed grate systems consists of a grate in the combustion chamber (thereby forming the furnace). Primary air, for combustion of the char, char is the material that remains after pyrolysis, the re-lease of the volatile fuel gases from the biomass. Char is supplied under the grate. Secondary air, for combustion of the volatile gases themselves, is supplied above the grate. Combustion of the char on the grate provides heat for continuing the pyrolysis of newly added fuel above the char. Combustion temperatures in fixed-grate systems range from 850° to 1,400℃. Traditionally, ash is r emoved manually from fixed-bed systems. These days automatic ash removal systems have been developed.

The fixed bed biomass combustion systems look similar to fixed bed combustion systems for coal, the design in detail is different, as there is a high volatile content in biomass the combustion systems for biomass need large combustion rooms above the grate in its furnaces. The biomass furnaces need a higher proportion of secondary to primary air when compared to coal fired furnaces for the same reason.

In the inclined grate was primarily developed for coal furnaces. The working principal is same for both coal and biomass furnaces. The fuel is supplied at the top and moves downward during the combustion process. The ash is removed from bottom for disposal.

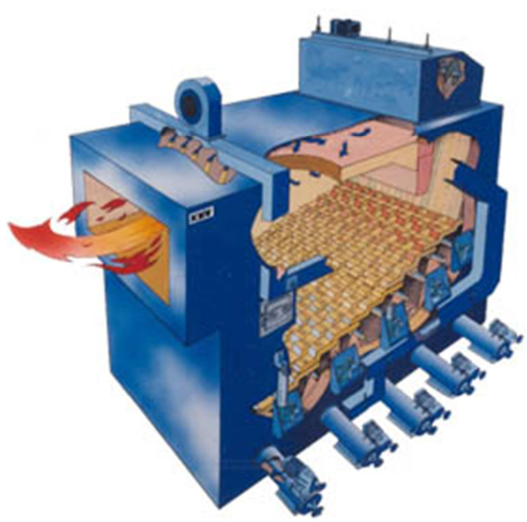

Figure 3.4: Sloping grate combustion system[25]

[25]http://www.kmwenergy.com/images/system_drawing.jpgRetrieved 28.04.10

.Later the moving or sloping grates were introduced. In the sloping grate furnaces, the residence time of the fuel pieces of fuel is fixed by the speed at which the grate elements move. The maximum size of the fuel piece is limited. The specific combustion capacity that is the heat release per square meter of grate can be increased if there is uniformity in the size of fuel pieces. In more sophisticated versions there are different stages of the combustion process in different zones[26]. A sketch of sloping grate combustion system is shown in Figure 3.4.

3.1.3 Cyclonic combustion systems

In order to enhance the combustion new techniques have been developed one of them is the cyclonic combustion system a sketch of this is shown in Figure 3.5 . The cyclonic combustion systems are suitable for burning particulate wood waste and agricultural residues.it is preferred in such a system to have uniform fuel piece shape and low moisture content. The system has a cylindrical chamber in to which the combustion air is introduced. The air form a cyclone and this mixes the suspended particulates, enhancing the combustion and making it more efficient. The hot combustion gases pass from the cylindrical chamber through the boiler or other heat removal devices.

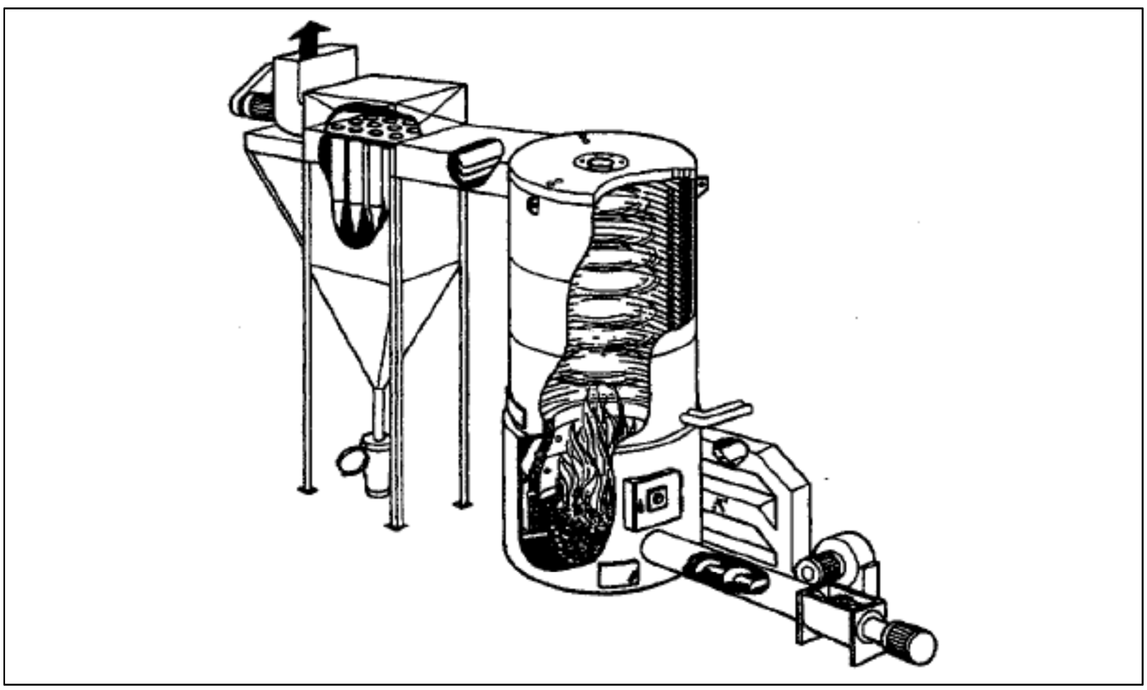

Figure 3.5: Cyclonic combustion chamber[27]

[26]Quaak/Knoef/Stassen(1999), p. 11ff
[27]Quaak/Knoef/Stassen(1999), p. 13

3.1.4 Fluidized bed systems

In a fluidized bed combustor system, the fuel is burned in a bed of sand, lime stone, or any other noncombustible material that is kept in turbulence suspension by fans ranging from temperature 700^{0}C to 1000^{0}C.

The sand bed that is contained in the combustion chamber acts as a heat transfer medium. By blowing air through a perforated plate from the bottom the bed is fluidized. This forces the sand upwards. Depending on the velocity of air a circulating fluidized bed or a bubbling fluidized bed is created this is shown in Figure 3.6.

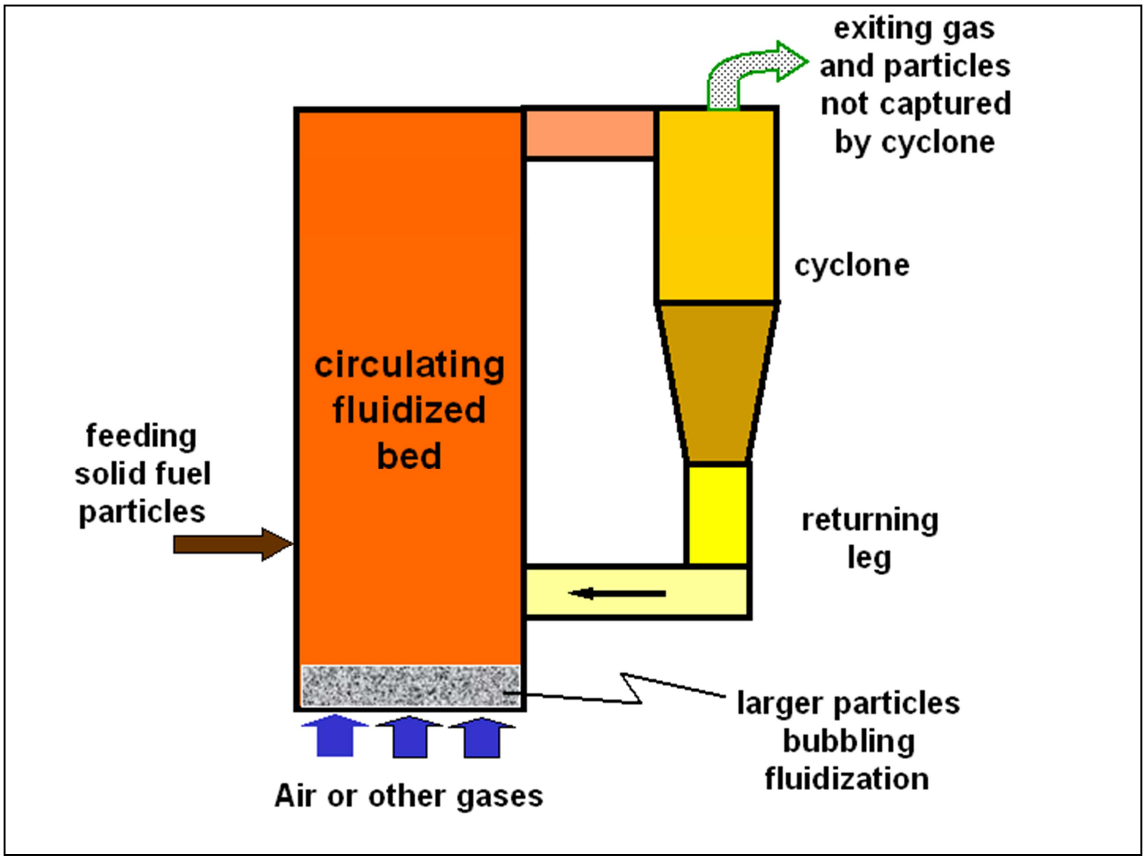

Figure 3.6: Fluidized bed combustion system[28]

In the bubbling fluidized bed, the reactor is divided into a zone containing freely moving sand particles which are supported by upward streaming air, and a freeboard zone above the fluidized bed. In a circulating fluidized bed, the velocity of air is high

[28] http://www.csfmb.com/yahoo_site_admin/assets/images/Fig_3_3.273131300_std.png Retrieved 28.04.2010

to that extent that the bed and fuel particles excluding large and heavy fuel pieces flow up ward with the gas stream. The heavy and large pieces are separated from the cyclone and rechanneled into the reactor. The lighter fuel particles burn during circulation and the heavy particles burn at a lower level, when their weight is reduced and they are light enough they join the cyclone.

Intensive mixing in the fluidized beds results in high heat exchange rates, and complete combustion using low excess air. There is a string integration of the furnace and heat exchanger, the walls of the furnace are constructed from tubes in which water is heated or evaporated and by which the bed is cooled. The combustion temperatures range from 750^{0}C to 950^{0}C[29].

The most important features of fluidized bed combustion system are

- Possibility of flexibility with fuel properties shapes and sizes
- High moisture content acceptability as high as up to 60 percent
- Possibility of fuel ash content up to 50 percent or even higher
- Compact construction that results in high heat exchange rates due to intensive mixing of bed
- Low excess air factor they by reducing the heat losses from flue gasses

3.2 Biomass Gasification plant

The biomass gasification plant is a CHP plant. In the process biomass is gasified in a circulating dual fluidized bed reactor. The producer gas is cooled cleaned and used in a gas engine. Woos chips from the forest are dried in a storage for 1-2 years they are transported to the plant and are chipped at the facility. When the chips are used they have a moisture content of 25-40%. The heat produced in plant is used for the plant operation for generation of steam, preheating and other operations where heat is required and the rest is circulated to the district heating system.

The chips are transported form a hopper to a metering bin and fed into the fluidized bed reactors via screw feeders. The gasifier has two zones, a gasification zone and a combustion zone. The gasification zone is fluidized with steam which is generated as a waste from the process. The combustion zone is fluidized by air and delivers the heat for gasification process via the circulating bed material.

The temperature of the gas is cooled from 850ºC to 150ºC and after the other filtration process the producer gas is reduced to a temperature of 40ºC this gas is

[29] Quaak/Knoef/Stassen (1999), p. 15

used now for heating or electrical production in a burner or in a gas engine[30]. A schematic sketch of a gasification and usage plant is show in Figure 3.7

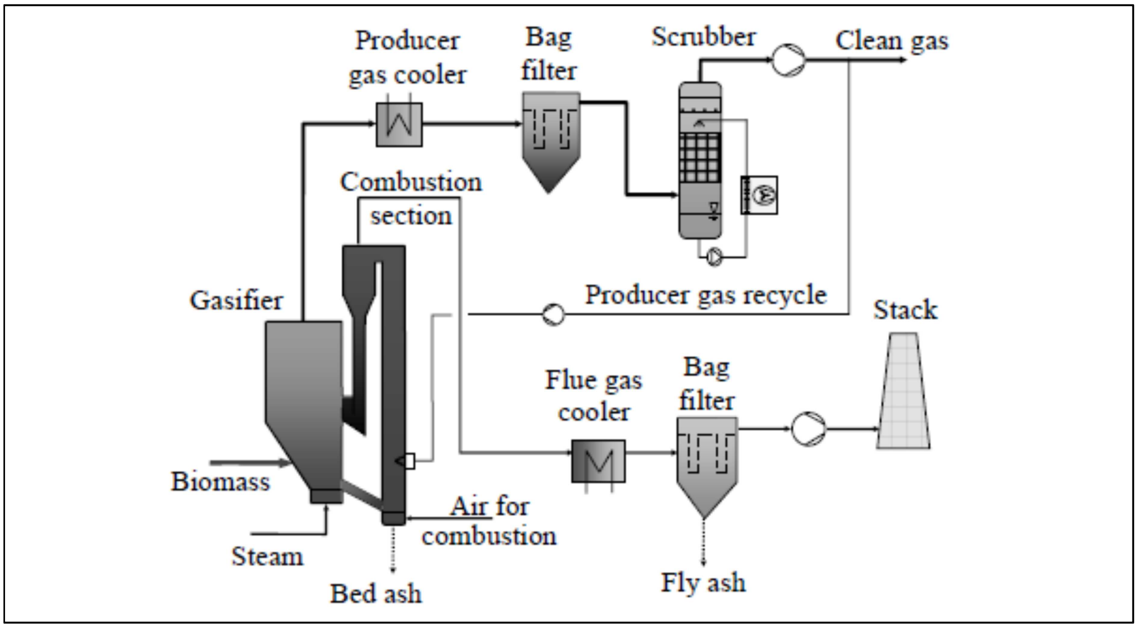

Figure 3.7Scheme of a biomass CHP plant[31]

3.2.1 Biomass Gasification systems

Gasification of biomass looks simple in principle, this being the reason many different types of gasification system have been developed. The gaseous fuel is easy to handle and has good combustion properties, these advantages makes it interesting to gasify solid fuels. The gas has less contamination and can be used in internal combustion engines also.

The biomass fuels used in gasification systems vary widely, these include many reactants this results in many possible reaction paths. The reaction rates are relatively very high, these factors make the process of gasification complex in nature and hard to control and operate satisfactorily.

When these gasification systems are built on a large scale like 2-3MW thermal power sophisticated devices can be built that may prove to be economical. These systems are promising, in particular when built for advanced power generation operations[32].

[30]Hofbauer (2009), p.1
[31]Hofbauer (2009), p.1
[32]Quaak/Knoef/Stassen (1999), p. 26-31

The various available technologies for gasification system are explained in this section.

3.2.2 Updraft Gasification system

The simplest form of gasification system is the fixed bed counter current gasification system. This is shown in Figure 3.8 the biomass is fed from top of the chamber and moves downwards as a result of conversion and finally is removed as ash. Air is supplied from the bottom and the gas is taken out after the throat. The biomass moves downwards and passes successively through drying, distillation zone, reduction, and hearth zones. In the drying zone the moisture is lost. In the distillation or pyrolization zone, it is decomposed into volatile gases and solid char. The heat for the processes is from the chamber temperature and the radiation from the hearth zone.

In the reduction zone may chemical reactions occur, which include char, carbon dioxide, and water vapor in which carbon is converted to carbon monoxide and hydrogen are produced as the main components of producer gas which is the output. In the hearth zone the remaining char is combusted, providing heat, carbon dioxide, and water vapor for reactions occurring in the reduction zone.

The major advantage of these types of systems is its simplicity, high charcoal burnout, and internal heat exchange which lead to low exit gas temperatures and high efficiencies in terms of gasification, therefore fuels of high moisture content up to 60 percent and some size variations in the fuels are accepted.

The disadvantages of the system are high amounts of tar and the gas does not pass the hearth zone and therefore is not combusted. When the gas is to be used for engines, extensive gas cleaning is required[33].

[33] Quaak/Knoef/Stassen (1999), p. 27

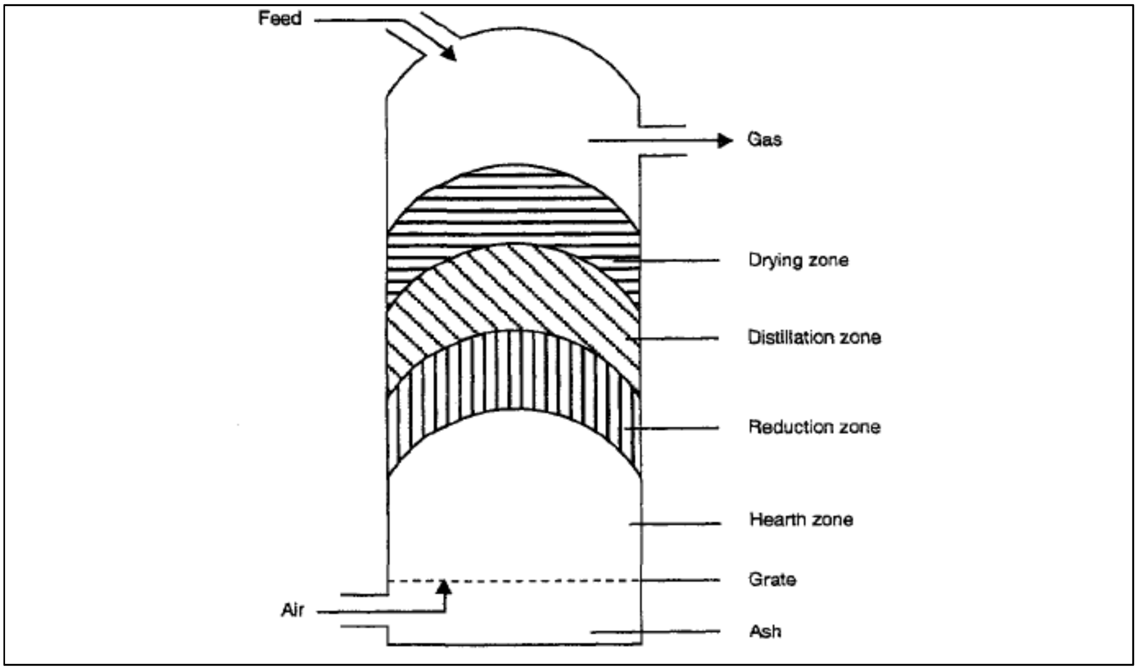

Figure 3.8: Updraft gasification system[34]

3.2.3 Downdraft Gasification system

In a downdraft gasification system, biomass is fed at the top, and the air intake is at the side. The gas moves in the same direction like the feed and is taken out from the bottom a sketch is shown in Figure 3.9. The zones are similar to those that are in the updraft system, but the order is different. The biomass is dried in the drying zone, then pyrolized in the distillation zone. These zones are mainly heated by radiation from the hearth zone, where a part of the char is burned. Pyrolysis gases also pass through this zone and are burned. The extent to which the pyrolysis gases are actually burned depends on design, biomass feedstock, and the skill so of the operator. After the oxidation zone, the remaining char and the combustion products-carbon dioxide and water vapor-pass to the reduction zone where CO and H2 are formed.

The main advantage of a downdraft gasification system is production of a gas with low tar content which is suitable for use in engines. In practice there is very less amount of gas produced that is completely free from tar. The main reason seems to be that not all gases pass through the hottest zones.

[34]Quaak/Knoef/Stassen (1999), p. 27

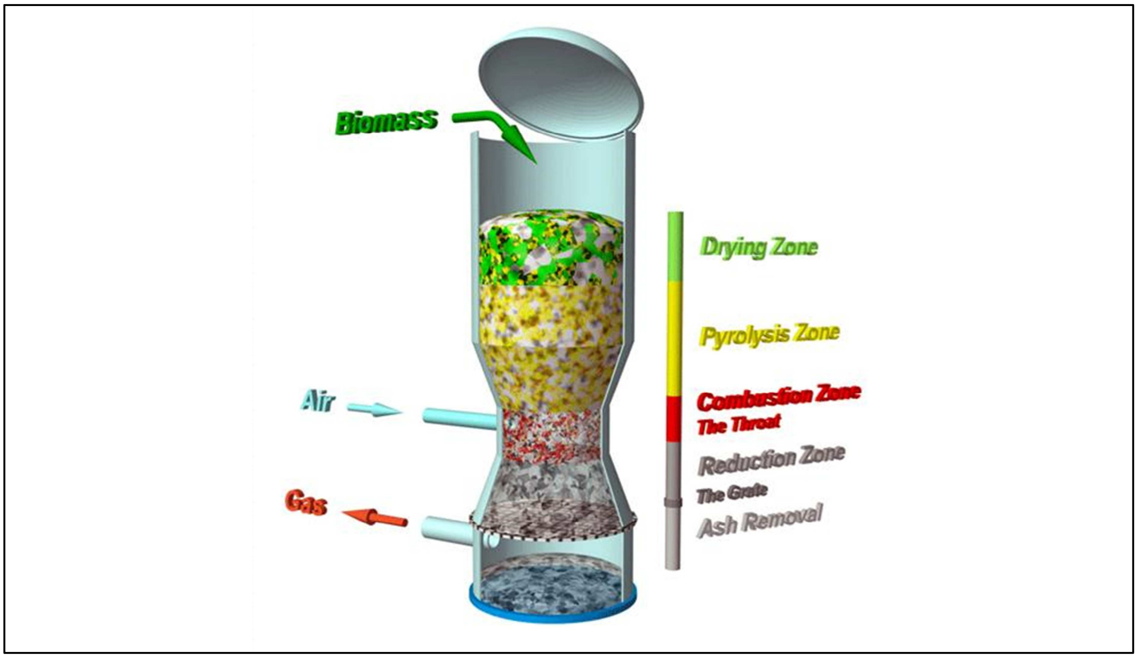

Figure 3.9: Downdraft gasification system[35]

The other reason is the residence time in the combustion zone may be too short. Depending on the design other features help in achieving a high conversion rate of pyrolysis gasses.

The drawbacks of the system are

- The produced gas consists of high amounts of ash and dust particles as the gas has to pass the oxidation zone, where it collects these particles.
- Fuel must be uniformly sized from 4 to 10 cm so as not to block the throat and allow pyrolysis gases to flow downward and heat from the hearth zone to flow upwards. For this reason pelletization or briquetting of the biomass is often necessary.
- The moisture content should be less than 25 percent
- Due to high temperatures of the exit flue gas results in lower gasification efficiency[36].

3.2.4 Open core gasification system

Open-core gasification systems are especially designed to gasify fine materials with low bulk density like rice husks, sketch of the system is shown in Figure 3.10. Due to the low density fuel throat cannot be employed. Special devices such as rotating

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[35] http://www.alternative-energy-fuels.com/wp-content/uploads/2009/03/biomass-gasification.jpg Retrieved 28.04.2010
[36] Quaak/Knoef/Stassen (1999), p. 29

grates are included to stir the fuel and remove the ash. This avoids bridging of the fuel, which may hamper or even stop the fuel flow. Rice husk gasification systems in particular require continuous ash removal systems due to the high content of ash in rice husk.

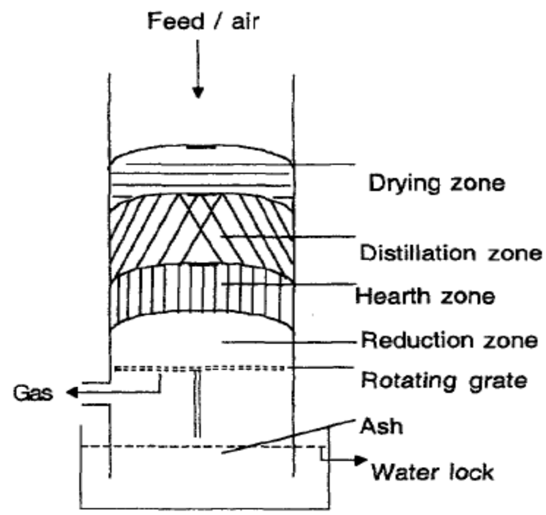

Figure 3.10Open core gasification system[37]

This accounts approximately to 55 percent. For the transport of the ash that has been separated from the gasification system a water basin is arranged to move the ash out of the system[38].

3.2.5 Fluidized bed gasification system

Fluidized-bed gasification was originally developed to overcome operational problems of fixed-bed gasification of fuels with high ash content, this is better suitable for capacities more than 10MW thermal applications. A sketch of the fluidized bed gasification system is shown in .The features of fluidized-bed gasification are similar to those of fluidized-bed combustion. Compared with fixed-bed gasification systems, the gasification temperature is relatively low-approximately it ranges between 750° and 900℃. In fixed-bed gasification systems, the t emperature in the hearth zone is as high as 1,200℃. The fuel is fed into a circulat ing or suspended hot sand bed. The bed behaves like a fluid and is characterized by high turbulence. Fuel particles mix quickly with the bed material, resulting in rapid pyrolysis and a relatively large amount of pyrolysis gases. Due to the low temperatures, the tar-conversion rates are not very high.

[37]Quaak/Knoef/Stassen (1999), p. 29
[38]Quaak/Knoef/Stassen (1999), p. 30

- The advantages of fluidized bed gasification system over fixed bed gasification system are

- Due to intensive mixing in the bed there is high heat exchange and reaction rate, compact construction size due to these factors
- Flexibility in fuel used, moisture, ash content, and other fuel characteristics can be used
- Relatively the ash has low melting point due to low reaction temperatures.

Drawbacks of the system are

- There is a high tar and ash content in the producer gas
- The high temperature of the producer gas leaves the alkali metals in vapor state
- Incomplete carbon burnout
- The plant operation is complex due to the parameters involving both the fuel and air requirements
- Power needed to run the auxiliary equipment[39]

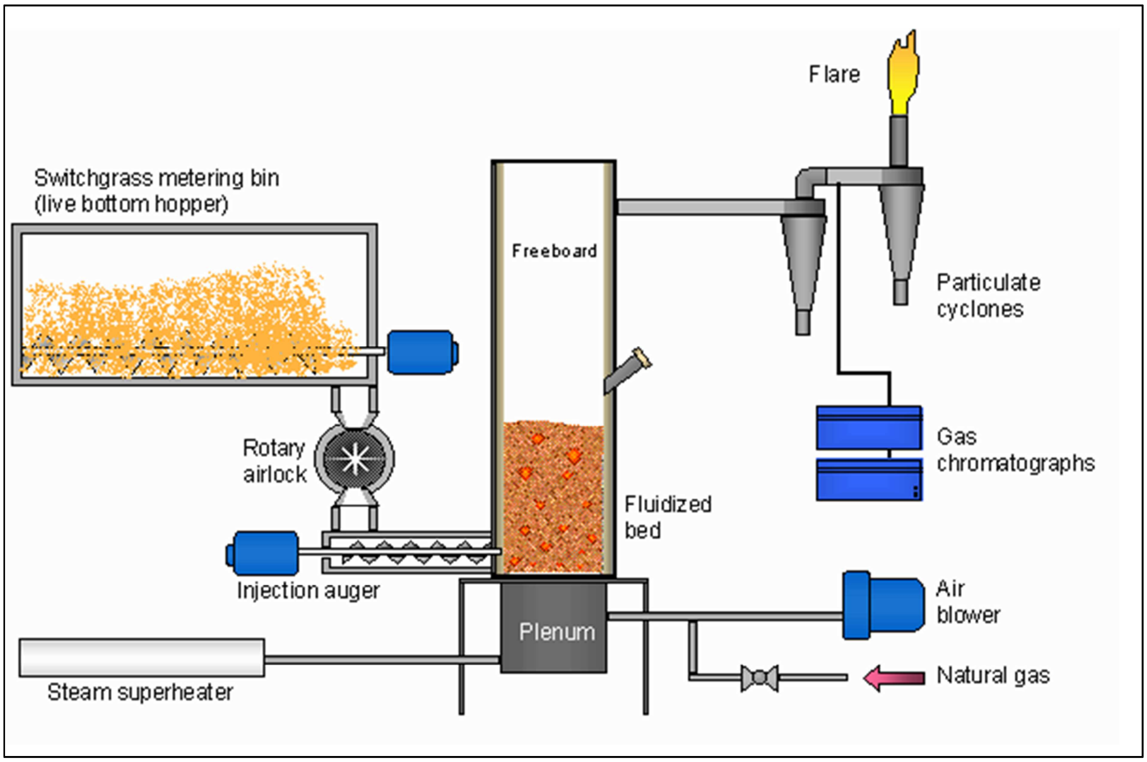

Figure 3.11 : Fluidized bed gasification system[40]

[39]Quaak/Knoef/Stassen (1999), p. 30ff.
[40]http://www.cvrcd.org/images/4Image5.gif Retrieved: 30.04.2010

3.2.6 Horse manure burner system

As there are 120 horses available and there is manure produced every day. There are some costs included in the disposal of the horse manure to maintain cleanliness in the campus. As horse manure has high energy content it would be wise to utilize this natural resource for generating energy, upon investigating,a company which is specialized in horse manure heating systems was found. in this section a brief description about the system is given.

The horse manure heating system form this extracts energy from horse manure and even other materials like wood chips horse boxes etc. can be used like a normal fuel for combustion up to a moisture content of 61%. The end product after combustion of horse manure in a first rate fertilizer so on an overall scale the input products are waste and it produces energy from waste and the waste from the system is also useful.

Figure 3.12Horse manure burning[41]

The horse manure burner is an completely automated system which only requires horse manure to be fed into the feeding system and the system itself feeds in the manure and the ash removal is also automatic which is generally outside the facility making it easy for disposal. An image of horse manure being used as a fuel is shown in Figure 3.12.

[41]http://www.swebo.com/fileadmin/panoramabilder/pan_energibrannare_530_280.jpg Retrieved 30.04.2010

3.3 Geo-Thermal Energy

Enormous heat that is generated in the earth's core by radioactive decay of unstable elements in the earth's crust can be used in the earth's surface in specific locations this energy is called Geo-thermal Energy this could be the cleanest, greenest and most abundant source of energy that has been ever used. Underneath the earth's crust the decay of radioactive substances produce temperature up to 5000 degrees Celsius. This heat can be used for all thermal applications like power generation, process heating systems, district heating systems and so on.[42]

Geothermal resources are strongly dependent on the location; factors that influence the resource are depth of the resource, the rock chemistry and the abundance of groundwater. Use of geothermal energy can broadly be classified into electric power generation and non-electric use. The type of the geothermal resource determines the method of its utilization this is illustrates in Figure.High-enthalpy resources, like dry steam and hot fluids which are available in volcanic regions and island chains, can be efficiently utilized to generate electric power. These days' by the use of modern technologies electric power can be generated even by using medium-enthalpy resources using binary cycle plants. Warm-to-hot waters that are found extensively in most continental areas are best suited for direct heating and cooling (non-electrical) purposes[43].

[42] Siegel/Nelder/Hodge (2008), p. 79
[43] Gupta/Roy (2007), p. 199

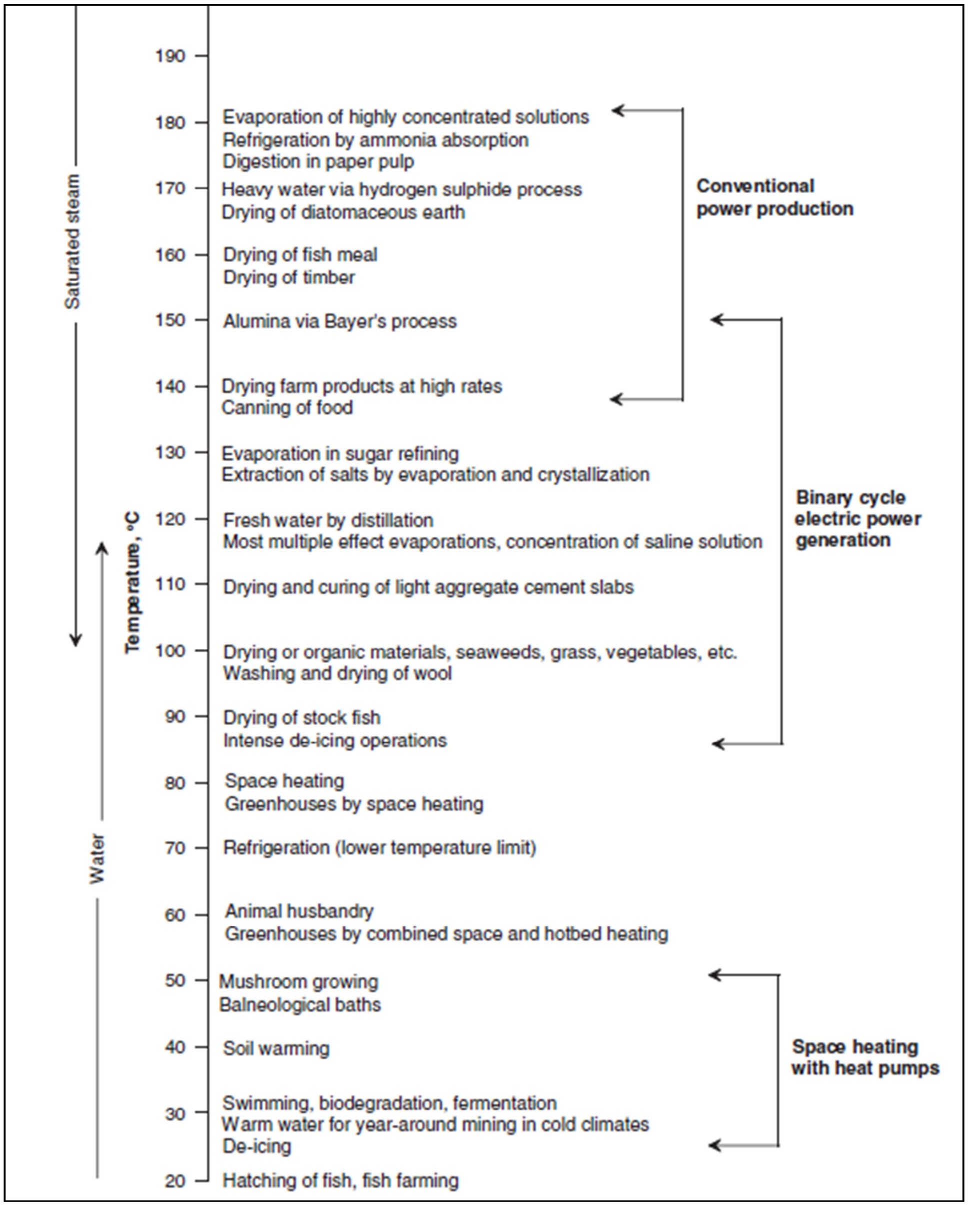

Figure 3.13 : Various applications of geothermal energy depending to resource temperature.[44]

3.3.1 Electric power generation by geothermal energy

At the present time there are there types of electrical generation system from geothermal energy these are: ‘‘dry’’ steam, flash and binary. A ‘‘dry’’ steam reservoir produces steam and very less water. The steam is directly piped into ‘‘dry’’ steam

[44] Gupta/Roy (2007), p. 208

power plant to provide power torun the turbinesFigure 3.14 gives a sketch of dry steam type power generation plant. The used steam (condensed water) is used in theplant's cooling system and sent back into the reservoir to maintain water andpressure levels.

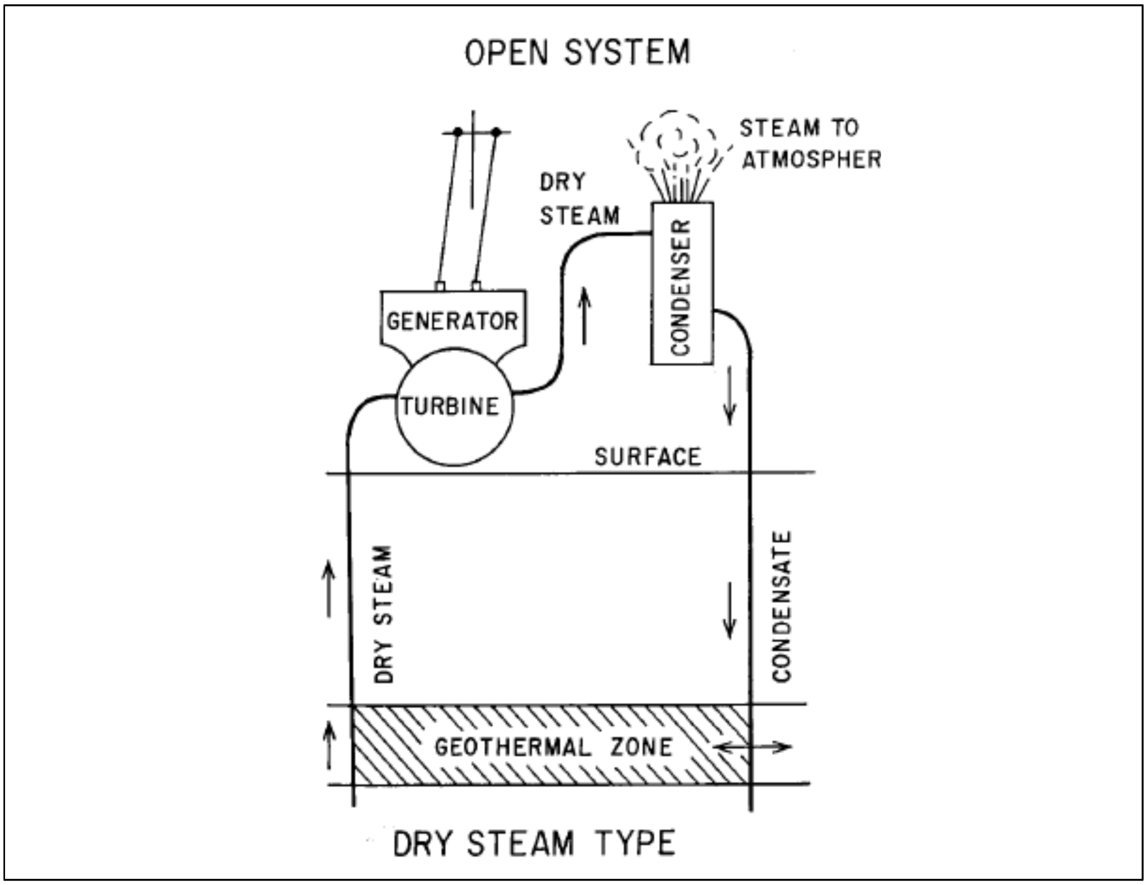

Figure 3.14: Dry steam type power generation from geothermal energy[45]

In a flash power point power generation system a hot water reservoir is used, in which fluids having temperature's approximately 180℃ are brought up to the surface by a production well where when released from the pressure of deep reservoir, some of the water flashes into steaming a ‘‘separator’’. The steam then powers the turbine which is shown in the Figure 3.15. The steam is cooled and condensed the cooled steam is either used in the plant's cooling system or injected back into the geothermal reservoir. Flash-steam plants are the most commonly used for electric power generation mainly as most reservoirs are liquid dominated hydrothermal systems.

[45]Gupta/Roy (2007), p. 200

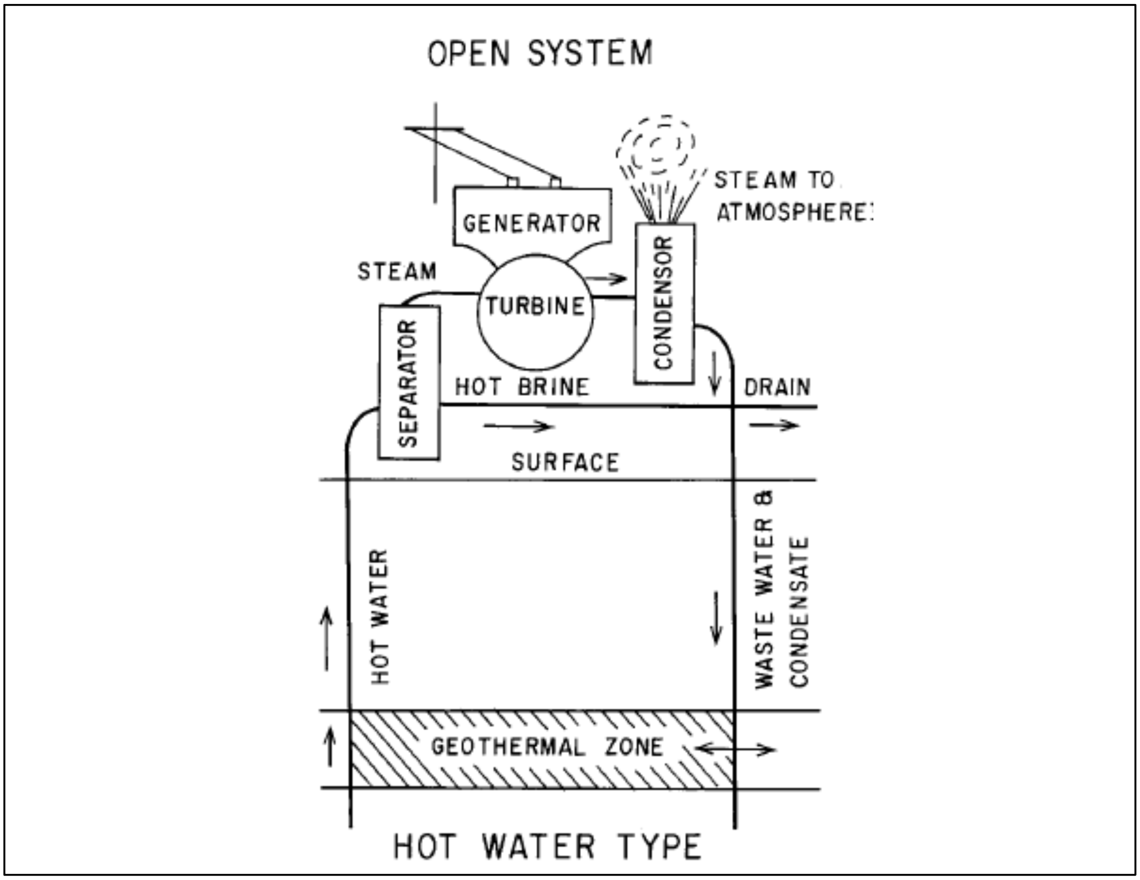

Figure 3.15: Hot water type power generation from geothermal energy (Flash power plant)[46]

Low-to-medium enthalpy reservoirs having temperatures ranging from 85 to 150 ℃ do not have enough enthalpy to flash enough steam but these can also be used to produce electricity using a binary power plant (Organic Rankine Cycle (ORC) power plant). In a binary system, the geothermal fluids are passed through a heat exchanger, where in heat is transferred into a low-boiling point (secondary) binary liquid such as propane, isobutene, iso-pentane and ammonia. When heated, the binary liquid flashes into vapor, which, like steam, expands and powers the turbines which has been show in Figure 3.16. The used vapor is then re-condensed to a liquid form as this a closed system the binary fluid runs in a loop and the re-condensed fluid can be used again.

Another form of binary cycle technology which is known as kalian thermodynamic cycle potentially has higher thermal efficiency when compared to ORC. The Kalina cycle uses two-component vapor containing typically 70% ammonia and 30% water as the working fluid. The improvement over the ORC is that the boiling of a mixture of ammonia and water occurs over a range of temperatures, unlike steam and pure

[46]Gupta/Roy (2007), p. 201

fluids that evaporate at a specific boiling temperature. The Kalina cycle technology is presently undergoing active testing in Iceland.[47]

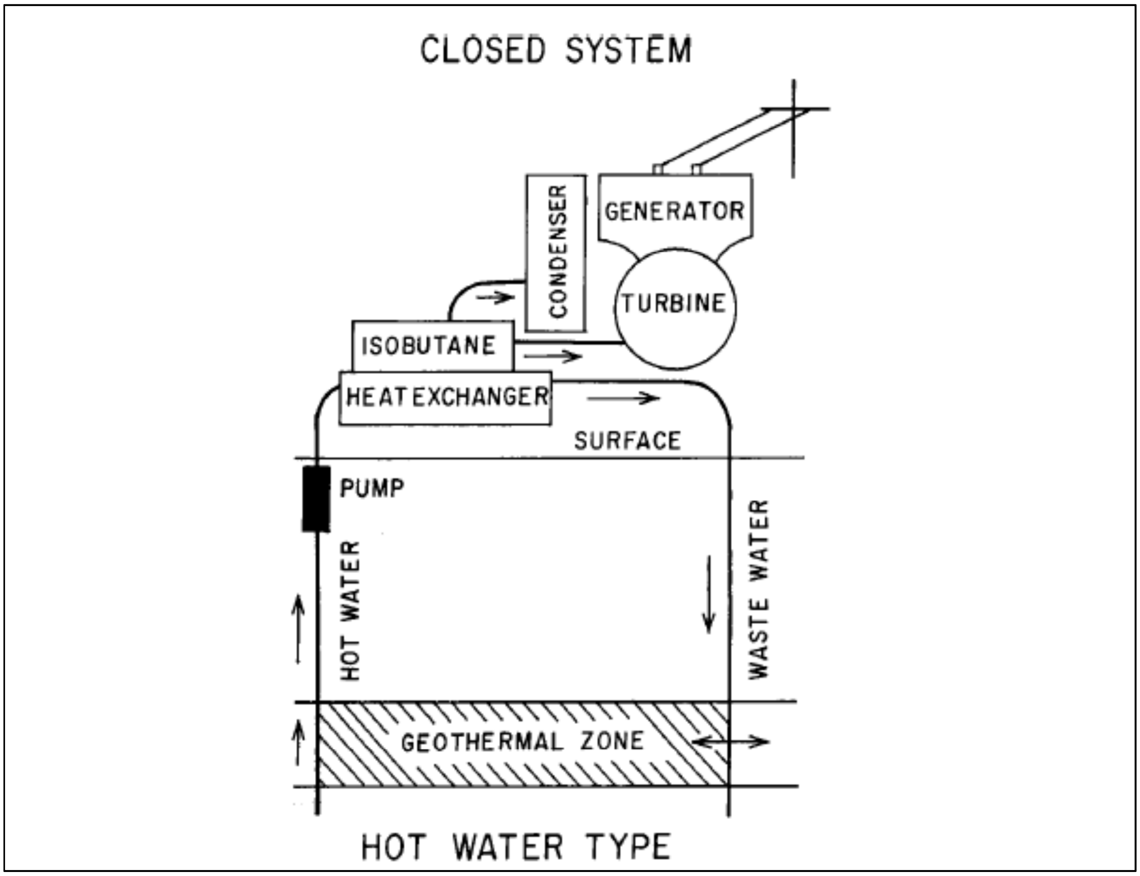

Figure 3.16: A binary power plant using isobutene as secondary working fluid.[48]

3.3.2 Other geothermal application

Rising prices of oil and the increase in atmospheric CO2 concentrations due to burning of these fuels and these factors greatly influencing global economy has created interests in efficient utilization of low-heat geothermal resources as an energy alternative for non-electrical applications such as aquaculture facilities, space heating, heat pumps and greenhouse and many industrial applications over the past few years. The long-term use of geothermal resources for nonelectrical applications is more economical when compared with the requirements of conventional fuel resources where geothermal energy is available.

[47]Gupta/Roy (2007), p. 201
[48]Gupta/Roy (2007), p. 202

Some applications of direct use of geothermal energy are classified as residential and commercial use, agricultural use and industrial used [49]

(1) Residential and commercial use: (a) space and district heating, space cooling, heat pumps, (b) water (potable, hot or cold utility, etc.), (c) bathing, swimming and balneology, (d) refrigeration, (e) de-icing, and (f) waste disposal and bioconversion (i.e., extraction of methane, ethanol and other chemicals by anaerobic digestion and fermentation of municipal solid waste thereby reduces the volume requiring disposal).

(2) Agriculture and related use: (a) animal husbandry, (b) aquatic farming, (c)greenhouse heating, (d) agricultural product processing such as drying, fermentation, waste disposal and conversion and canning.

(3) Industrial use: (a) pulp, paper and wood processing, (b) heap leaching for recovery of gold, silver and other minerals, (c) waste water treatment, (d) production of diatomaceous Earth (a naturally occurring substance comprised offossilized remains of microscopic hard-shelled creatures found in marine as wellas fresh waters; used as insect deterrents).

3.3.3 Geothermal use and global scenario.

In our modern society the energy needs have been increased rapidly and is same with the energy costs and oil prices under these circumstances the use of geothermal energy as one of the alternative energy source has become unavoidable. The high-enthalpy sources are highly concentrated and these are used for power generation directly. Similarly the low enthalpy sources are used to generate power by employing the binary cycles and even for other district energy resources. At several low-enthalpy locations combined heat and power plants (CHP) are encouraged. For power generation water at 100℃ issued in the binar y cycle plants and then cascaded for low-temperature for direct use applications such as, greenhouse heating, space heating and aquaculture, bathing and swimming. In USA, Northern Europe and China geothermal heat pumps have gained a great attraction and are extensively used.

There are 24 countries in the world to date which are producing electricity from geothermal energy. There are 486 generating units having a capacity of 8,900MWe are installed. Over the past three decades there has been a significant growth in geothermal energy usage for power generation which has been shown in Figure 3.17. The annual electrical energy produced from geothermal resources is

[49]Gupta/Roy (2007), p. 207

about57,000GWh yr_1, which is less than 0.4% of all electricity generation worldwide.

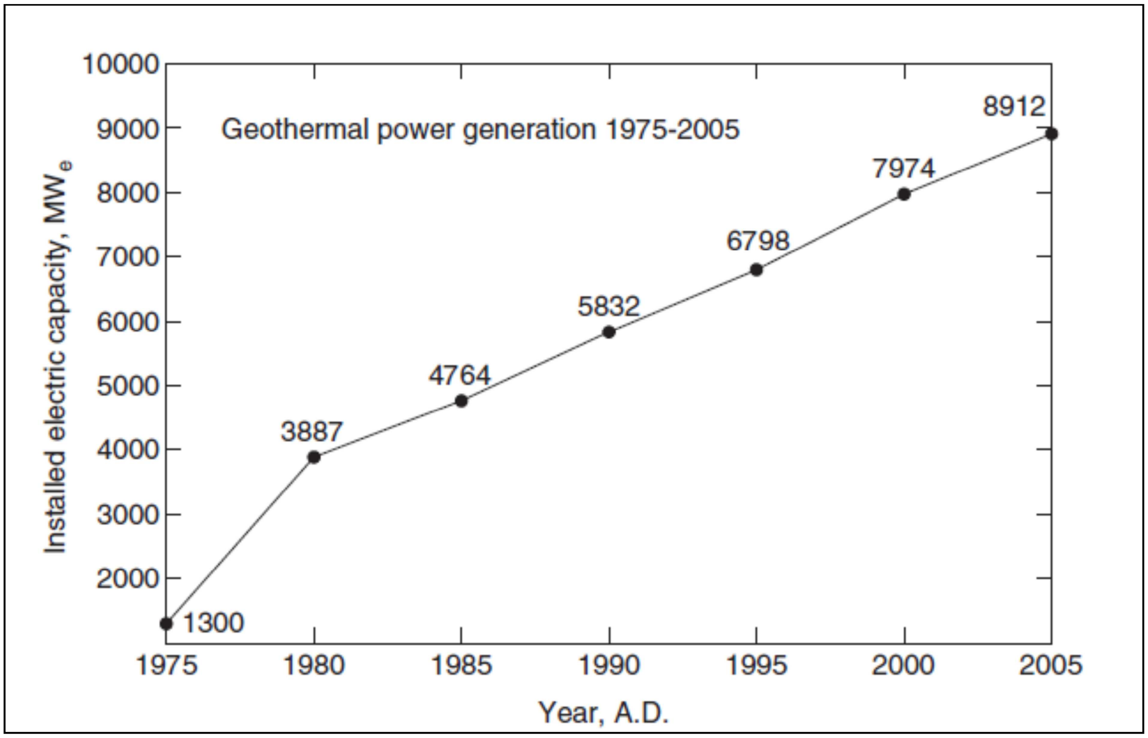

Figure 3.17: Geothermal power generation scenario[50]

Therefore, the contribution of geothermal power to the overall world electricity generation is very modest. In contrast, direct use of geothermal energy resources play an important role in several countries. 72 countries unitizing (Leon Freris, 2008) the geothermal energy resources have an installed capacity of energy application roughly about 28,000MWt this accounts to an annual energy saving equivalent to 25 million tons of oil and a carbon reduction of 24 million tons. In Figure 3.18 various direct applications of geothermal energy and their energy share in given.

[50]Gupta/Roy (2007), p. 210

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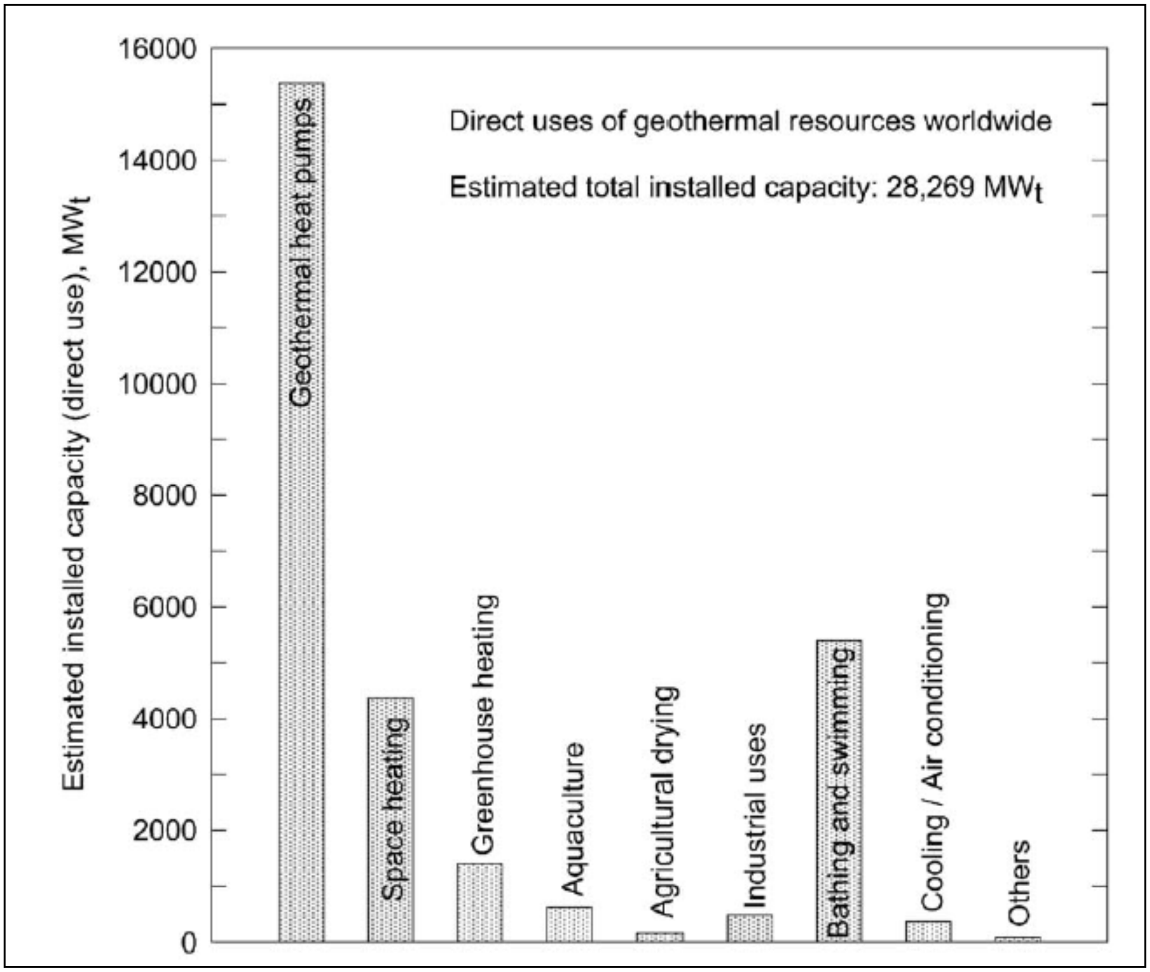

Figure 3.18: Direct use of geothermal energy for various applications[51]

3.4 Solar energy

Of all the energy sources available to us, the Sun is our largest source by far, dropping 970 trillion kWh worth of free energy on us every day put another way, the amount of solar energy the Earth receives every Minute is greater than the amount of energy from fossil fuels the world uses in a year. Modern solar energy technologies harvest the sun's energy waves. Photovoltaic (PV) cells make electricity from photosensitive materials that respond to the visible light spectra of sunlight. Solar thermal technologies, such as solar hot - water systems and concentrating solar power (CSP) systems, directly capture heat from infrared light spectra.

[51]Gupta/Roy (2007), p. 212

Modern attempts to harvest the sun's energy directly date back to the 1870s,and the first solar motor company was founded in 1900. The first documented design was a concentrating solar power (CSP) device, which focuses the heat of the sun using lenses or mirrors to drive thermal engines or generators. In the1870s, CSP systems were used to drive steam engines, which in turn were used to do something else, usually to pump water

3.4.1 Solar thermal systems

The major solar appliances sued are in the principal of solar thermal applications. Solar thermal applications date back to 214 BC when Archimedes boiled water using a concave mirror. Solar thermal systems are the most cost-effective use of solar energy. There are a number of different technical applications that are based in the principal of solar thermal heating. Solar thermal application are not only used for space heating and water heating but can be used for cooling and power generation applications also. Some of the applications of solar thermal heating are:

- Electricity Generation
- Process heating
- Domestic water heating
- Swimming pool heating
- Low temperature heat for space heating

3.4.2 Solar thermal systems for water heating

Domestic water heating systems use collectors that have lower losses at higher water temperatures. These are evacuated flat-plate, flat-plate or evacuated tube collectors and are integrated with collector storage systems

A thermo syphon system is shown in Figure 3.19 this uses gravity. As cold water has a higher specific density than warm water. As it has more density it's heavier and moves downwards. The storage tank is always mounted above the collector. The water from the tank flows down into the collector. When the collector heats up the water, the water rises again and flows back to the tank through an ascending water pipe at the upper end of the collector. Until a temperature equilibrium has reached the cycle of tank, water pipes and collector heats. The consumer can draw off hot water from the top of the tank. Used water is replaced through a fresh supply of cold water through an inlet at the bottom of the tank. This cold water joins the cycle and is heated in the collector in the same way as before. Due to higher water temperature differences at higher solar irradiances, the warm water rises faster than at lower irradiances and the flow rates are increased. Therefore, the water circulation adapts itself nearly perfectly to the available solar irradiance[52].

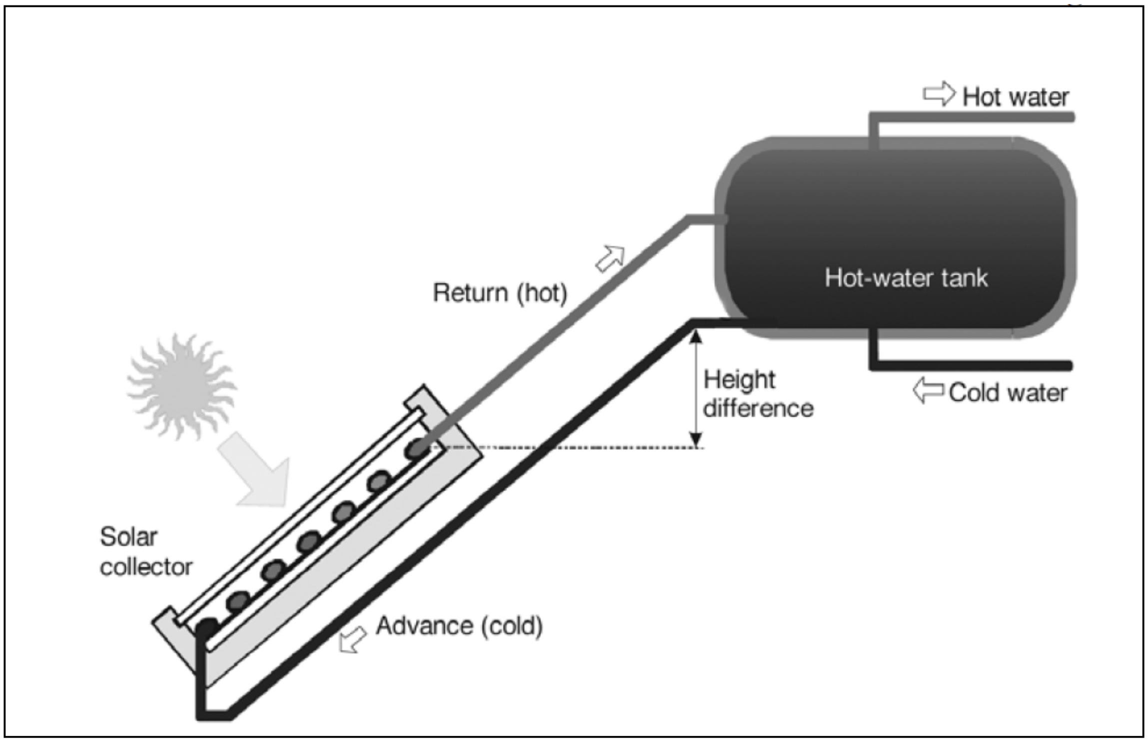

Figure 3.19: Solar thermal water heating system[53]

3.4.3 Solar Collectors

To order to obtain the higher temperatures for water heating, collectors are used the different types of collects are

- Integral storage collector systems
- Flat-plate collectors
- evacuated tube collectors

3.4.3.1 Integral collector storage systems

For integral collector storage systems the hot water storage tank is integrated in the collector Sunlight must pass through the front with low absorption and reflection losses. The cover must therefore be transparent, and yet this leads to large heat

[52]Quaschning/Volker(2005), p.79-84
[53]Quaschning/Volker(2005), p.83

losses through the cover. A vacuum can reduce the heat losses, but not as much as is necessary to design an integral collector storage system.
For the problem of having a transparent cover and to have an insulating cover a new material called transparent insulation materials (TIM) brought a solution to this problem. These materials have a slightly lower transmittance compared to low-iron solar safety glass. However, the heat transition coefficient is significantly lower so that the heat losses are reduced to levels acceptable for integral collector storage systems. A sketch of an integral storage collector system is shown in Figure 3.20.

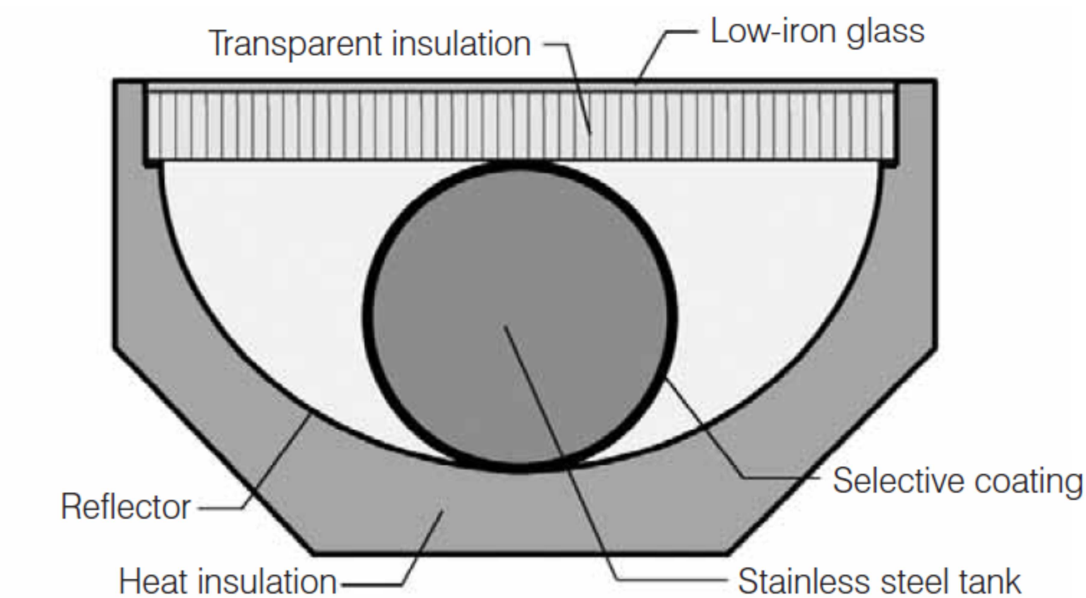

Figure 3.20Cross section of an internal storage collector system[54]

A stainless steel tank is used to store water in an ICS system. The back is perfectly insulated. Solar radiation is reflected on to the storage tank by the reflectors on the inner side of the back, which is also the absorber of this system. There is a transparent insulation material is under the glass front cover. A system covering two square meters has a storage volume of about 160 liters[55].

3.4.3.2 Flat plate collectors

The most common collectors employed for solar domestic water heating systems in many countries are flat-plate collectors. These mostly consist of the following components

[54]Quaschning/Volker(2005), p.85
[55]Quaschning/Volker(2005), p.85-88

- Transparent cover
- Collector housing
- Absorber.

Flat plate collectors have housing and the absorber is inside this housing. There is water in this this tubes the absorber converts the sunlight to head and transfers it to the water in the tubes, which passes through the system. To keep the heat loess to a minimum extent the collector housing is highly insulated on the back and sides, however, there are still some collector heat losses, the main factors influencing the losses are the temperature difference between the absorber and ambient air.

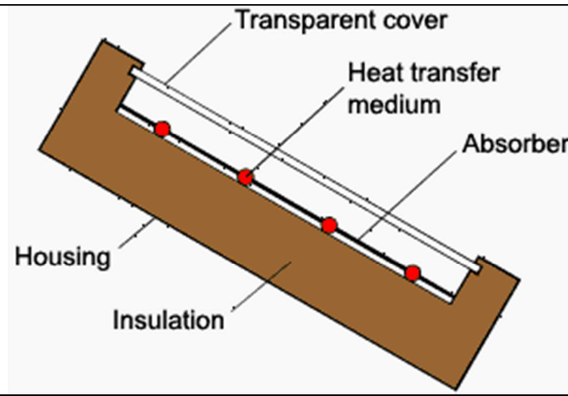

Figure 3.21: Flat plate collector[56]

3.4.3.3 Evacuated tube collectors

The high vacuum inside the closed glass the evacuated tube collector is easier to maintain over a long period of time when compared to that in an evacuated flat plate collector. No support is necessary between the back and the front sides as glass tubes can resist the ambient air pressure due to their shape. Inside the closed glass tube with few centimeters diameter a metal absorber sheet with a heat pipe is embedded. The heat pipe is filled with a temperature sensitive working medium such as methanol. The solar thermal energy heats up the medium. The vapor rises to the heat exchanger and condenser at the end of the heat pipe. The vapor condenses and transfers the heat to the heat carrier of the solar cycle. The condensed heat pipe fluid flows back to the bottom of the heat pipe where the sun starts heating it again.

To work properly, the tubes must have a minimum angle of inclination to allow the vapor to rise and the fluid to flow back. A cross-section illustrating the operating principle of the evacuated tube collector is shown in Figure 3.22.

[56] http://www.solarserver.de/wissen/images/flachkollektor-e.gif Retrieved: 09.04.2010

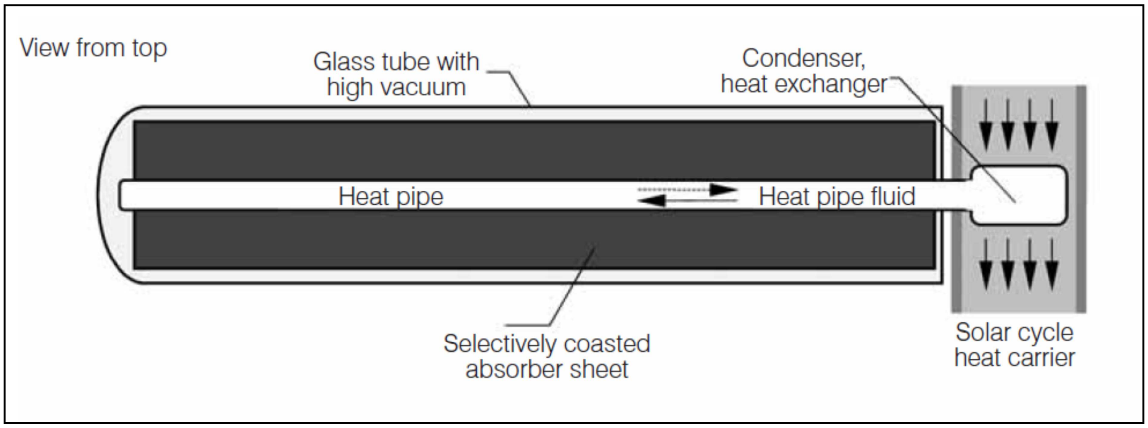

Figure 3.22 Cross section and working principle of an evacuated tube[57]

3.5 Wind energy

Wind is a result of large scale movements of air in the atmosphere. The movement of air is produced on a global scale initially by differential heating of the earth's atmosphere by the sun. Therefore, wind energy is an indirect form of solar energy. In the equatorial regions air is heated more intensely than at other Areas, thereby it becomes lighter and less dense. Produced warm air rises to high altitudes and flows southward and northward towards the poles where the air close to the surface is colder. This movement stops at about 30 °S and 30 °N, where the air temperature starts to decrease and sink then a return flow of this cooler air takes place in the lowest layers of the atmosphere.

The areas in the world where air is descending are the zones of high pressure. Conversely where the air is ascending, low pressure zones are developed. This horizontal pressure gradient drives the flow of air from high pressure to low pressure, which regulates the speed and initial direction of wind. The higher the pressure gradient, the higher is the force on the air and the higher is the wind speed. As the direction of the force is from higher pressure to lower pressure, the tendency of the wind is to flow perpendicular to the isobars (lines of equal pressure).
However, after the wind motion is established, a deflective force is produced due to the rotation of the earth, which alters the direction of motion. This force is known as the Coriolis force. It is important in many of the world's windy areas, but has a minor role closer to the equator.[58]

Wind resources are high in coastal areas as wind's can move unobstructed across the smooth surface of the sea. Furthermore, temperature differences between the sea and land causes local compensating streams. The sun heats the land faster than the water during the day. This results in pressure differences and compensating

[57]Quaschning/Volker(2005), p.180
[58]Freris/Infield(2008), p. 27

winds in the direction of the land area. These winds can reach up to 50 km inland. During the night the land cools much faster than the sea; this causes compensating of the winds in opposite direction.[59]

In Meteorology the beaufort scale is referred generally to give the wind force. This scale allows an approximate estimation of wind without complicates measuring systems. As this system is not useful in technical applications the wind speed is given in m/s and their effects are illustrated in
Table 2[60]

Bf	v in m/s	Description	Effects
0	0-0.2	Clam	Smoke rises vertically
1	0.3-1.5	Light air	Smoke moves slightly and shows direction of wind
2	1.6–3.3	Light breeze	Wind can be felt. Leaves start to rustle
3	3.4–5.4	Gentle breeze	Small branches start to sway. Wind extends light flags
4	5.5–7.9	Moderate breeze	Larger branches sway. Loose dust on ground moves
5	8.0–10.7	Fresh breeze	Small trees sway
6	10.8–13.8	Strong breeze	Trees begin to bend, whistling in wires
7	13.9–17.1	Moderate gale	Large trees sway
8	17.2–20.7	Fresh gale	Twigs break from trees
9	20.8–24.4	Strong gale	Branches break from trees, minor damage to buildings
10	24.5–28.4	Full gale/storm	Trees are uprooted
11	28.5–32.6	Violent storm	Widespread damage
12	From 32.7	Hurricane	Structural damage

Table 2: Wind speed classification of the beaufort wind scale.

3.5.1 Wind Turbines

In olden days wind energy was extensively converted to mechanical energy for daily applications; the same principal is still used in some wind pumping systems also. However, today it is extensively used for power generation. A wind rotor is connected

[59] Quaschning/Volker(2005), p.182f.
[60]Quaschning/Volker(2005), p.183

to an electrical generator which intern produces electrical energy .There are different types of wind mill designs which are explained in the following chapters

3.5.2 Wind Turbines with vertical axis

Windmills with vertical axes are one of the oldest systems that are used to harness the wind energy which dated as old as 1000 years. Today there some modern wind turbine concepts that also have vertical axes these are described in this section. The advantages of wind power plants with vertical axis are. They have a simple construction and assembly. The gear and other electrical components can be placed on the ground with simplifies the maintenance procedures. Wind turbines with vertical axis need not be oriented towards the wind direction; they are perfectly suitable for regions with very fast changes of wind direction.

3.5.2.1 Savonious Rotor

Figure 3.23: Savonius Rotor[61]

[61] http://www.oswego.edu/nova/facts/wind/Image1.gif Retreived:18.03.2010

The Savonius rotor has two semi-cylindrical blades that are open on opposite sides. Near the axis, the blades overlap this design allows the wind can flow from one blade to the other. The blades use the lift principal this makes the Savonius is more efficient compared to simple drag devices. But when compared to good lift devices the efficiency of a savonius rotor is worse. Savonius rotors have the advantage that they can start at very low wind speeds. Due to this advantage these rotors are used for ventilation purposes on buildings or utility vehicles. As Savonius rotors have the disadvantage of a high material demand. These are not used in large systems.

3.5.2.2 Darrieus Rotor

The name darrieus rotor was obtained from its French developer Georges Darrieus in 1929. The Darrieus Rotor has two or three blades which have a shape of a parabola. The profile of these blades refers to lift devices so the Darrieus rotors use the lift principle. The efficiency of a darrieus rotor when compared to Savonius rotor is high but reaches only 75 percent when compared to rotors with horizontal axes.

Figure 3.24 : Darrieus Rotor[62]

[62] http://www.wind-energie.de/fileadmin/bilder/highres//Historische_Muehlen/darius_rotor.jpg Retreived:18.03.2010

The greatest disadvantage of a Darrieus rotor is that it cannot start on its own. It needs an auxiliary system which is generally a drive motor or it is coupled to a Savonius rotor.

3.5.2.3 H-Rotor

An improved model of the Darrieus rotor is the *H rotor* or H-Darrieusrotor. This rotor is also called the Heidelberg rotor as it was first designed and developed by a company Heidelberg Motor. There is no need of a gearbox as a permanent magnet generator is directly integrated in the rotor structure. The rotor works on the same principal as the Darrieus rotor as a lift device. The three rotor blades of the H rotor are attached vertically. To maintain its shape a there is a support to the vertical axis. For extreme weather conditions like in the Antarctica and in the high mountains a robust H-rotor was developed.an model of an H-rotor is shown in Figure 3.25.

Figure 3.25: H-Rotor Installation[63]

3.5.3 Wind Turbines with vertical axis

Most of the electricity produced today from wind turbines is mostly from horizontal axis machines.it is mainly due to the medium sized companies that have encouraged the wind market developments. Wind Turbines have reached high technical level and the present systems can reach powers up to several megawatt’s, compared to those of 1980’s which had a power range below 100kW.The components of a horizontal wind turbine are shown in Figure 3.26.

[63]http://www.lenergy.co.uk/slides/A3%20H-rotor.jpgRetrieved 18.03.2010

General parts of a horizontal wind turbine are

•Rotor hub, rotor blades, a pitch mechanism and a brake.
• Gearbox and an electrical generator.
• Wind measurement system and yaw drive (azimuth tracking)
• Foundation tower and a nacelle.
• Connections substations and control.

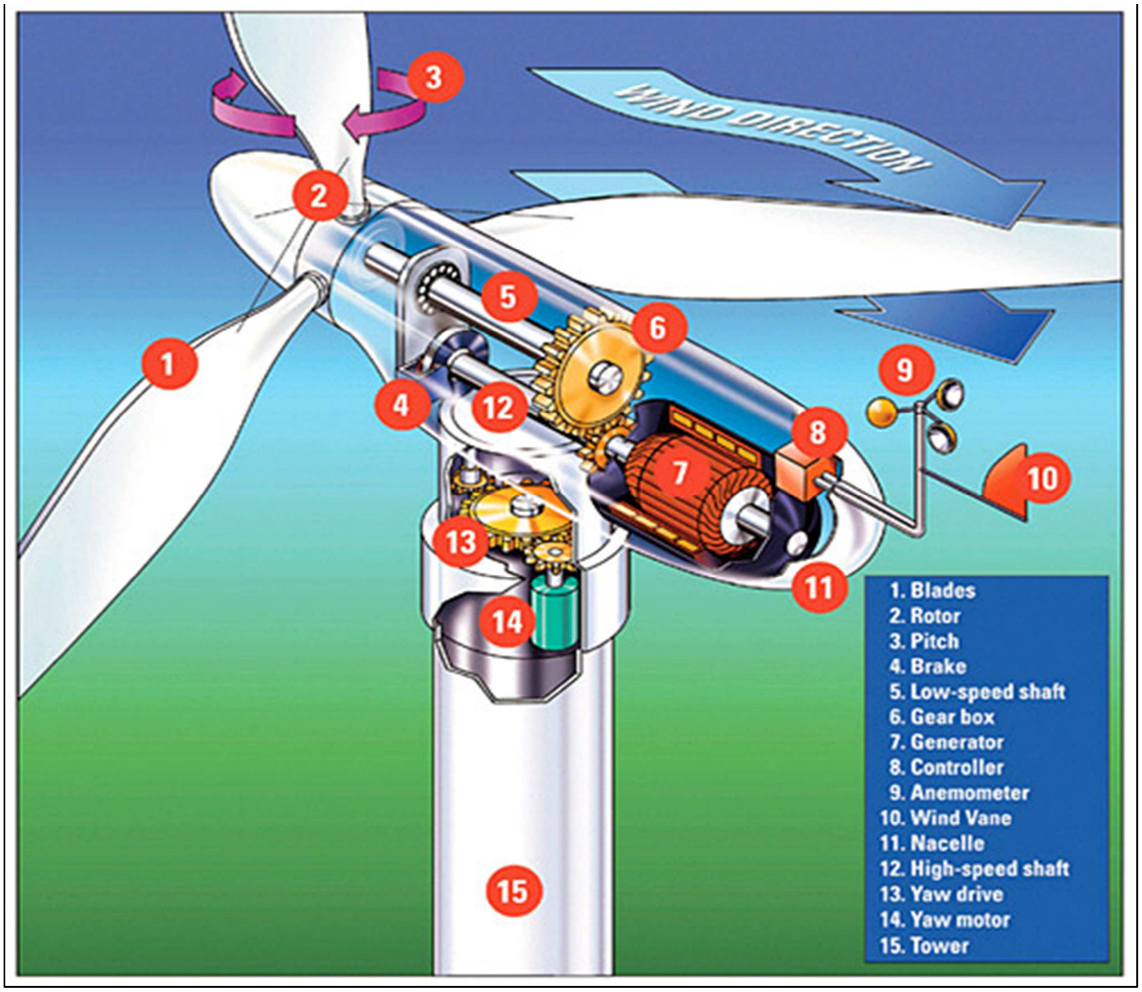

Figure 3.26: Assembly of a horizontal axis wind turbine[64]

Horizontal axis wind generators produced today have one, two or three rotor blades. Generally more than three blades are not used. As the less number of rotor blades directly refers to less manufacturing cost.

[64]http://www.petervaldivia.com/technology/energy/image/wind-turbine.jpg Retrieved 18.03.2010

There are few prototypes with one rotor blade which are in operation at the moment and there are not expected to come into existence any soon. Single blade rotors have a counterweight on the opposite side of the rotor. As these wind turbines have only blade these exhibit high material stress.

Today mainly wind turbines with three rotor blades are built as the optimal power coefficient of three-bladed rotors is slightly high when compared to that of two-bladed rotors. Three-bladed rotors have an optically smoother operation and hence visually integrate better into the landscape. The mechanical strain is also lower for three-bladed rotors. The advantages of three-bladed rotors compensate for the disadvantage of the higher material demand.[65]

3.6 Technologies needed for implementing alternative energy

As it is not possible from bio-mass or horse manure to produce electricity or perform cooling operations directly, there is a need of other equipment. Which could use the heat produced and convert them to needed application.

3.6.1 ORC Turbine

ORC Turbine refers to organic Rankine cycle here in this chapter the thermodynamic explanation of rankine cycle are not given. As the work is more concentrated in using these technologies and find the economic importance of these systems. Here a brief explanationof the working principle of an ORC turbine is given.

When a CHP (combined heat and power) plant is considered using biomass as a fuel the working principle is as follows

1. The heat source (in our case the biomass burner) heats the thermal oil to high temperature of 300^0C in a closed circuit.
2. The hot medium that is the oil is drawn to the ORC Module which is a closed circuit. This heat is transferred through an organic working fluid which evaporates.

[65] Quaschning/Volker(2005), p.199f.

Figure 3.27 : Modular ORC turbine from infinity turbine[66]

3. The vaporized organic fluid expands in the turbine producing mechanical energy which could be used for any application. When coupled to an electrical generator this would produce electricity.
4. The vapor after expansion is cooled in a condenser. The water that is used for cooling has a temperature of 80-90^{o}C which could be used for other purposes.
5. The condensed organic fluid is returned to the closed loop and the cycle starts again[67].

3.6.1.1 Efficiency of ORC Turbine

The overall efficiency of an ORC Turbine is 98% of incoming thermal power in the thermal oil is transformed to 20% electrical and 78% thermal. In a non co generative cycle the electrical efficiency of the unit is increased to 24%.

3.6.2 Adsorption chiller

In order to use the heat produced by the bio-mass plant or a horse manure heating system for cooling applications there is a need for a hot water fired chiller there are the absorption chillers and adsorption chillers now in this section a simple working principal of adsorption chillers is given.

Adsorption chillers use solid sorption materials. Market available systems silica gel as absorbent and water as a refrigerant; but recently, Zeolith a new absorbent has been

[66] http://www.oceanethanol.com/CO2/Ocean_Ethanol/Entries/2008/6/5_Production_Power_-_Via_Waste_Heat_Organic_Rankine_Cycle_files/shapeimage_1.jpg 11.04.2009
[67] http://www.turboden.eu/en/rankine/rankine-theory.php 11.04.2009

developed and these are used by some of the manufactures these days. The two technologies now available are: Silica gel/H_2O and Zeolith/H_2O.
The adsorption chiller consists of two sorbent compartments as shown in Figure 3.28 one of it is evaporator and the other is condenser.

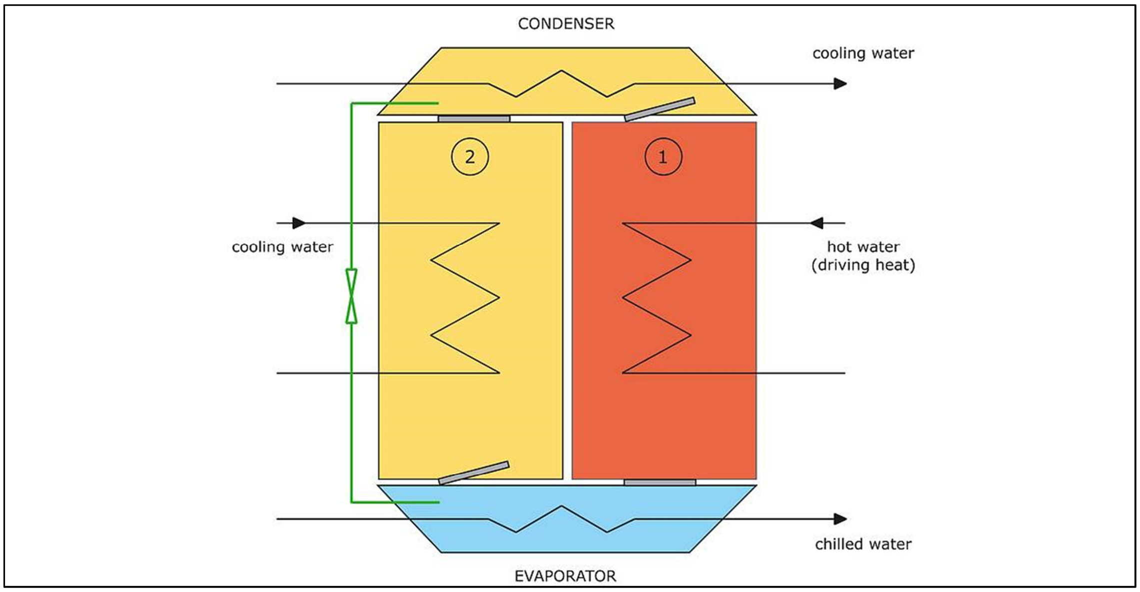

Figure 3.28Schematic drawing of an adsorption chiller[68]

Using an external heat source like hot water the sorbent in the first compartment is regenerated, for example the heat form a CHP plant or a solar collector, in the second compartment the sorbent adsorbs the water vapor entering from the evaporator. Compartment 2 has to be cooled in order to enable a continuous adsorption. The refrigerant in the evaporator is transferred into the gas phase due to the low pressure conditions in the evaporator. The refrigerant takes up the evaporation heat from the chilled water loop and thereby producing the useful "cold". If the sorption material in the adsorption compartment is saturated with water vapor to a certain degree, the chambers switch over in their function.

Under typical operation conditions, the systems achieve a coefficient of performance (COP) of about 0.6with a driving temperature of 80 ℃, but this is possible even when the temperatures are less as 60 ℃ [69].

[68] http://www.solair-project.eu/142.0.html Retreived:11.04.2010
[69]http://www.solair-project.eu/142.0.html Retreived:11.04.2010

3.6.3 Absorption chillers

The absorption chillers use a solution of lithium bromide and water, as a working fluid and the working is under a vacuum environment. Lithium bromide which is a non-toxic salt is used as an absorbent and water is used a refrigerant. Refrigerant which is liberated by heat from the solution produces a refrigerating effect in the evaporator when cooling water is circulated through the condenser and absorber.

When the heat medium that is water at a temperature above 68℃ enters the unit, the solution pump pumps dilute lithium bromide solution into the generator. As a result the solution boils under vacuum and the concentrated solution is carried to the primary separator. After separation refrigerant vapor flows to the condenser and concentrated solution is precooled in a heat exchanger before moving to the absorber.

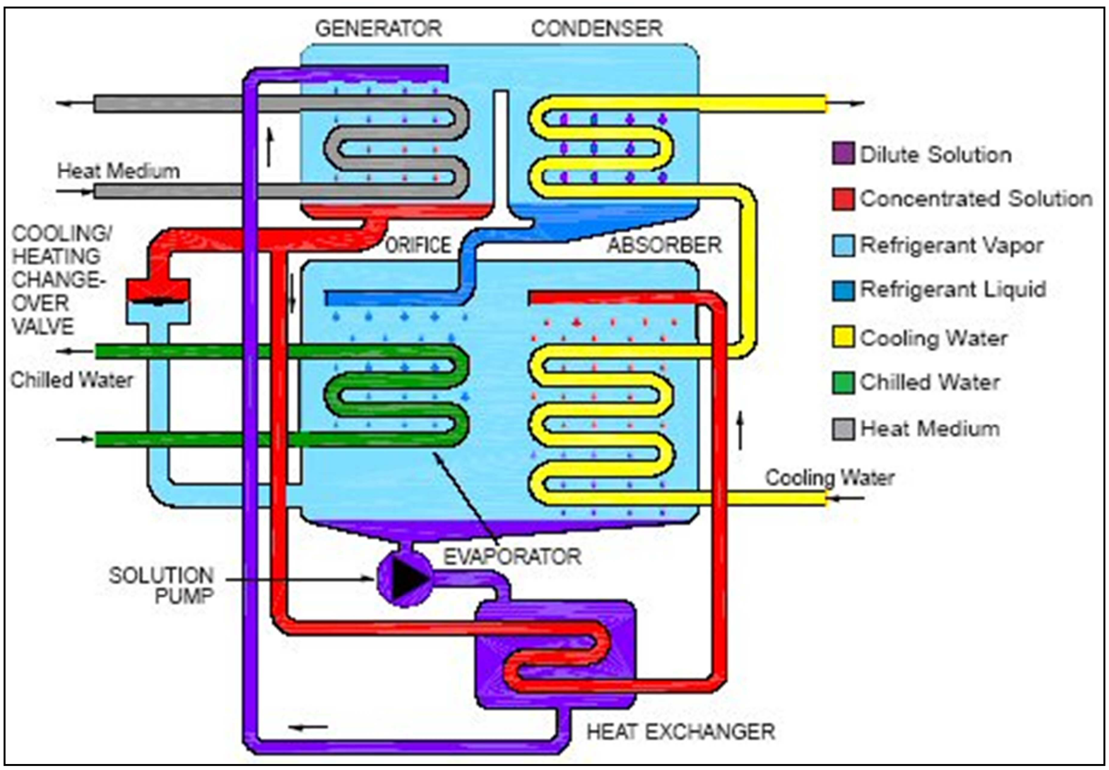

Figure 3.29 Schematic representation of absorption chilling process[70]

In the condenser, the vapor is cooled when flown over the cooling water circuit and the latent heat is removed by the water in the circuit the refrigerant liquid accumulates in the condenser and passes to the orifice to the evaporator. In the evaporator the refrigerant is exposed to a deeper vacuum compared to the condenser due to the effect of the absorber. When the fluid flows over the evaporator

[70] http://www.yazakienergy.com/waterfired.htm Retreived:19.04.2010

coil it boils and removes heat that is equal to the latent heat of the refrigerant from the chilled water circuit. The water in the chilled water circuit is cooled to 7℃ and this could be used for cooling purposes[71].

[71]http://www.yazakienergy.com/waterfired.htm Retreived:11.04.2010

4 Scenarios

To the given task as a solution there were three scenarios developed. The technologies used in these scenarios are the available alternative energy sources utilizing technologies that are explained in the previous chapters. The schematic diagrams of the scenarios, the technical details and economic effects of these scenarios are given in this following chapter.

4.1 Scenario 1

In this scenario the alternative energy sources used are

- Wind energy
- Heat from Horse manure

The basic energy needs of the campus are electricity and heat. Electricity is used for lighting, powering electrical equipment and at present for cooling needs in summer. Heat is used in winter for heating applications and for heating water along the year. The schematic diagram for the scenario is shown in the Figure 4.1.

In this scenario electricity is generated from a wind mill; the basic construction of a windmill is explained in the chapter 3.5.3.Thewind mill would be place in a wind farm. Wind farms are large areas where there is ambient wind for electricity production. These are maintained by external firms, a place in the farm includes the service and maintenance of the wind turbine as well. The electricity from the wind turbine is fed into the national grid and a payment is made as per the feed in tariff. which is explained in section 2.5. Electricity from the grid is used as it is used at the moment and pay the same charges.

The wind turbines are not places in the campus, as there is not such high wind velocities that the wind turbine can function to the required specifications. The other problems are like the high sound, and vibrations caused during operation if the turbine.

For the comfort systems employed in the building i.e. the cooling and heating systems, which are hereafter stated as comfort systems would have to be replaced. The replacement of the whole systems would not be required the ducts which are running in the building can be used, as they are at the moment. Only the cooling system which is a evaporative radiant cooling system would be replaced by a hot water fired adsorption chiller. The chiller supplies cold water or a cold medium that can be used for cooling in the existing system.

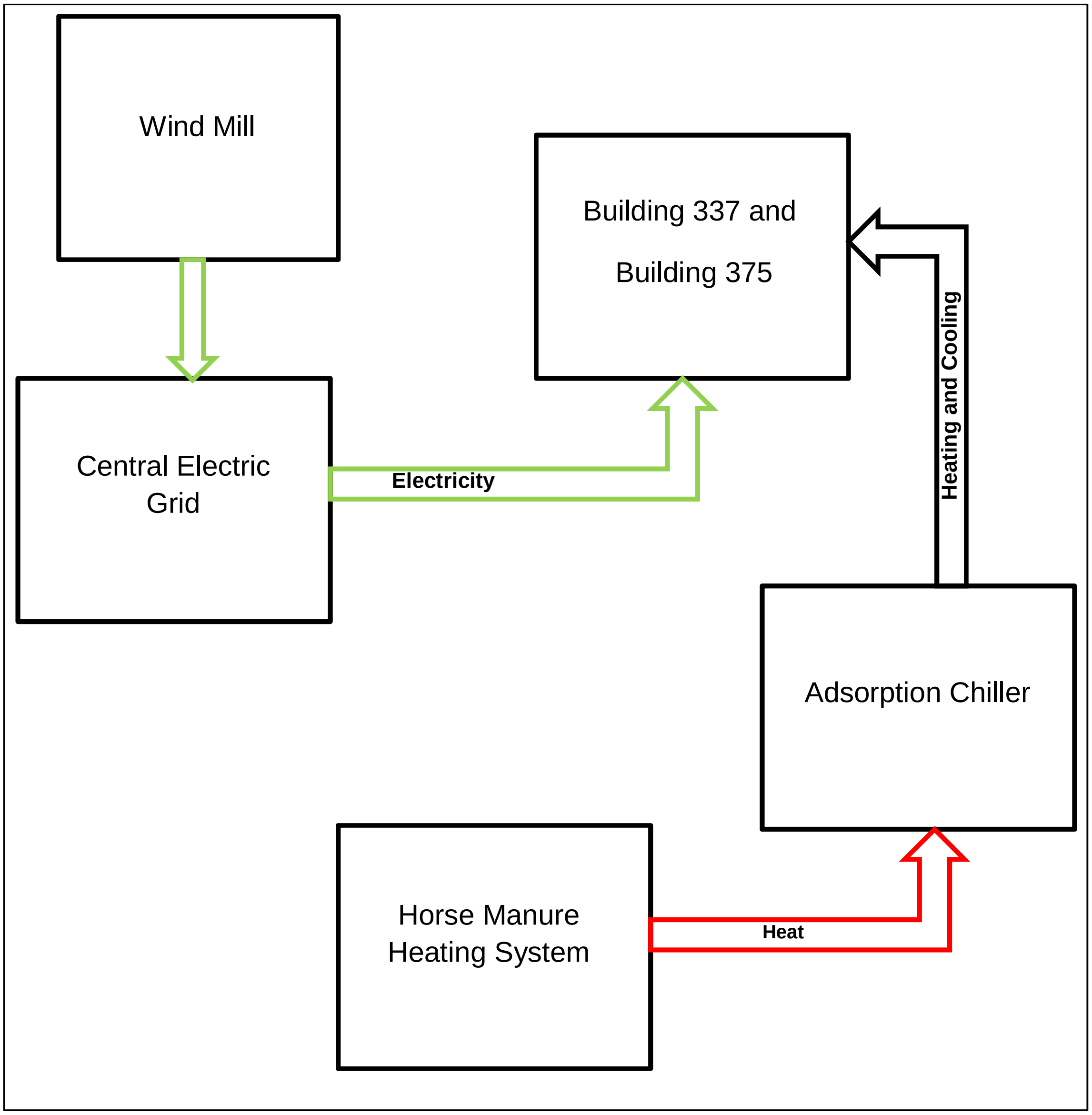

Figure 4.1Schematic diagram of scenario 1

For the hot water fired adsorption chiller hot water is needed .In order to supply this heat energy, possibilities for using the biomass from the campus were sorted. There is a horse manure heating system develop by Swedo bio energy. The technical details are explained in section 3.2.6.The horse manure that is produced by the horses that are available at the moment in the campus can be used as a fuel to power this heating plant. This would be enough for heating and cooling needs of the buildings. As the adsorption chiller can be used for cooling during summer and heating in winter. The heat generated can also be used for heating water, for use in these buildings with the existing system. The need for changes is not much and the new system can be easily integrated into the existing system.

4.1.1 Facts for scenario 1

The working principal and the basic components of the wind turbines are explained in section 3.5.3 and for the selection of the wind turbine a comparison of wind turbines produced by the major wind turbines manufacturers for 1.5 MW were conducted and the results are shown in Figure 4.2. The manufactures of wind turbines produce wind turbines in ratings with an increasing factor of 0.5MW. These range from 0.5MW-3MW. Considering the electrical needs from the buildings, 1MW would be insufficient and 2 MW would be excess. In order to be optimistic 1.5MW is selected.

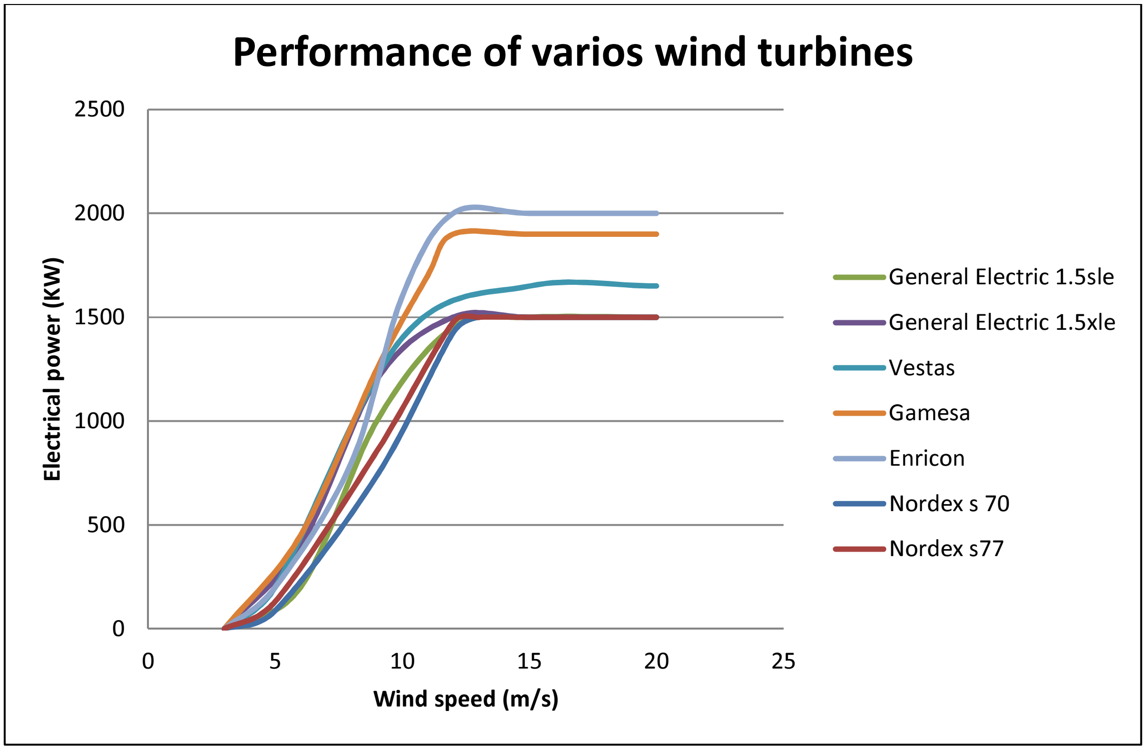

Figure 4.2 Performance of various wind turbines[72]

After the comparison of performances from the wind turbines, the performance directly depends on the wind speed, and is nearly the same, when all the wind turbines of 1.5MW are taken into consideration. The average wind data was collected from the ministry of natural resources Canada. This is shown in Figure 4.3 this data is at a height of 80 meters above the ground level, which is the normal installation height for a wind turbine.

[72] From various wind turbine brochures (General electric, Vestas, Gamesa, Enricon, Nordex)

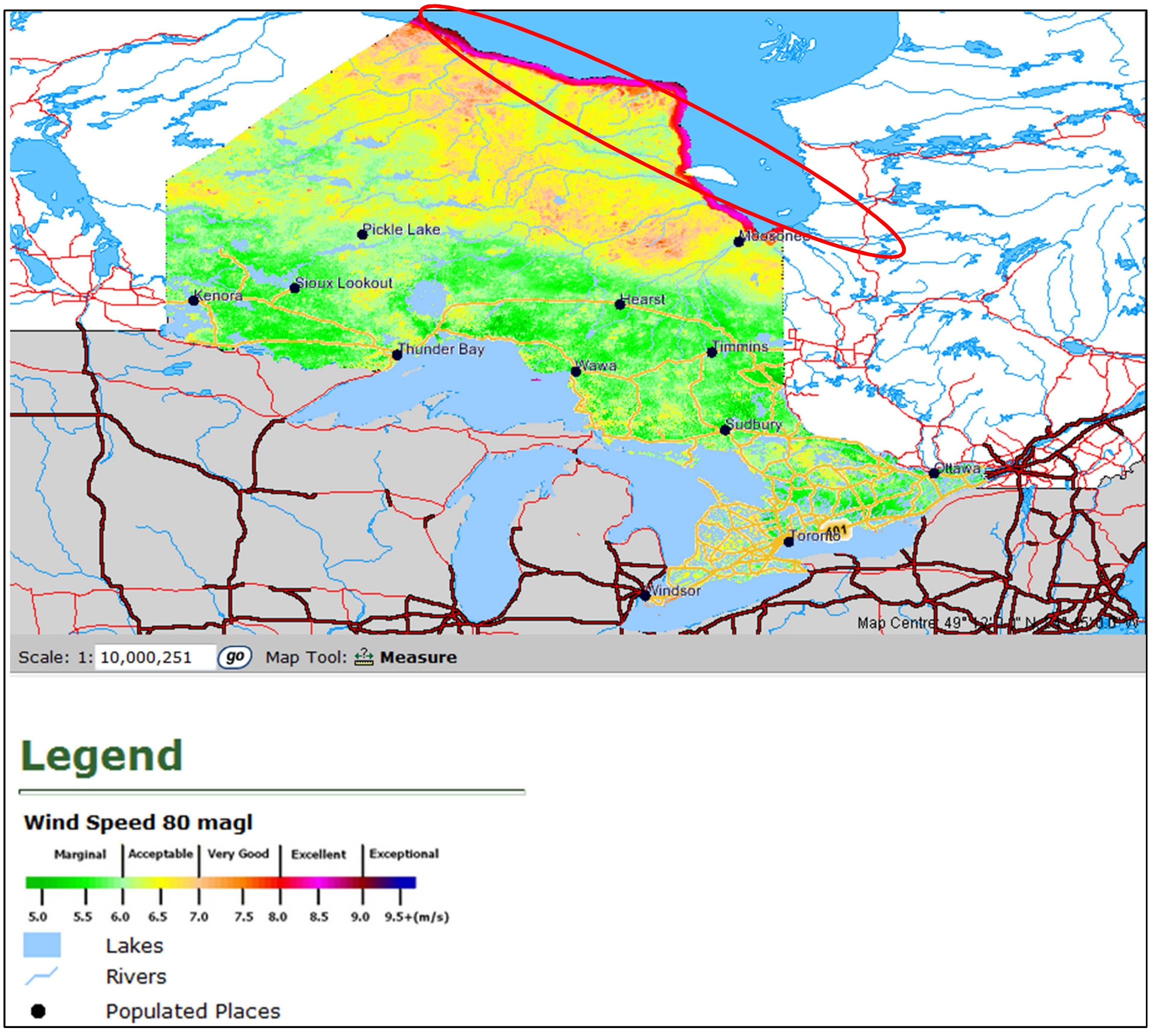

Figure 4.3 Wind atlas Ontario[73]

There are wind parks available in the high wind regions which are suitable for our applications. A place can be purchased for installation of the wind turbine. If a combined contract is made this would include the maintenance of these turbines. This would decrease the need for people employed by Magna in this scenario for maintenance.

The installation could be made in areas of high wind velocity as indicated in Figure 4.3. There are companies which are maintaining wind farms in the same areas and a place could be brought easily.

73 http://www.lio.ontario.ca/imf-ows/imf.jsp?site=windpower_en Retreived:10.04.10

4.1.2 Economic facts and impacts

Investment	Value	Unit
Wind turbine (1.5MW):	2Mio	CAD
Horse manure heating system (0.5MW):	360000	CAD
Adsorption chiller (250Ton):	400000	CAD
Total	**2.76Mio**	**CAD**

Costs and pay back calculation for wind turbines:

Factor	Value	Unit
Per month Electrical needs	348057.6667	kWh
Per day Electrical needs	11601.92222	kWh
MWh	11.60192222	
1.5 MW turbine running for 24 hrs	36	MWh
60 % running time	21.6	MWh
Buying cost 10cents /Kwh		
100$/Mwh		
per day costs	1,160	CAD
revenu from production	2,808	CAD
money earnt/day	1,648	CAD
investment	2000000	CAD
Per month	49,434	CAD
Months required to pay back	40.45779342	Months
Payback time in Years	**3.371482785**	**Years**

For calculating the electrical energy produced from the wind turbine a nominal consideration of 60 percent running time is made. The other 40 percent includes maintenance time. As the wind required for 1.5MW output might not be available all the time. Consideration of all these factors is made and the value is calculated as 60 percent to be optimistic. All the calculations are made on this consideration that it would work only for 60percent of the time. The worst case scenario it works for 60percent time. If the turbines works for more than 60 percent of the time, then the payback time would be even less.

Costs and payback time for cooling and heating and cooling systems

Investment	Value	Unit
Adsorption chiller	412500	CAD
Horse manure Heating system	358600	CAD
Total Investment	771100	CAD
Fuel	0	CAD
Maintainanace/Year	20000	CAD
savings per year	**217364**	**CAD**
payback time in years	**3.54751**	**Years**

Considerations made in calculating the costs and payback times for the comfort system are:

Fuel costs are nil as there is manure already available in the campus.

Maintenance costs are approximations as there is no record or the company doesn't give any costs of maintenance. These costs include the service and dumping charges for horse manure. At the moment 200CAD/Ton are paid for disposal of horse manure. These charges are not included as earnings. As the maintenances charges are not accurate, to be optimistic these charges are not added in the calculation.

The system could run all along the year so there is no need for a backup system, for heating and cooling systems. In case of yearly maintenance it could be stopped in the month of April where there is no need for cooling or heating, as the outside temperature is mild. According to the historical data the comfort systems are not used in this time. If maintenance operations are planned during this time there would be no need of a backup system.

4.1.3 Payback time of the complete system

When the wind turbine and the horse manure system is considered as a single system for complete energy needs in the campus. The whole system payback time would be approximately 3.5 years. This would be if the calculations are too optimistic, and when the worst case scenarios are taken into consideration for calculating the payback time. If the maintenance costs for the horse manure burning system, and if the wind turbine works on a more efficient scale the payback time would be still less. It could be summarized that when this system is employed, and the conditions are optimistic for the boundaries, and calculation of payback time. The whole system would pay back in 3.5 years.

4.1.4 SWOT analysis

The term SWOT stands for strengths, weaknesses, opportunities, threats. SWOT summarizes the key issues from the business environment and the strategic capability of an organization that are most likely to impact on strategy development[74]. Internal factors (Strengths and Weaknesses) highlight the company's own facilitating or exacerbating capabilities and resources towards the project, whereas external factors (Opportunities and Threats) consider conducive or adverse effect of the business venture's external environment[75].

SWOT analysis of all the scenarios has been made in this master thesis. The analysis would be a start to concentrate on weaknesses and threats, at the same time try to reduce their negative effect in the project or to eliminate them.

Strengths	**Weaknesses**
• No fuel costs • Costs for disposal of waste eliminated • Plant waste can be used as manure	• Not completely independent from grid • Lack of technical expertise in energy business • New technologies • Cannot be easily expanded for future energy needs
Opportunities	**Threats**
• New business • Opportunities to build wind farms as new business • New partners for business expansion • Future increase in energy prices	• Uncertainties in wind energy • Reduced in feed-in-tariffs • New technologies which are more cost effective

Figure 4.4: SWOT analysis for scenario 1

[74] Johnson/Scholes/Whittington(2005), p.119
[75] Weber(2009), p. 70

4.2 Scenario2

In this scenario the alternative energy source used is biomass.

The basic energy needs of the campus are electricity and heat. Electricity is used for lighting, powering electrical equipment and at present for cooling needs in summer. Heat is used in winter for heating applications and for heating water along the year. The schematic diagram for the scenario is shown in the Figure 4.5.

In this scenario for generating electricity a biomass burner system is used. This system is the heart of the whole scenario, as this is the initial energy generating system in the form of heat. The fuel used in this system is a wide choice anything that is listed as biomass can be used in this system. There is an availability of horse manure and the grass chippings from the campus which are a disposal burden at the moment can be used in this system as fuel. The heat from the system is sent to an ORC Turbine module connected to an electrical generator. The working principal for an ORC Turbine is given in section 3.6.1. After the expansion in the module the water still has temperature that can operate an adsorption chiller. The use and need of the adsorption chiller is illustrated in the coming section.

For the comfort systems employed in the building i.e. the cooling and heating systems which are hereafter stated as comfort systems, would have to be replaced. The replacement of the whole systems would not be required. The ducts which are running in the building can be used as they are at the moment. Only the cooling system which is an evaporative radiant cooling system would be replaced by a hot water fired adsorption chiller. The chiller supplies cold water or a cold medium that can be used for cooling in the existing system.

It was decided to by experts in the field of alternative energy consulting business to have a bio-mass burner of 1.5MW thermal capacity. This heat is not sufficient to full fill the complete electrical needs of the campus. After the system is employed and running, there is a need to take some amount of electricity from the grid as well.

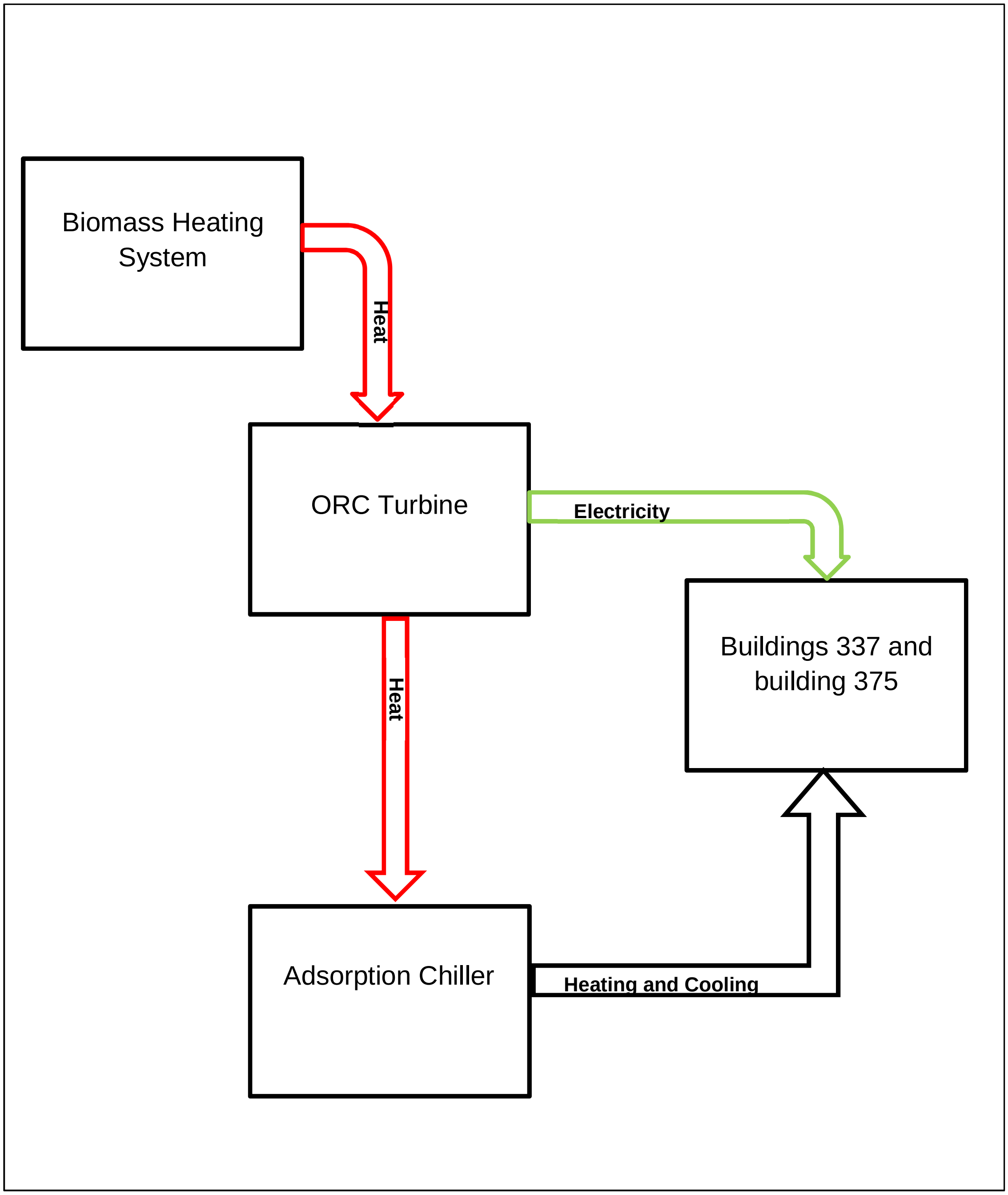

Figure 4.5Schematic sketch of scenario 2

The amount of heat generated can be used for running the comfort systems completely. As the cooling system is running in the summer months and the heating system is running in the winter months the system runs along the year. In the months of April and May where heating and cooling are not used according to the previous data these months could be used for yearly maintenance operations.

4.2.1 Facts of scenario 2

A biomass burner of size 1.5MW thermal capacity has been decided to be implemented as this would be ideal size for the campus. This was decided in collaboration with technology patterns who have been working in the field of burners from years. The cost of wood chips is enquired form Canadian colleagues who have these special prices from their sources.. The heat to electricity conversions are made according to instructions from an ORC turbine company engineer. The working principal and the equipment details about the ORC Turbine are explained in 3.6.1, and a basic working principal of a woodchip burning system is explained in 3.1.1.1

4.2.2 Economic facts and impacts

Total investments to be made

Investment	Value	Currency
Wood chip Heating system	354312	Euros[76]
	496036.8	CAD
ORC Turbine 250Kw	3,40,000	USD
	343400	CAD
Adsorption chiller	412500	
Total Investment	1251936.8	CAD

Payback time calculation for wood chip heating system

Electrical Production	Value	Unit
Electrical Production		
From ORC turbine	876000	KW
Revenue from Production	113880	CAD
Our electric costs	346540.8	CAD
Electric costs	232660.8	CAD
Our costs for Heating and cooling	237363.5	CAD
savings from Heating and cooling	237363.5	CAD
Total Savings	**313743.5**	**CAD**
Investment pay back time	**3.9**	**Years**

[76] http://www.xe.com/ Retrieved 02.03.2010

Factor	Value	Unit
Calorific value of wood	4.1	kW-h/Kg
Efficiency of the Bio-mass Plant	80	%
Calorific value of wood with respect to plant efficiency	3.3	Kw-h/Kg
	43200000	W-hr
Capacity of the Heating system	1500	kW
In Watts	1500000	W
Per Hr from ORC Turbine	125	kW
For 6000 Hrs	750000	kW
In tonns total requeirment	750	
Price per MT	50	CAD
Total	**37500**	**CAD**

Taking the calculation into account the payback time for the whole system would be approximately 4 years.

Facts for calculating electricity production from heat generated from woodchip heating system.

Heat generated is taken in units Btu/hr. and divide by 35,000 Btu which is equivalent to10.23kWh.

For example: if total heat 8,750,000 Btu / 35,000 Btu = 250 kWe / hr.

This basic calculation was suggested by Infinity turbines Inc. USA. This is one of the major producers of ORC turbines in USA. The maintenance costs and approximate operating costs are added to the calculation the fuel price is from a source enquired form the Canadian partners. All the data that is taken into consideration is on the most optimistic. The feed in tariff is taken as into consideration is 13 cents whereas the feed in tariff is 13.8 cents actually. This has been done deliberately in order to have optimistic results. The system could run all along the year as heating is required in winter and cooling in summer. The system is running all the time for comfort systems and there is a possibility of producing electricity which is an added advantage and this would help to payback faster.

The fact that the ORC turbine is to be purchased cannot be neglected. If there is no ORC turbine in the system the system could still function without any hazels but the payback time would be more. While investing in ORC turbine we could see that the payback time gets less which is a great advantage. This would be environmental friendly as we are using the whole energy without wasting it. As the heat used by ORC module would be wasted if not used by the module.

4.2.3 Payback time of the system

In the worst case scenario the payback time for the whole system including the cooling system investments would be 4 years in any worst case scenario provided that there is not much fluctuation in the fuel costs. All the calculations made assumptions are made that what is earn is always less than the earnings that are really generated form the system and the input costs are the same as they occur during the operation and installation of the system. This is done in order be on a safe side as when it is seen that the payback time is more and we are paid back soon this is considers to be a positive issue in the planning phase.

4.2.4 SWOT analysis

Strengths	**Weaknesses**
• No fuel costs • Costs for disposal of waste eliminated • Plant waste can be used as manure	• Not completely independent from grid • Lack of technical expertise in energy business • New technologies • Cannot be easily expanded for future energy needs
Opportunities	**Threats**
• New business • Opportunities to build wind farms as new business • New partners for business expansion • Future increase in energy prices	• Uncertainties in wind energy • Reduced in feed-in-tariffs • New technologies which are more cost effective

Figure 4.6 : SWOT analysis of scenario 2

4.3 Scenario 3

In this scenario the alternative energy source used is biomass.

The basic energy needs of the campus are electricity and heat. Electricity is used for lighting, powering electrical equipment and at present for cooling needs in summer. Heat is used in winter for heating applications and for heating water along the year. The schematic diagram for the scenario is shown in the

In this scenario for generating electricity biomass gasification system is used. This system is the heart of the whole scenario as this is the only initial energy generating system in the form of heat. The fuel used in this system is a wide choice anything that is listed as biomass can be used in this system. There is an availability of have horse manure and the grass chippings from the campus which is a disposal burden at the moment can be used in this system as fuel. The heat from the system is sent to a steam turbine module connected to an electrical generator. After the expansion in the module the water still has temperature that can operate an adsorption chiller and the water is sent to the adsorption chiller. The use and need of the adsorption chiller is illustrated in the coming section.

For the comfort systems employed in the building i.e. the cooling and heating systems which are hereafter stated as comfort systems would have to be replaced. The replacement of the whole systems would not be required. The ducts which are running in the building can be used as they are at the moment. Only the cooling system which is an evaporative radiant cooling system would be replaced by a hot water fired adsorption chiller. The chiller supplies cold water or a cold medium that can be used for cooling in the existing system.

It was decided by the experts in the field to have a bio-mass Gasification system for generating producer gas in the scenario. The produced gas can be used for thermal use. The thermal energy produced is used to generate steam to run a steam turbine. The steam turbine is coupled to an electrical generator for electrical production. The expanded steam can still power an adsorption chiller which is the heart of the cooling and heating system. The system runs all along the year, the cooling system is running in the summer months and the heating system is running in the winter months the system runs along the year. In the months of April and May where heating and cooling are not used according to the previous data these months could be used for yearly maintenance operations.

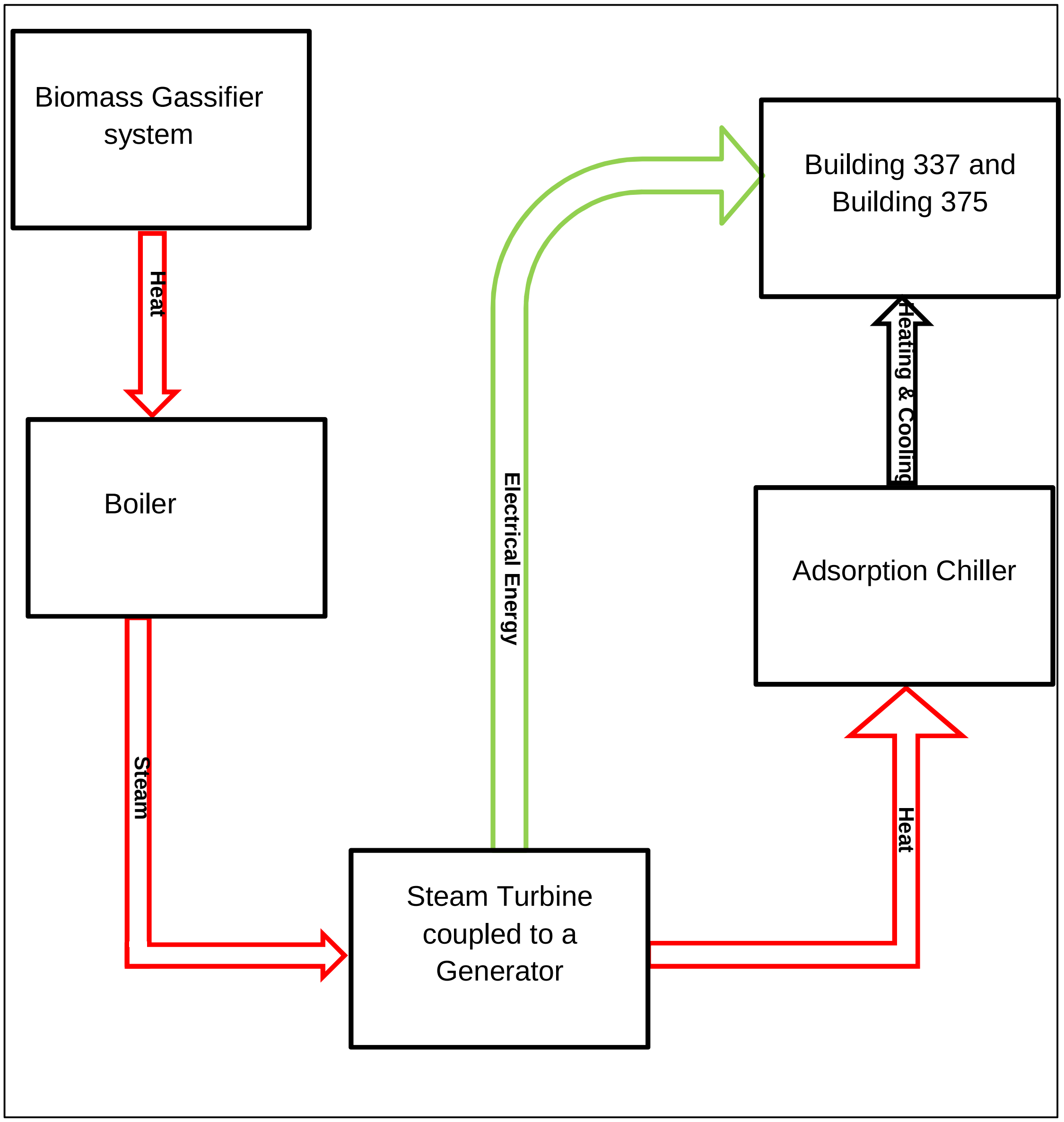

Figure 4.7: Schematic representation of scenario 3

4.3.1 Facts of scenario 3

The scenario has been designed for 1.16MW total capacity. The plant would deliver 28MWh of thermal energy and 7MWh of electrical energy during its full load operation. This energy delivered by the plant is the peak load of the capacity. When the system is employed the buildings would be independent form the grid. The scenario is developed in collaboration with technology patterns who have been working in the field of fluidized ash bed systems. The cost of wood chips is enquired form Canadian colleagues who have these special prices from a source. The horse manure which is a waste at the moment can also be used as fuel. The working principal is explained by a schematic sketch in

Figure 4.7. The working principal of the fluidized bed system is explained in 3.2. The working principal of the heating and cooling system by an adsorption chiller is explained in 3.6.2.

4.3.2 Economic facts and impacts

Investments	**CAD**	
Fluidized bed system and boiler	1.45	Mio
Flue Gas cleaning system	470000	
Turbine	600000	
Adsorption Chiller	450000	
Total	**2.97**	**Mio**

4.3.3 Payback time calculation for the system

Factor	**Value**	**Unit**
Fuel in the campus		
Horse manure	3000	kg/day
Fuel to be purchased		
Wood chips/wood/biomass	6.5	Tonn
Biomass at CAD50/tonn	325	CAD/day
savings per day	1470.68	CAD/day
savings per year	0.50003	Mio
Payback time	**5.9**	**Years**

Factor	Value	Units
Carofic value of fuel	14.5	MJ/kg
In kWh/kg	4.03	kWh/kg
Efficiency (Thermal)	0.72	
Efficiency (Electric)	0.18	
Days in operation per year	340	days
Input/day	9.6	Tonn
Input/Year	3504	Tonn
Thermal energy per day	27840	kWh/day
Electrical energy per day	6960	kWh/day
Thermal Power output in Kw	1160	Kw
Electrical Power output in Kw	290	Kw
Revenu From electrical production	960.48	CAD/day
Revenu From Thermal production	835.2	CAD/day
Total	**1795.68**	**CAD/day**

The calculations made for the scenario are completely based on assumptions. The opinions on these assumptions were taken from professionals in the respective fields. After an opinion taken from them that these assumptions and being certified by the professionals that these are optimistic the calculations are made.

For the calculation that has been made the tipping fee which is paid to the company for disposing horse manure was not included. The maintenance charges are not included in the calculation, as this is not certain at the moment about the maintenance charges. As these charges depends in the location and other factors. As the location and material handling operations are not yet designed at this phase of the project, this is hard to calculate. To compensate to these costs in future the costs for horse manure tipping fee and the bio mass from the campus are not included as earnings in the calculation. The maintenance charges are approximated to the earnings in horse manure tipping fee and the fuel costs form the biomass from the campus.

4.3.4 Payback time of the system

The payback time is calculated approximately to be 6 years. The building costs and the piping costs for water and other necessities have not been included. The location and the need for building a new facility have not been decided. There is a construction that is undergoing at the moment in the campus so the possibility to integrate the energy system in this. If this could be possible then the costs for constructing the facility are completely eliminated.

4.3.5 SWOT analysis

Strengths	**Weaknesses**
• No fuel costs • Costs for disposal of waste eliminated • Producer gas can be used for other research's • Could be completely independent from grid if wanted	• Not completely independent from grid • Lack of technical expertise in energy business • New technology
Opportunities	**Threats**
• New business • Producer gas research for automotive can be done • New partners for business expansion • Smaller size systems for medium sized business's • Future increase in energy prices	• Uncertainties in fuel availability • Reduction in feed-in-tariffs • New technologies which are more cost effective

Figure 4.8 SWOT analysis of scenario 3

4.4 Comparison of scenarios

Comparison of scenarios has been done on economic and both technical grounds. The economic comparison gives figures about investments and paybacks. The comparison is stated in Table 3. It is interesting to see how the payback time changes with investments maid.

Scenario	Investments	Payback time
Scenario 1	2.76 Mio	3.5 Years
Scenario 2	1.25 Mio	4 Years
Scenario 3	2.97 Mio	6 Years

Table 3: Investment and payback time for 3 scenarios

For an comparison of these scenarios in technical terms these are summarized and compared inTable 4.

Scenario	Fuel Used	Mechanical power for electrical production	Heating and cooling
Scenario 1	Wind, biomass	Wind turbine	Adsorption Chiller
Scenario 2	Biomass (burner)	ORC Turbine	Adsorption Chiller
Scenario 3	Biomass (Gassifier)	Steam turbine	Adsorption Chiller

Table 4: Technical comparison of scenarios

From the technical comparison it is clear that there is a similar system that is employed for cooling and heating. Bio mass is the common fuel that is used in all the three scenarios. There is a great difference in the methods for electrical production and the usage of biomass. Although the fuel used in the three scenarios is biomass there is a great difference in the fuel usage in the first and second scenario the fuel is burnt and in the third scenario is fluidized and producer gas is generated. The produced producer gas is then used for producing steam by heating water in a boiler, and the steam is used for electrical generation and heating and cooling purposes.

The earnings of these scenarios project for the next ten years are shown in Figure 4.9.

For the calculation made for the earnings for the next 10 years the interest rates that apply on the investments are not taken into account. The feed in tariff considers after five years is the same like it is now. This consideration has been made as the prevailing feed in tariff is to encourage investments in green energy. After some time to be optimistic the fee in tariff may still be the same has been taken into consideration. And a price increase in the current energy charges is taken as two percent per every year.

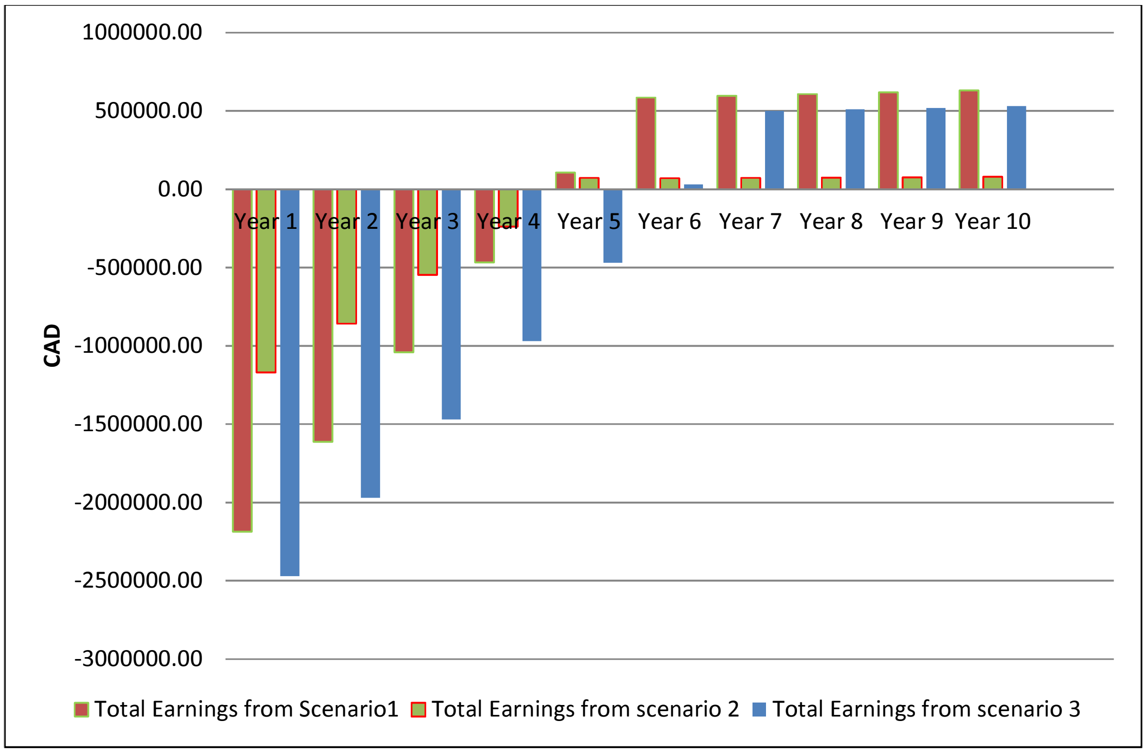

Figure 4.9 Earnings from scenarios project for next 10 years

5 Conclusion

The goal for the thesis was to have an alternative energy system for the buildings 337 and 375 in magna campus. As a result three scenarios have been developed with technical and economic facts.

The three scenarios are developed in collaboration with Canadians as they have more knowledge about their surroundings and environment. Care has been taken in order to utilize all the biomass that is available in the campus, this would decrease the disposal costs and fuel cost for the system.in the initial phase all the available alternative energy sources were investigated. After investigating the energy sources the sources that are feasible for the campus are considered.

All the considered energy sources are designed to scenarios to check the feasibility in terms of technical and economic conditions. All the environmental factors for the functioning of these scenarios are also mentioned along with the SWOT analysis of each scenario.

All the scenarios are compared in terms of technology and in terms of economic impacts. The investments and the payback times when calculated are optimistic, as the data for maintenance and running costs are not available as these systems are tailor made an exact calculation has not been possible. As the goal for the project was to have an alternative energy plan for the campus, three scenarios are developed and the facts for these scenarios are stated.

From a new business idea from magna international, in the area of biomass heating systems and energy systems there could be a great opportunity. As stated before the prospective of major electrical equipment manufacturers. In the near future they are planning to develop intelligent energy management systems, which would manage energy production and consumption. If this is the case, there would be a market for complete systems which could supply the whole energy needs of the houses. In non-peak times this produced energy could be sold by this smart energy management systems.by implementing these smart systems and having small energy systems at homes would decrease the overall energy costs of the household. At the same time would be environmental friendly if fossil fuels are not used.

5.1 Future Work

The planning phase has been done with the thesis work. The development and facts for the scenarios are worked out to be most optimistic. The future work includes completely on the system that has to be implemented in the campus. If the first scenario has to implemented more investigation has to be done in the wind park area. If the second and third scenarios have to be implemented the long term contracts for biomass supply have to be worked out well that there are no problems in future.

The business point of view there could be new business opportunities in the field or alternative energy. One option could be consulting for alternative projects and developing scenarios for whole energy management for medium sized campuses. There is an opportunity for developing and manufacturing biomass heating systems, the market research and partner study was already done by Mr.Weber and a business plan was also developed.

With the governments focus on alternative energies and incentives provided by the states, the interest of companies and individuals has increased in alternative energies. This could be a good time to enter the alternative energy business as magna has the engineering capabilities they could easily enter the business field.

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7 List of figures

8 List of tables