بسم الله الرحمن الرحيم

udan University of Science & Technology

College of Graduate Studies

Electric Performance and Efficiency of Wind Turbines in Electric Vehicles

الكفاءة والأداء الكهربائي لتوربينات الرياح للسيارات الكهربائية

A Thesis Submitted for Fulfillment of Requirement for Degree of Doctor of Philosophy in Physics

Prepared By :

Arwa Azhry Mohammed

Supervise:

Associated Professor Dr. Rawia Abdelgani Elobaid

Co. Supervisor Professor Dr. Mubark Dirar Abdalla

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بسم الله الرحمن الرحيم

الآية

قَالَ تَعَالَىٰ:

﴿ وَمِنْ ءَايَٰتِهِۦٓ أَن يُرْسِلَ ٱلرِّيَاحَ مُبَشِّرَٰتٍ وَلِيُذِيقَكُم مِّن رَّحْمَتِهِۦ

وَلِتَجْرِيَ ٱلْفُلْكُ بِأَمْرِهِۦ وَلِتَبْتَغُوا۟ مِن فَضْلِهِۦ وَلَعَلَّكُمْ تَشْكُرُونَ ﴿٤٦﴾ ﴾

سورة الروم

DEDICATION

I dedicate this thesis ...

To reason for my existence and my smile

My parents

To light of my eyes and my sun that light my way

Nagib

To stood beside me and helped me all my senses were, my sister, I can't get here without you

Islam

To source of my inspiration, you give me the ambitious, my daughter

Talya

ACKNOWLEDGMENT

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ABSTRACT

Recently, mankind's need for more amount of energy has been increasing day by day, though there is a trend to reduce the usage of the traditional energy source to an energy carrier (or fuel) that results in emitting harmful gases to the environment that is separated in the air and water. Researchers have conducted researches to increase projects that will generate clean and renewable energy .

Usage of renewable energy via mankind is in continuous progress such as solar energy, bioenergy, ocean energy and wind energy. Wind energy waste while the car moved was used to produce electric energy.

The term "electric vehicle" refers to any vehicle using electric propulsion motors. The maximum speed of travel on public roads and city streets varies by country. Electric cars need to charge their batteries every 300 km or 400 km, we propose to add wind turbines to an electric car for using wind energy neglected during the movement of the vehicle to produce electricity.

In this research, the usage of unused wind energy in vehicles was developed so that additional power for vehicles is made possible and that is via converting wind power into electric one. The wind turbine was assembled from a fan and transducer. Indoor test showed generation of different electric voltages when varying the ambient temperature and has inverse proportionality with the ambient temperature**.** The main experiment was carried out so that the wind turbine was installed above the car and connect it with a battery; values of voltages and currents in various speeds of the car were recorded. When two transducers and five fans were used with different specification, the consequence was a direct proportionality instead was recorded power, between voltages, currents and power car's speeds.

A comparison between the five fans with two transducer showed that: the light weighted fan with big blade dimensions was the best one to generate voltages. Finally, These results offer a solution that we can avail from wind energy to supply batteries or operate the vehicle directly as long as vehicles move along the way.

المستخلص

في الآونة الاخيرة, ازدادت حاجة الإنسان لكميات أكبر من الطاقة كل يوم, على الرغم من وجود اتجاه لتقليل استخدام مصدر الطاقة التقليدي (النفط) الذي ينتج عنه انبعاث الغازات الضارة بالبيئة التي تنتشر في الهواء والماء. أجرى الباحثون أبحاثاً لزيادة المشاريع التي من شأنها توليد طاقة نظيفة ومتجددة.

إستخدام البشر للطاقات المتجددة في تقدم مستمر, مثل الطاقة الشمسية وطاقة المحيط وطاقة الرياح.

السيارات الكهربائية هي أي مركبة تستخدم محركات الدفع الكهربائية, وتختلف السرعة القصوى للتنقل على الطرق العامة وشوارع المدينة حسب البلد. تحتاج السيارات الكهربائية الى شحن بطارياتها كل 300 كلم او 400 كلم. اقترحنا اضافة توربينات الرياح الى السيارات الكهربائية واستخدام طاقة الرياح المهملة أثناء حركة السيارة لإنتاج الكهرباء.

في هذا البحث, تم تطوير استخدام طاقة الرياح المهملة في المركبات المتحركة بحيث أصبحت بالإمكان انتاج طاقة إضافية للسيارة عن طريق تحويل طاقة الرياح الى طاقة كهربائية. تم تركيب توربين الرياح من مولد –حركي كهربي- مع الريشة, أظهرت التجربة المعملية أن توليد الفولتية يتغير عند تغير درجة الحرارة المحيطة وتتناسب عكسيا مع درجة الحرارة المحيطة. أُجريت التجربة الرئيسة بحيث تم تثبيت التوربين الهوائي فوق السيارة ثم وصلت البطارية. تم تسجيل قيم فرق كلا من فرق الجهد والتيار عند سرعات مختلفة للسيارة. عند استخدام اثنين من المولدات وخمس ريش بمواصفات مختلفة, اظهرت النتائج التناسب الطردي بين القدرة و فرق الجهد والتيار عند السرعات المختلفة .

اظهرت المقارنة بين الريش الخمسة والمولدين أن: الريشة ذات الوزن الأخف والابعاد الأكبر هي الأفضل في التوليد الكهربي. أخيراً, تقدم هذه النتائج حلاً يمكننا من الاستفادة من طاقة الرياح لشحن البطاريات او تشغيل المركبات مباشرةً طالما أن المركبات تتحرك على طول الطريق.

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CHPTER ONE

Introduction

1.1. Energy and Human

People needed energy for cooking, lightening , beside operating machines and electronic systems. Now a day petroleum fuel is used widely. unfortunately it cause severe pollution. Thus there is a need of energy source which is why clean and renewable and pollution free .The need for this type of research is very well documented, the current consumption of energy is unsustainable and humans have to change their habits.

Coal fuelled the industrial revolution in the 18th and 19th century. It remained as prime fuel supplying steam engines used in road vehicles and rail road trucks. The industrialized nations were in huge competition in their search for additional fuels and the discovery of oil in the Middle East and elsewhere extended the use oil opening the applications to a wider rang. With the advent of the automobile, airplanes and the spreading use of electricity, oil became the dominant fuel during the twentieth century. Coal and nuclear became the fuels of choice for electricity generation and conservation measures increased energy efficiency. The use of fossil fuels has continued to grow and their share of the energy supply has increased .

Air pollution from coal is a short-term, local externality, meaning that people who live near the coal plant experience the negative impacts almost immediately. Climate change, however, is a long-term, global externality: the impacts are felt farther in the future and around the world[1].

Coal is the work horse of the nation's electric power industry and coal combustion accounts for 83% of GHG emissions in U.S. The country accounts for 19% of the global addition of atmospheric CO_2. The increasing demand for electricity results in 3.9% growth in coal consumption. The

United States ranks second, next to China in coal consumption and carbon emissions. Both these nations use coal primarily for generating electricity[2].

In the last few years, there has been a growing interest in Technological alternatives to reduce CO_2 emissions from power plants and factories to the atmosphere include: (a) usage of less carbon-intensive fuels, for example natural gas instead of coal; (b) increasing the use of renewable energy sources or nuclear energy sources, which produce little CO_2; and (c) capturing CO_2[3]. Most of the researches on renewable energy technologies focus on their land requirements and the potential environmental and social impacts. Although renewable energy technologies often cause fewer environmental problems than fossil energy systems, they lead to new conflicts. On a global scale, the environmental benefits of renewable energy are enormous, and do not dispute their significant contributions to reducing global greenhouse gases emissions. However, the benefits are less clear at a local scale. Due to tapping more diffuse forms of energy, these technologies require greater areas of land[4]. Previous research has demonstrated that the use of renewable energy sources is a key strategy for reducing greenhouse gases. As the source of hydro, biomass or geothermal energy are limited in many countries, wind power and solar photovoltaic (PV) play an increasing role[5].

However, focusing on the electricity sector means not only neglecting the significant greenhouse gas emissions from other energy sectors, such as heating and transport, but also ignoring important sources of flexibility from these sectors. In what some authors term ‘smart energy systems, demand from, for example, battery electric vehicles or intelligent heating systems can be brought forward or delayed to reduce system costs, and low-cost long-term storage can be provided either chemically, with power-to-gas units to produce hydrogen and methane (so called ‘electro fuels’),or thermally[6]

The estimates of remaining non-renewable worldwide energy resources vary, with the remaining fossil fuels totaling an estimated 400000 EJ (1 EJ = 10

18J) and the available nuclear fuel such as uranium exceeding 2500000v EJ. The sun provides the world with a renewable usable energy of 3800000 EJ/Yr. dwarfing all non-renewable resources. However, it is there to be utilized. The sun energy needs to be harnessed, stored, and converted into the required from for a particular use. Whatever fossil fuel remains will be more difficult to mine, and as it become scarcer the security of supply will become a major issue, with the definite outcome that the cost will the exponentially increase and that would lead ultimately to major quarrels and possibly wars .

Wind energy is natural and renewable, wind turbines are similar to hydraulic turbines, hence the technology is mature and well establish.

What is good about wind energy, it’s available even in winter when solar energy is not so good, so it makes a natural complement to solar energy.
Wind energy is becoming popular despite some concerns about visual impact and so on, and it is one of the most competitive renewable energy in most cases, According to the World wind energy association 121 GW, with over half the increase in the United States, Spain and China[7].

A wind turbine is a device that converts the kinetic energy of the wind into mechanical energy. This mechanical energy can be used for specific tasks (such as grinding grain or pumping water) or for driving a generator that converts the mechanical energy into electricity that is supplied to the power grid or individual users. The earliest recorded (traditional) windmill dates from the year 1191 in Suffolk, England. The popularity of the windmill grew as a replacement for animal power for grinding grain. With the introduction of iron components in the 19th century, the traditional windmill reached its summit and was a common sight in towns and villages. The first use of a windmill to generate electricity was by Charles F. Brush in Cleveland, Ohio in 1888 and by 1908 there were over 70 in operation with capacities ranging from 5 to 25 KW. By the 1930s, windmills with capacities as high as 100 KW were in use as a source of electricity, particularly in remote areas where centralized distribution systems had not yet been installed[8]. the UK is the windiest country in Europe, and if utilized effectively it could easily provide power to satisfy the 20% contribution of the UK market. The cost of wind energy equipment fell steadily between the early 1980s and the early 1990s. so it can be expected that wind energy will become economically competitive with fossil fuels during the coming decades[9].

There are mainly two type of wind turbine: horizontal axis and vertical axis. The horizontal axis turbine (HAWT) and the vertical axis wind turbine (VAWT) are classified or differentiated by the axis of rotation the rotor . Wind turbine usually has six mind components: the rotor, the gearbox, the generator, the control and protection system, the tower and the foundation[7].

Modern wind turbines connected to the commercial network have evolved from small and simple machines to large and highly sophisticated machines. Both technological developments have supported scientific and engineering expertise and progress, as well as improved computational tools, design standards, manufacturing methods, and operating and maintenance procedures. Generating electricity from the wind requires that the kinetic converted the energy of moving air to electric energy, and the challenge of engineering for the wind industry is to design wind turbines and power plants in terms of cost effectiveness. Although a variety of turbines have been investigated, the commercially available turbines are primarily horizontal axis machines with three blades installed in the wind direction of the tower. In order to reduce the standard cost of wind power.

The development of the design of wind turbines, improved design and testing methods have been codified in International Electro technical Commission standards[10].

1.2. Research Problem

The problem in the research is related to the fact that fuel energy causes pollution. The production of electrical buying solar calls is hot technically available in Sudan.

1.3. Literature Review

Many previous studies have developed techniques to generate electric power from wind turbines, even though, much has to be done. Wind energy is increasing and could become a major source of electricity in the coming years because wind is widely available and often abundant in many parts of the world[11].

1- **Aziza Abdalgadir Omer Adam, Calculation of Wind Power by Using the Annual Aver Wind Speed in Different Areas in Sudan**:

   This research conducted to study the ability of uses wind energy and its important, which is the one of renewable energy resources, which contribute in solving the problem of world energy in general, and in Sudan specially within the high demand of fossil fuel resources specially petrol which is highly prices .

   To achieve the objective of the study, the data of the annual average wind speed for selected sites in Sudan were use, within which data we can obtain the suitable sites to establish wind farms, to utilize from this energies which is available from these resources .

   The study findings can be summarized in the following : the increase of the wind speed in selected site, the increase of wind power obtained from specific wind turbine [12].

2- **Tabassum, S. et al**, **Design and Analysis of Different Types of Rotors for Pico-Turbine**:

   Small-scale vertical axis wind turbine (VAWT) rotor is developed for use in areas lacking adequate energy infrastructure. The materials and methods of construction are selected to minimize cost as much as possible. The paper describes the design of different kinds of vertical axis wind turbine rotors having different number of blades and twist angle. The aim of the work is to study the influence of the different designs on rotational speed and power of rotor in different wind speed[13].

3- **Jie Li, Zili Zhang, Jianbing Chen, Experimental Study on Vibration Control of Offshore Wind Turbines Using a Ball Vibration Absorber:**

To minimize the excessive vibration and prolong the fatigue life of the offshore wind turbine systems, it is of value to control the vibration that is induced within the structure by implementing certain kinds of dampers. In this paper, a ball vibration absorber (BVA) is experimentally investigated through a series of shake table tests on a 1/13 scaled wind turbine model. The reductions in top displacement, top acceleration, bottom stress and platform stress of the wind turbine tower system subjected to earthquakes and equivalent wind-wave loads, respectively, with a ball absorber are examined. Cases of the tower with rotating blades are also investigated to validate the efficacy of this damper in mitigating the vibration of an operating wind turbine. The experimental results indicate that the dynamic performance of the tested wind turbine model with a ball absorber is significantly improved compared with that of the uncontrolled structure in terms of the peak response reduction[14].

4- **Jenkins, P.E. and Younis, Flow Simulation to Determine the Effects of Shrouds on the Performance of Wind Turbines:**

This paper describes a flow simulation model used to determine the effects of a shroud on the performance of a wind turbine. Also, it focuses on comparing the standard type of wind turbines upwind turbine with three blades fixed on a horizontal axis with a new type that is called a shrouded wind turbine. In addition, the two types of turbines are compared in terms of velocities profiles, pressure distribution and power output when applying four different velocities of winds: 10, 20, 30, 40 mph. Numerical values and graphs are highlighted in order to show the main differences between the shrouded turbine and the conventional one. Finally, a conclusion and some recommendations are provided to summarize the scope of this research and give a better prediction for a future optimal design of the shrouded turbines[15].

** The shrouded wind turbine and the conventional horizontal-axis wind turbine have same configurations and components, but the shrouded wind turbine has an extra component called the shroud that holds the blades and nacelle inside*

5- E.H. Wang,et al, Study of Working Fluid Selection of Organic Rankin Cycle (ORC) for Engine waste Heat Recovery:

Organic Rankin Cycle (ORC) could be used to recover low-grade waste heat. When a vehicle is running, the engine exhaust gas states have a wide range of variance. Defining the operational conditions of the ORC that achieve the maximum utilization of waste heat is important. In this paper the performance of different working fluids operating in specific regions was analyzed using a thermodynamic model built in Mat lab together with REFPROP. Nine different pure organic working fluids were selected according to their physical and chemical properties. The results were compared in the regions when net power outputs were fixed at 10 kW. Safety levels and environmental impacts were also evaluated. The outcomes indicate that R11, R141b, R113 and R123 manifest slightly higher thermodynamic performances than the others; however, R245fa and R245ca are the most environment-friendly working fluids for engine waste heat-recovery applications. The optimal control principle of ORC under the transient process is discussed based on the analytical results[16].

6- **Jee-Ho Kim, et al. An Experiment on Power Properties in a Small-Scaled Wind Turbine Generator**:

This study configures a simple wind tunnel using a blower for generating wind energy, which is equivalent to natural wind, and a test system that measures properties of power. Also, the mechanical and electrical power in a small-scaled wind turbine are empirically measured to analyze the relationship between the mechanical and electrical power[17].

1.4. Aim of Research

- The research aims to describe the fundamentals of wind energy and the pertinent parameters that control the amount of energy available form a given wind turbines .
- Use laws of fluid mechanic to determine the suitable geometry and orientation to increase performance.
- Study effect of wind speed , power and temperature or performance.

1.5. Methodology

1. Manufacture wind turbine having different geometries and study their performance under the same condition.
2. Determine output electric energy for different wind speeds.
3. Study the effect of temperature by heating air artificially by a heater or by operating the turbine at different time of the day, by producing artificial with by electric fan.
4. 4-Study effect of humidity by air condition.

1.6. Layout of The Research

The research deal with Wind energy is natural and renewable, wind turbines and structure design. The research is in three chapters, chapter two is brief general introduction of the renewable energy .

The third chapter handled wind turbines, classification, advantages and disadvantages.

The fourth chapter is brief structure design of wind turbine to using in a car.

CHAPTER TWO

RENEWABLE ENERGY

2.1. Introduction

Demand for energy and associated services, to meet social and economic development and improve human welfare and health, is increasing. All societies require energy services to meet basic human needs (e.g., lighting, cooking, space comfort, mobility and communication) and to serve productive processes. Since approximately 1850, global use of fossil fuels (coal, oil and gas) has increased to dominate energy supply, leading to a rapid growth in carbon dioxide (CO_2) emissions, Figure 2.1 explain the Shares of energy sources in 2008 .

Greenhouse gas (GHG) emissions resulting from the provision of energy services have contributed significantly to the historic increase in atmospheric GHG concentrations. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) concluded that “Most of the observed increase in global average temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

Recent data confirm that consumption of fossil fuels accounts for the majority of global anthropogenic GHG Emissions. Emissions continue to grow and CO_2 concentrations had increased to over 390 ppm, or 39% above preindustrial levels, by the end of 2010 .

There are multiple options for lowering GHG emissions from the energy system while still satisfying the global demand for energy services. Some of these possible options, such as energy conservation and efficiency, fossil fuel switching, RE, nuclear and carbon capture and storage (CCS) were assessed in the AR4. A comprehensive evaluation of any portfolio of mitigation options would involve an evaluation of their respective mitigation potential as well as their contribution to sustainable development and all associated risks and costs. As well as having a large potential to mitigate climate change, RE can provide wider benefits. RE may, if implemented properly, contribute to social and economic development, energy access, a secure energy supply, and reducing negative impacts on the environment and health .

Under most conditions, increasing the share of RE in the energy mix will require policies to stimulate changes in the energy system. Deployment of RE technologies has increased rapidly in recent years.

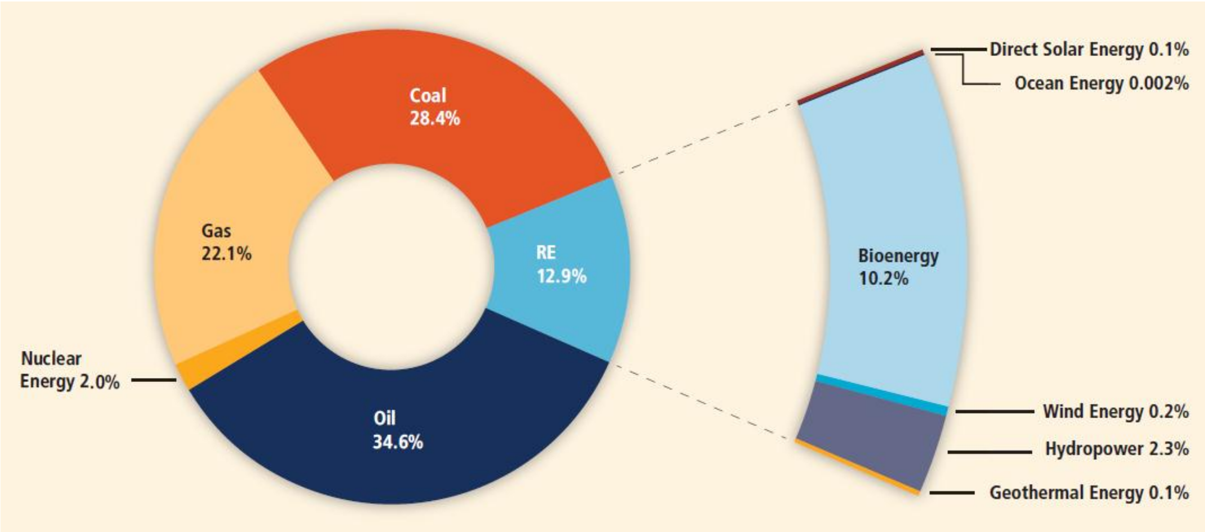

Figure 2.1: Shares of Energy Sources in Total Global Primary Energy Supply in 2008 (492 EJ). Modern Biomass Contributes 38% of The Total Biomass Share.

Additional policies would be required to attract the necessary increases in investment in technologies and infrastructure[10].

Africa has substantial new and renewable energy resources, most of which are under-exploited. Only about 7% of Africa's enormous hydro potential has been harnessed. Existing estimates of hydro potential do not include small, mini and micro hydro opportunities, which are also significant. Geothermal energy potential stands at 9000MW, but only about 60MW has been exploited in Kenya. Estimates further indicate that a significant proportion of current electricity generation in 16 Eastern and Southern African countries could be met by bagasse-based cogeneration in the sugar industry. Based on the limited initiatives that have been undertaken to date, renewable energy technologies (RETs) could contribute significantly to the development of the energy sector in eastern and southern African countries .

Renewable energy technologies (RETs) provide attractive environmentally sound technology options for Africa's electricity industry. RETs could offset a significant proportion of foreign exchange that is used for importing oil for electricity generation in most countries. In addition, renewables are modular and are well suited for meeting decentralized rural energy demand. The modular nature (i.e. can be developed in an incremental fashion) of most renewable energy technologies and the low investment levels makes them particularly suitable for capital-constrained African countries. Most renewable energy technologies utilize locally available resources and expertise, and would therefore provide employment opportunities for the locals[18].

2.2. Renewable Energy Sources

Bioenergy offers farmers an alternative to petroleum-based energy sources, and new market opportunities for farm products. When biomass feedstocks are burned, fermented or reacted through an energy conversion process, they return some carbon dioxide and water and release the sun's energy. Because plants have the capability to store and then release energy in this way, they act as a natural battery[19].

Most reports used zeolites for cracking and deoxygenating biomass pyrolysis liquids and numerous comprehensive reviews of biomass thermochemical conversion to oil provide specific details[20].

2.2.1. Bioenergy

Biomass energy, or “bioenergy”, is energy produced from recently living organisms. There are three forms of bioenergy available with today’s technology: heat, fuels, and electrical power. Farmers are potentially in a good position to utilize bioenergy because they are already knowledgeable and well equipped for the production of biomass, including that which can produce energy. As consumers of energy, farmers can produce and utilize bioenergy at the same location. Bioenergy, primarily in the form of heat, has been produced for thousands of years, providing a good precedent to build upon in planning for its use in agriculture. This burning of the biomass or products from it is known as direct combustion. Direct combustion is a comparatively efficient means of using bioenergy, due to its minimal processing needs, the diversity of feedstock that can be used, relatively simple equipment needs, and a relatively high rate of energy recovery. For most operations, direct combustion is the only practical means of harnessing bioenergy. For some select types of farming operations, anaerobic digestion and gasification of biomass are also practical bioenergy technologies for on-farm use. On-farm production of biodiesel from oil crops is also possible. This fact sheet will therefore focus primarily on direct combustion and secondarily on anaerobic digestion, gasification, and biodiesel production[21].

2.2.2. Bioenergy Supply

- **Forest**

Around the world, woody biomass is used for cooking, production of electricity and heat for industries, towns and cities and production of liquid biofuels. The primary energy supply of forest biomass used worldwide is estimated at about 56 EJ, which means woody biomass is the source of over 10% of all energy supplied annually. Overall woody biomass provides about 90% of the primary energy annually sourced from all forms of biomass.

Woody biomass used is in the form of cut branches and twigs, wood chip and bark, and pellets made from sawdust and other residues. Some of it is wood from demolition and construction, from urban parks and gardens and from industrial wood waste streams (broken pallets, building form work and industry packing crates). Wood is also the source of more than 52 million tons of charcoal used in cooking in many countries, and for smelting of iron and other metal ores.

While this utilization of woody biomass has real scope to increase and to become much more efficient, there is understandable concern about the sustainability of this renewable energy source globally. However, many initiatives are in place and being developed to ensure that at least, the woody biomass that is traded internationally (in the form of woodchip, pellets, charcoal, pyrolysis oil, and other semi-processed forms) is certified by one or other recognized programs as being sustainably sourced.

Production of woody biomass on agricultural land does not automatically displace the amount of food or fiber produced per unit area, as there are many alternative ways to have production of both biomass and other outputs from the same land. It is common practice in many countries to establish dispersed multi-purpose plantings on farmed land that shelter livestock, crops and pastures, while sequestering carbon, reducing wind erosion and drying of surface moisture, and adding to habitat and wildlife linkages. These properly planned plantings of suitable species produce yet more biomass in a sustainable way, as well as round wood for sawmills and other end uses such as for pulp and paper, or for fencing It is hard to conceive of a more sustainable practice that produces more side benefits, than agroforestry. The world's forests have been over-cleared (100 million hectares in Australia alone), and worldwide hundreds of millions of hectares of this farm land could be planted back to indigenous bio diverse species using a multi-purpose shelterbelt model, without loss of food and fibre production , In some countries, including Brazil, USA, Turkey, New Zealand, China, Australia, South Africa, and elsewhere, the replanting is often done across entire landscape. While the suitability of species chosen and sustainability of some of these plantings can be questioned, this is not a new practice, and similar plantings or reversion of cleared land to forest has occurred in the past in southeast Sweden, the north-eastern states of the USA, and elsewhere. In general, the long-term outcomes of these earlier reforestation programs have been good, despite the loss of production from those farms. So, land use changes need to be assessed using a short list of rational criteria to weigh up the benefits and costs.

- **Agriculture**

While it has been suggested that biomass produced on land inevitably displaces the growing of food, this is rarely the case in practice. On the contrary, biomass almost always is a by-product, waste product or residue produced during the production of food, fibre or timber products. One of the few exceptions could be with some first generation biofuels, such as ethanol from wheat, corn or sugar beet; although, even in these cases the biofuel is made from a component that is a small fraction of the feedstock, and so is only one of several products made from that feedstock. Nowadays, 2nd generation ethanol using lignocelluloses feedstock is being produced on an industrial scale in USA, Brazil and Italy etc.

Straw is one example of biomass that is a residue from food production. Straw is produced during production of annual cereals and usually at a ratio of about 0.6-0.8 tons of straw per ton of grain yield. In countries where yields are high (of the order of 8-10 tons of grain per hectare), the amount of straw per hectare might be six to eight tons and most of this has to be removed to allow cultivation for the following year's crop. As an example, of Denmark's straw production of about six million tons a year, over one million tons is used to fuel district heating or combined heat and power plants, another million tons is used for animal bedding or other on-farm uses (including for heat production), about two million tons finds other commercial uses including to be pelleted, converted to ethanol or used in mushroom production. The balance of about two million tons is incorporated back into the soil (along with millions of tons of the cereal roots), where it is rapidly broken down into greenhouse gases by bacteria and fungi which is then converted to bioenergy.

Around the world, billions of tons of straw (and similar plant material including stalk, seed husks and foliage) are annually available but the utilization is very low. Less than 100 million tons are utilized for energy each year and the rest is generally free-burned or allowed to rot, with consequent release of greenhouse gases. This applies whether the crop is rice in Asia, sugar cane in Brazil, wheat in Australia, soybean in Argentina, cotton in Egypt or palm oil in Indonesia. This also applies to the vast amount of higher moisture content biomass around the world, such as manures, abattoir wastes, and green leafy material.

All production of food, fibre or wood products results in production of biomass, with the amount of this often as much or more than the dry weight of the product. This biomass can be efficiently converted into energy, including on-demand electricity, by mature technologies. While at present final energy from biomass is about 50 EJ of energy or 14% of the world's final energy use, the realistic potential for final energy from biomass worldwide could as much as 150 EJ by 2035. According to International Renewable Energy Agency (IRENA), about 38 – 45% of total supply is estimated to originate from agricultural residues and waste while the remaining supply is shared between energy crops and forestry products and residues. According to Wisconsin Bankers Association (WBA), the estimated potential of using agricultural residues for energy ranges from 17 EJ to 128 EJ. This high range of values is due to the dependence on various factors including moisture content, energy content of the residues etc. The highest potential for using agricultural residues is in Asia and Americas due to the high production of rice and maize respectively[22].

Biofuels such as ethanol and biodiesel are produced using agricultural crops. Environment friendly farming practices reduce atmospheric carbon dioxide by sequestering carbon into the soil. Carbon that is fixed during photosynthesis in the form of starch, sugar, and different forms of cellulose is released back to the atmosphere during energy production. This makes bio based energy production carbon-neutral. Scientists and policy makers strongly believe that a scalable amount of fossil fuel can only be substituted using cellulosic biomass feedstock's. Research continues to look to invent economically competitive technologies to produce cellulose based biofuels and chemicals[2].

2.2.3. Harvest and Storage

Bioenergy crops are generally harvested when they are either dead or dormant. Unlike hay, crops for bioenergy may be allowed to collect moisture at times, as long as they are dry at harvest and are allowed to re-dry before use. For tall herbaceous bioenergy crops harvested while living, such as switchgrass, miscanthus, or canarygrass, harvesting should be done after at least one hard frost has made the stems dormant. This will reduce moisture content and allow some P and K to return to roots, rhizomes, and the soil from translocation and weathering of the plant. Harvest can also be conducted in the winter, further reducing moisture and ash content of harvested material. However, yields may suffer from a reduction in plant mass due to weathering. Tall grasses for bioenergy are either baled for combustion as-is, chopped, or converted to pellets for storage and transportation. Baling can be accomplished using a typical hay baler. After harvest, bales can be stored covered at the field edge. They should be kept dry and away from sources of ignition, much like feed hay. Storage requires a tarpaulin, and can benefit from racks which keep wood off the soil surface. Tall woody plants for bioenergy should be harvested during the coldest months of the year, because the moisture content is lower and any leaves have fallen off. Such material should be covered for no less than six months, to allow for drying, or combustion efficiency is reduced nearly to the point of being impractical. For this reason, a practice that works well for cordwood is to use wood the winter after it is harvested. Equipment needed includes chainsaws, a truck with high sides and dumping body, either axes and mauls, a hydraulic splitter, or sometimes a skidding frame for a small tractor[21].

2.2.4. Biofuel Use in Transport

Bio-ethanol is primarily used to replace gasoline in spark ignition engines, although it may also be mixed with fossil diesel for use in diesel engines. Bio-diesel, which is an oil product, is used in diesel engines only. Bio-diesel may be produced from oil seeds or from solid biomass through pyrolysis, Biogas or landfill gas is primarily used in spark ignition engines[23].

2.3. Geothermal Energy

Geothermal Energy is heat (thermal) derived from the earth (geo). It is the thermal energy contained in the rock and fluid (that fills the fractures and pores within the rock) in the earth's crust. In most areas, this heat reaches the surface in a very diffuse state. In the production of geothermal energy, wells are used to bring hot water or steam to the surface from underground reservoirs. Geothermal energy has often been accepted as a renewable energy resource, but they are not, especially on the time scale usually used in human society. It is emphasized that “they are renewable only if the heat extraction rate does not exceed the reservoir replenishment rate” .Therefore, the reinjection of fluids into the reservoir is significant for the sustainability of the resource.

Geothermal resources are classified as low temperature (less than 90°C or 194°F), moderate temperature (90°C - 150°C or 194 - 302°F), and high temperature (greater than 150°C or 302°F). The highest temperature resources are generally used only for electric power generation. Uses for low and moderate temperature resources can be divided into two categories: direct use and ground-source heat pumps .

2.3.1. The Applications of Geothermal Energy

for direct use include space heating both district and individual heating systems, geothermal heat pumps, bathing and swimming, greenhouse heating, aquaculture pond heating, agricultural drying, industrial uses, cooling, and snow melting. Worldwide installed capacities and annual energy uses of those given direct use applications are given in Figure 2.2 District heating is one of the most common and efficient utilization of geothermal energy. It is estimated that about 75 % of 42,926 TJ/year utilization (total use in space heating) is for district heating. The majority of the district heating systems is in Europe where France and Iceland are the leaders. Other countries with extensive district heating systems are China, Japan and Turkey. The U.S, on the other hand, dominates the individual home heating systems use, which is typical of Klamath Falls, Oregon and Reno, Nevada.

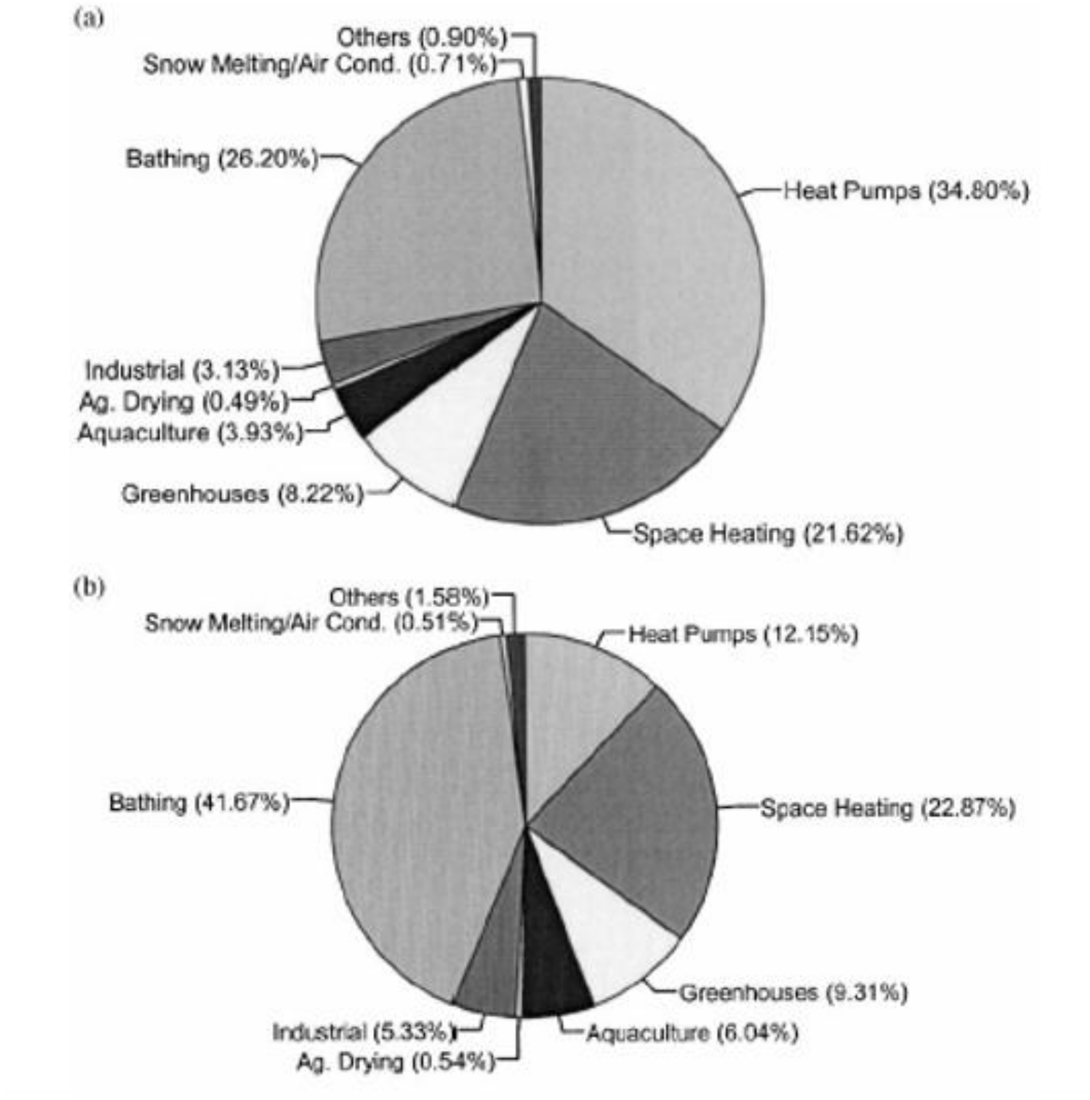

Figure 2.2 : a) Categories of Capacity in % for 2000, b) Categories of Energy Use in % for 2000

In geothermal development for the generation of electricity, about 50 % of total costs are related to the identification and characterization of reservoirs, and above all, to the drilling of production and reinjection wells. Of the remainder, 40 % goes to power plants and pipelines, and 10 % to other activities. Therefore, the cost of the geothermal kWh (2-10 US cents) is characterized as a high share of capital cost and relatively low operation and maintenance costs. These projects are more site-specific than oil and gas projects as geothermal fluids are normally used at the geothermal field. It is uneconomical for the modest energy content of the geothermal resource to be moved over long distances due to the high cost of insulating the pipelines to avoid heat losses. In general, it is assumed that development costs are difficult to predict because of the uncertainty involved in drilling, and that the cost of drilling is the main obstacle to geothermal development. If environmental impact geothermal energy is to be considered. Moreover, geothermal plants do not emit nitrogen oxides. However, site-specific chemical content of the fluids causes pollution of air and bodies of water. Steam from geothermal fluids has a content of non-condensable gases (CO_2, H_2S, NH_3, CH_4, N_2 and H_2) that ranges from 1.0 to 50 g/kg of steam. Geothermal gases in steam may also contain ammonia (NH_3), traces of mercury (Hg), boron vapors (B), hydrocarbons such as methane (CH_4) and radon (Rn). Boron, ammonia, and to a lesser extent mercury, are leached from the atmosphere by rain, leading to soil and vegetation contamination. Boron, in particular, can have a serious impact on vegetation. These contaminants can also affect surface waters and impact aquatic life. Therefore, water pollution of rivers and lakes is a potential hazard in power production and the management of spent fluids. Geothermal fluid passing through a heat exchanger and reinjected without exposure to the atmosphere does not discharge either gas or fluid to the environment during normal operation. Reinjection through wells drilled into selected parts of the reservoir is the most common method of disposal. Wells newly drilled or during maintenance have a noise level of 90-122 dB(decibel) at free discharge, and 75-90 dB through silencers[4].

2.4. Solar Energy

Earth receives 174 PW (only 1.5 trillionth of total solar energy), 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. For detail see Figure 2.3. In one hour the earth receives more energy from the sun than the world consume in one year[24].

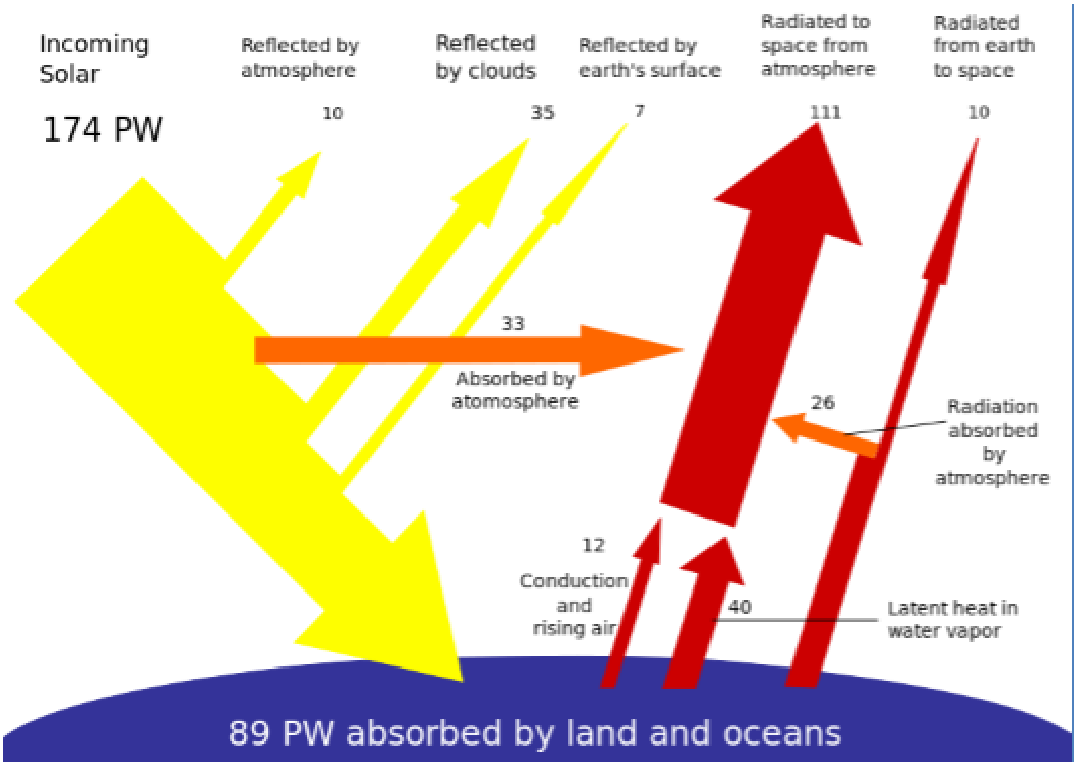

Figure 2.3: Amount of Sun Energy That Earth Receives in One Hour

Recent and upcoming sail craft demonstration missions are beginning to utilize the free and abundant momentum of solar photons for in-space navigation and propulsion . An alternative to the longstanding assumption of a reflective sail has recently been proposed, whereby a thin single order diffraction grating replaces the metal-coated polymer film. The net force on a single order diffraction grating owing to the broadband solar spectrum is reported here for a trans missive grating that is suitable for orbit-raising[25].

Molecular photoswitches can be used for solar thermal energy storage by photo isomerization into high-energy, meta-stable isomers; we present a molecular design strategy leading to photoswitches with high energy densities and long storage times. High measured energy densities of up to 559kJkg^{-1} (155Whkg^{-1}), long storage lifetimes up to 48.5 days[26].

2.4.1. Solar PV Technologies Principle

Solar absorbed light is transferred to the electrons of the PV cell atoms exiting them and producing the electrical current with the help of a “built-in electric field” which provides the needed voltage. The “built-in electrical field” is created by two layers of semiconductor material: n-type with excess of negative electrons and p-type with excess of positive holes. Most commonly used of semiconductor material is silicon, when n- and p-type silicon come into contact, at the p/n junction excess electrons move from the n-type side to the p-type side, resulting in a positive charge in the n-type side of the interface and a buildup of negative charge in the p-type side.

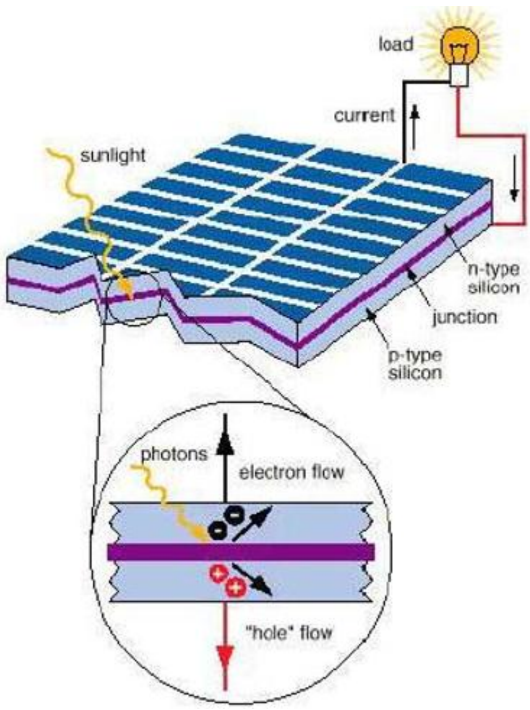

Figure 2.4: Silicon Based PV Cell

Two types of semiconductor (n and p) are created by doping the silicon with an external element that has either extra electrons or lack of electrons, respectively. Figure 2.4 show sketch of solar PV[24].

Photovoltaic (PV) is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity (Fig. 2.5) [27]

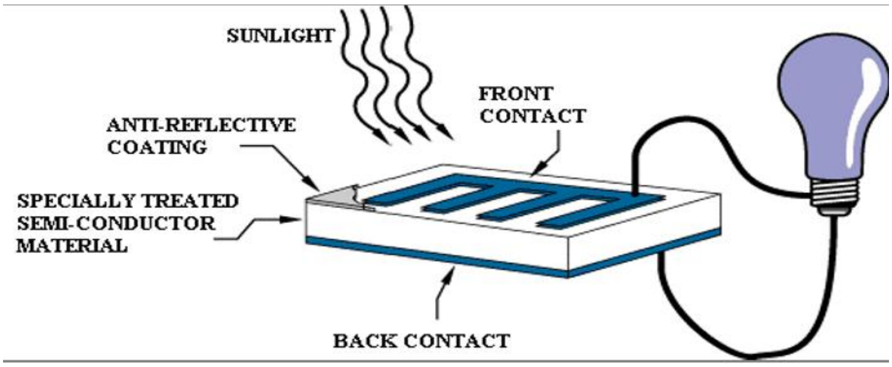

Figure 2.5 Photoelectric Effect: Materials Absorb Light and Release Electrons.

Despite such successful accomplishments, they have a ubiquitous experimental limitation. Unlike the well-defined structures of small molecular semiconductors, for a given polymer prepared from transition metal-catalyzed cross-coupling reactions, the batch-to-batch variations in molecular weight (Mw) and polydispersity index (Đ) have given rise to inconsistent process-dependent material properties and consequent performance variations in device applications[28].

Mobile ions in hybrid perovskite semiconductor devices introduce a new degree of freedom for electronics suggesting applications beyond photovoltaic. An intuitive device model describing the interplay between ionic and electronic charge transfer is needed to unlock the full potential of the technology[29].

2.4.2. Advantages of PV Technology

-Reliability

•In harsh conditions the system has been shown to work

•Durability

•Most modules are guaranteed for 25 years with production even after that

•Low maintenance cost

•Systems require periodic inspection and occasional maintenance

•No fuel cost

•No liquid fuel to deal with to produce power

•Reduced sound pollution

•Only sound produced is from the pump and tracking system if used

Photovoltaic Modularity

•Modules can be added to increase power

•Safety

•No fuel required to be stored or used

•Independence

•Based on the use, it system can be a standalone system with no grid tied components

•Electric grid decentralization

•For larger systems a small decentralized power station can reduce power outages

2.4.3. Disadvantages of PV Technology

-Initial Cost

- •The cost of a solar power system generally has to be expended up front and benefits received over time
- •Variability of solar radiation[30].

2.5. Ocean Energy

The ocean has been an integral part of human civilization and development since ancient times, and although its potential use in generating power has been the subject of patents dating back to the 18th century, technologies capable of harnessing this vast resource have only been deployed recently. Ocean energy resources are vast, with the theoretical potential to generate between 20000 terawatt-hours (TWh) and 80000 TWh of electricity each year enough to meet between 100 and 400% of the present global demand for electricity (International Energy Agency (IEA), 2013). In recognition of this energy resource, various initiatives are being promoted worldwide to harness the potential of the ocean, an example of which is the(International Energy Agency, IEA-Ocean Energy Systems Implementing Agreement (IEA-OES), which has an international vision for ocean energy that includes a goal of installing 337 gigawatts (GW) of capacity worldwide by 2050.

Along with other renewables, ocean energy technologies generate carbon dioxide (CO_2) emission-free power and as an indigenous resource can promote energy independence. Ocean energy technologies can also contribute to a balanced, diversified energy portfolio, with generation profiles that complement those of other renewables – such as solar and wind thus helping to balance the variable generation of different renewable energy sources. Furthermore, ocean energy technologies can extend the range of options for densely populated coastal nations with limited land space, to increase their use of renewables. The issue of competing land use is often a significant advantage for many ocean energy technologies, as they provide the opportunity to put renewable generation plants "under the surface" or "over the horizon" .

Member states of the (IRENA) have mandated the agency to make the credible case for the widespread adoption and sustainable use of all forms of renewable energy. Over the years the agency has received several requests on ocean energy from policy makers in various member states on a range of issues including: resource availability, the status and outlook for the various forms of ocean energy conversion technologies, deployment viability of each technology type, capital and operational costs and cost reduction potential of different technologies, operation and maintenance aspects, particularly in the case of island states, which policies and support mechanisms to apply in support of ocean energy technology.

development and deployment, what sources of funding and finance models exist, barriers to ocean energy deployment, and opportunities for cooperation on ocean energy. Similarly, the agency receives on a regular basis requests from ocean energy technology developers and potential project developers seeking current information on ocean energy and opportunities worldwide.

Figure 2.6 provides a visual representation of the relative measure of each ocean energy technology's level of technological maturity, using the so-called Technology Readiness Level (TRL) scale. The TRL assess the maturity of evolving technologies during their development and early operations. It should be noted that although TRL scaling has some limitations, it is useful nonetheless in providing an indicative value of maturity for various technologies.

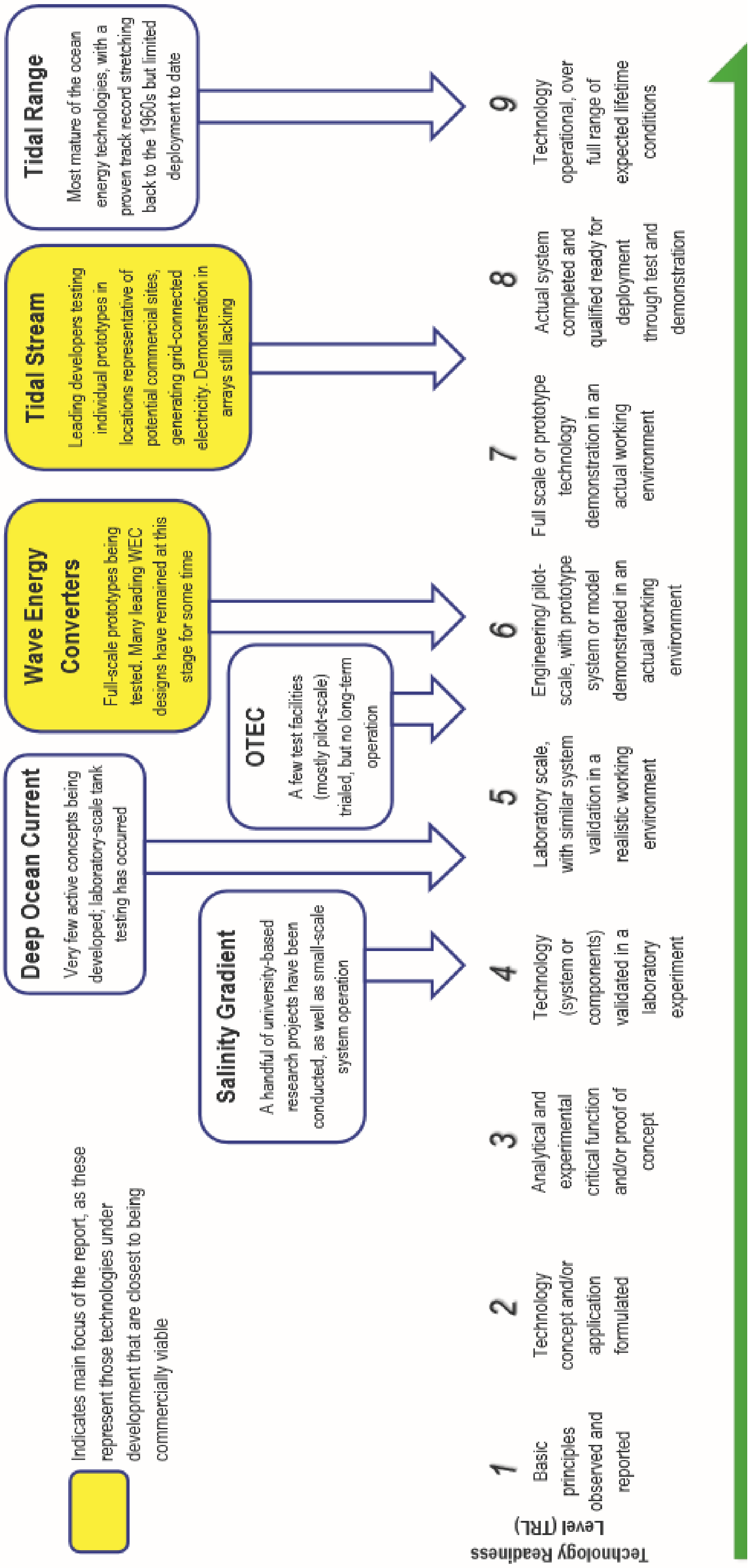

Figure 2.6: Ocean Energy Technology Readiness

2.5.1. Resource and Technology Characteristics

Ocean energy, often referred to as marine renewable energy, is a term encompassing all of the renewable energy resources found in the oceans that is those that use the kinetic, potential, chemical or thermal properties of seawater. Ocean surface waves, tidal currents, tidal range, ocean currents, thermal gradients, and changes in salinity all represent energy resources that can be harnessed using a variety of different technologies. Ocean energy technologies convert these renewable energy resources into a useful form typically electricity.

Certain renewable resources found in and around the ocean are excluded from the above definition. For example, the production of biofuels from marine biomass is generally considered a form of bioenergy rather than ocean energy. Similarly, concepts for harnessing energy from submarine vents are considered a form of geothermal energy and offshore wind (fixed or floating) is considered a particular application for wind energy technology in the same vein, floating photovoltaic technology is not normally included in the definition of ocean energy technology.

Considering the above, ocean energy technologies are most broadly classified by the resource. The most typical technical options are reviewed in the following subsections.

- **Tidal Range:** Solar and lunar gravitational forces, combined with the rotation of the Earth, generate periodic changes in sea level known as the tides. This rise and fall of ocean waters can be amplified by basin resonances and coastline bathymetry to create large surface elevation changes at specific geographic locations. High and low tides occur twice a day at most coastal sites throughout the world (semi-diurnal tides), although some places experience just one high and low tide per day (diurnal tides). Other places are characterized by a combination of diurnal and semi-diurnal oscillations (mixed tides). The difference in sea level height between high and low tide at a given location is called the tidal range, and it can vary each day depending on the location of the sun and moon, and globally depending on the coastal location. Tides have been well studied for centuries, and can be accurately predicted years in advance. As tides are caused by the aforementioned gravitational interactions, they are considered a renewable energy resource.

- **Tidal Stream (Current):** The vertical rise and fall of water, known as tides as described in the section on tidal range above, is accompanied by an incoming (flood) or outgoing (ebb) horizontal flow of water in bays, harbors, estuaries and straits. This flow is called a tidal current or tidal stream. Tidal currents can be exceptionally strong in areas where large tidal ranges are further constrained by local topography. There will also be periods of time when there is little or no horizontal flow of water (i.e., slack water – the short time before the tide changes between ebb and flood and vice versa)[31]. Harnessing the tide could supply 11% of Wales's household electricity needs. Proving that such a barrage can feasibly capture energy from the daily ebb and flow was just the beginning [32].

Hydrokinetic turbines convert the kinetic (moving) energy of free flowing water into electricity using the same principles that wind turbines use to convert the kinetic energy of flowing air (wind). When hydrokinetic systems are used in a tidal environment they are often referred to as tidal stream turbines, tidal in-stream energy converters, or tidal/ marine/ hydrokinetic current turbines. Most designs of tidal stream energy converters are representative of modified wind turbines made to suit the higher density and different characteristics of the surrounding environment, since the principles of energy conversion are the same.

- **Wave Energy:** Wave Energy Converters (WECs) transform energy from the kinetic and potential energy of ocean surface waves into another form of energy (e.g. electricity). These waves, generated primarily by wind blowing across the ocean surface (ripples), can propagate over deep water with minimal energy loss and will combine and continue to gain energy from the wind over long open ocean stretches (leading to swells). Although the air-sea interactions and energy transfer mechanisms are complex, ocean surface wave formation is primarily influenced by the speed of the wind, its duration and the fetch (distance of open water over which the wind blows). As it is solar energy that creates the differences in air temperature that cause wind, wave energy can be considered a concentrated form of solar energy. The spatial concentration of energy is one key advantage of wave energy in comparison to other renewable energy resources.

  Although there is seasonality, with higher wave conditions experienced in the winter than in the summer at most locations, waves arrive day and night, 24 hours a day, and sea states have more inertia than solar/wind conditions, with less potential for sudden changes in the resource potential.

- **Ocean Thermal Energy :** A significant portion of solar energy incident on the ocean surface is retained as thermal energy stored as heat in the upper layers of the ocean. The temperature gradient between the sea surface water and the colder, deep seawater – generally at depths below 1000 meters (m) – can be harnessed using different ocean thermal energy conversion (OTEC) processes. OTEC requires practical temperature differences of at least about 20 degrees Celsius (°C). As can be expected, in those tropical latitudes the ocean surface temperatures are highest and there is often stable stratification of the oceanic water column.

Although there is a slight seasonal variation in temperature gradients, the resource can be considered continuously available, and as such OTEC represents an ocean energy technology with the potential to generate base load power. The theoretical global total resource potential for ocean thermal energy is the highest among the ocean energy resources. However, compared to other ocean energy technologies such as wave and tidal stream energy converters, the energy density of the OTEC systems is quite low. This represents one of the ongoing challenges towards a cost-effective OTEC operation[31].

2.6. Hydroelectric Energy

Hydroelectric power comes from water at work, water in motion. It can be seen as a form of solar energy, as the sun powers the hydrologic cycle which gives the earth its water see figure 2.7. In the hydrologic cycle, atmospheric water reaches the earth's surface as precipitation. Some of this water evaporates, but much of it either percolates into the soil or becomes surface runoff. Water from rain and melting snow eventually reaches ponds, lakes, reservoirs, or oceans where evaporation is constantly occurring.

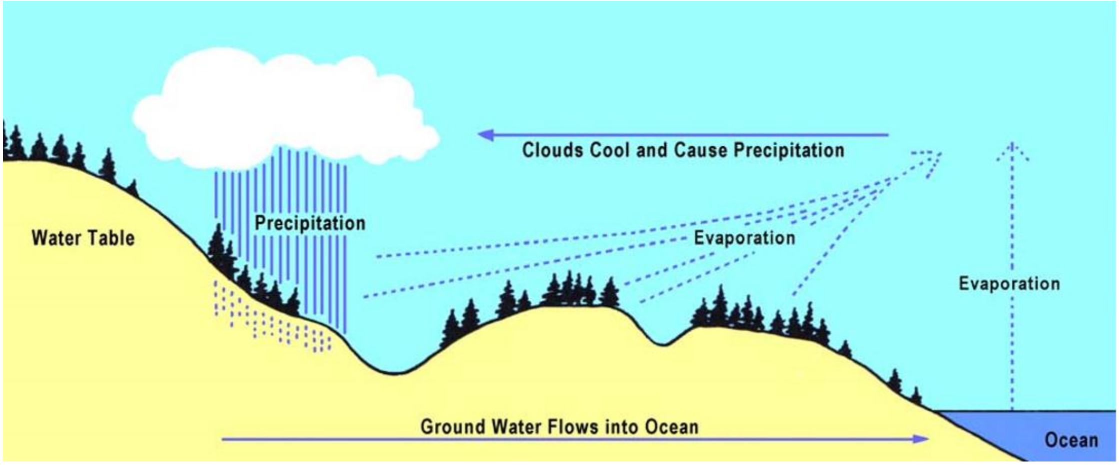

Figure 2.7: Hydrologic Cycle.

Moisture percolating into the soil may become ground water (subsurface water), some of which also enters water bodies through springs or underground streams. Ground water may move upward through soil during dry periods and may return to the atmosphere by evaporation.

Water vapor passes into the atmosphere by evaporation then circulates, condenses into clouds, and some returns to earth as precipitation. Thus, the water cycle is complete. Nature ensures that water is a renewable resource.

2.6.1. Generating Power

In nature, energy cannot be created or destroyed, but its form can change. In generating electricity, no new energy is created. Actually one form of energy is converted to another form.

To generate electricity, water must be in motion. This is kinetic (moving) energy. When flowing water turns blades in a turbine, the form is changed to mechanical (machine) energy. The turbine turns the generator rotor which then converts this mechanical energy into another energy form electricity. Since water is the initial source of energy, we call this hydroelectric power or hydropower for short.

At facilities called hydroelectric power plants, hydropower is generated. Some power plants are located on rivers, streams, and canals, but for a reliable water supply, dams are needed see figure 2.8. Dams store water for later release for such purposes as irrigation, domestic and industrial use, and power generation. The reservoir acts much like a battery, storing water to be released as needed to generate power.

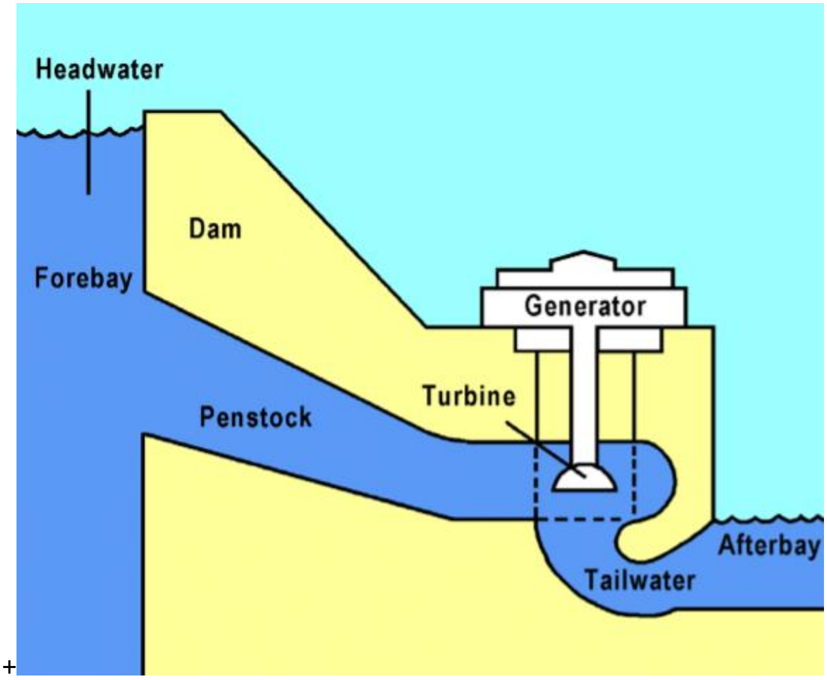

Figure 2.8: Generate Electricity by Hydroelectric Power.

The dam creates a "head" or height from which water flows. A pipe (penstock) carries the water from the reservoir to the turbine. The fast moving water pushes the turbine blades, something like a pinwheel in the wind. The waters force on the turbine blades turns the rotor, the moving part of the electric generator. When coils of wire on the rotor sweep past the generator's stationary coil (stator), electricity is produced. This concept was discovered by Michael Faraday in 1831 when he found that electricity could be generated by rotating magnets within copper coils. When the water has completed its task, it flows on unchanged to serve other needs[33].

In countries where this is the main source of electricity, glacial runoff contributes significantly to its generation (Iceland: 91% and Norway: 15–20%) (93). Austria generates 70% of its electricity from hydropower, with many large facilities being glacier-fed, while the glacier-fed Rhone River has 19 hydropower plants, supplying 25% of France’s hydropower. In Switzerland, 25% of its electricity is sourced from glacial runoff. The effects of glacier retreat on hydropower revenue are uncertain as a consequence both of predictions in melt water runoff in future as well as market fluctuations[34].

2.7. Wind Energy

The energy generated by the wind can be used in the production of electrical energy. The device used to generate power is called a wind turbine or a wind mill. The kinetic energy from wind is converted by the turbine into mechanical energy. This energy is given to a generator, which delivers electrical energy. The wind turbines can be classified into horizontal and vertical turbines depending on the axis on which it spins[35].

The primary application of relevance to climate change mitigation is to produce electricity from large wind turbines located on land (onshore) or in sea or freshwater (offshore). Onshore wind energy technologies are already being manufactured and deployed on a large scale. Offshore wind energy technologies have greater potential for continued technical advancement. Wind electricity is both variable and, to some degree, unpredictable, but experience and detailed studies from many regions have shown that the integration of wind energy generally poses no insurmountable technical barriers[10]. for details see chapter three.

2.8. Storage of Intermittently

2.8.1. Generated Renewable Energy

Intermittent energy sources exemplified by solar, wind, wave, and tidal do not produce energy continuously, but do so in fits and starts. In order to make full use of the energy that is generated by intermittent sources, it is necessary to devise systems which can store the energy in a manner that is reliable, affordable, and enables integration with the rest of the nation-wide energy system. Given this necessity, the energy storage systems will play an increasingly important role in energy management and become an integral part of the future renewable-based infrastructure.

2.8.2. Energy Storage Systems: General

In general, intermittent renewable energy can be stored in four forms: electrical, thermal, chemical and mechanical (or kinetic) energy. The current options include :

A- Storage as Electrical Energy

Batteries.

Super capacitors.

Electromagnetic systems.

B-Storage as Mechanical Energy

Compressed air.

Hydrostatic energy.

Flywheels.

C-Storage as Chemical Energy

Reversible fuel cell.

Hydrogen.

Thermochemical systems.

D-Storage as Thermal Energy

2.8.3. As Electrical Energy

The conventional electrical energy storage systems such as rechargeable batteries are expensive, have rather limited lifetime, and do not have a sufficient capacity (per unit of volume or weight) to be considered for very large energy systems. The world's largest battery is housed at to Fairbanks, Alaska. It can provide 40 MW systems power for world's 7 minutes largest or 27 MW for 15 minutes.

In comparison to batteries, other energy storage systems such as compressed air, hydrostatic storage and reversible fuel cell (FC) have better promise for the integration into a large renewable energy-based network.

2.8.4. Storage as Mechanical Energy

- **Compressed Air Energy Storage**

  Compressed air energy storage (CAES) has recently emerged as an efficient and cost-effective means of storing large quantities of electrical energy. According to this approach, electricity from PV or wind farms compresses air and pumps it into underground caverns, abandoned mines, aquifers and depleted natural gas (NG) wells Figure 2.9. On demand, the pressurized air is released to drive a turbine generating electricity.

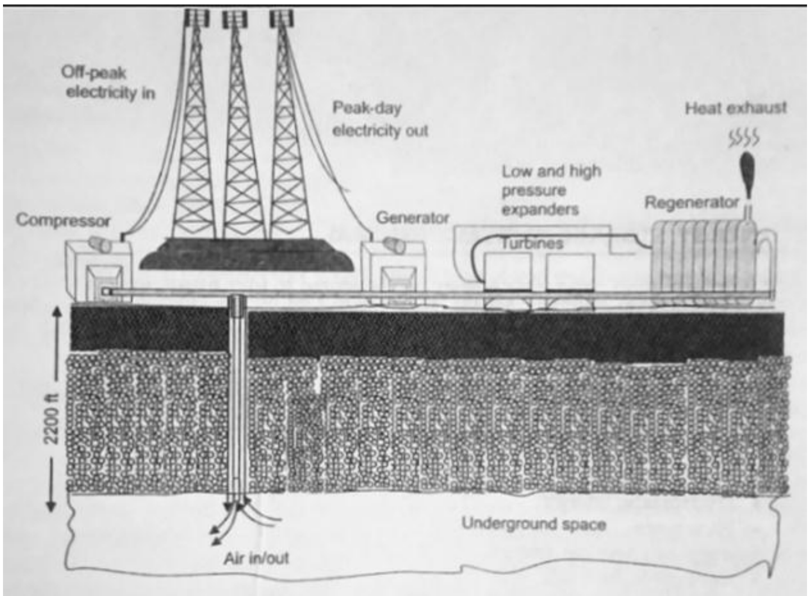

Figure 2.9 : Schematic Diagram of an Underground Compressed Air Storage System

- **Hydrostatic Energy Storage**

  A Hydrostatic (or pumped hydro) storage is another possible technology for storing large quantities of electrical energy. When surplus or wind energy is available , water is pumped from a lower to an upper reservoir (e.g. a basin at the top of mountain).

  When electrical energy is needed ,it is generated by letting the water fall back to drive a generator located at the lower level. The power output, energy efficiency of the storage system and its cost per KW stored depend on the difference in height between lower and upper levels.

- **Flywheel Energy Storage (FES)**

  An FES system is based on the principle of storing energy in the form of a flywheel rotating at a very high and speed maintaining the energy in the system as rotational energy. the energy is converted back slowing down the flywheel. FES systems have found market application for providing large-scale uninterrupted power supply (UPS) at capacities exceeding 100 kVA. Active Power, based in USA, is among the manufacturing companies with a large market share in UPS systems operating with FES technology. Most FES systems use electricity to accelerate and decelerate the flywheel, but devices that directly use mechanical energy are being developed.

First generation FES systems used a large steel flywheel rotating on mechanical bearings. Now the more advanced systems have rotors made of high strength carbon composite filaments, suspended by magnetic bearings and spinning at speeds of 2000 rpm(revolution per minute) to over 50000 rpm in high-vacuum enclosures. Such flywheels can come up to their top speed in a matter of minutes-much quicker than some other forms of energy storage.

A typical FES system see Figure 2.10 consists of a rotor suspended by bearings inside a vacuum chamber (to reduce friction). It is connected to a combination electric motor / electric generator.

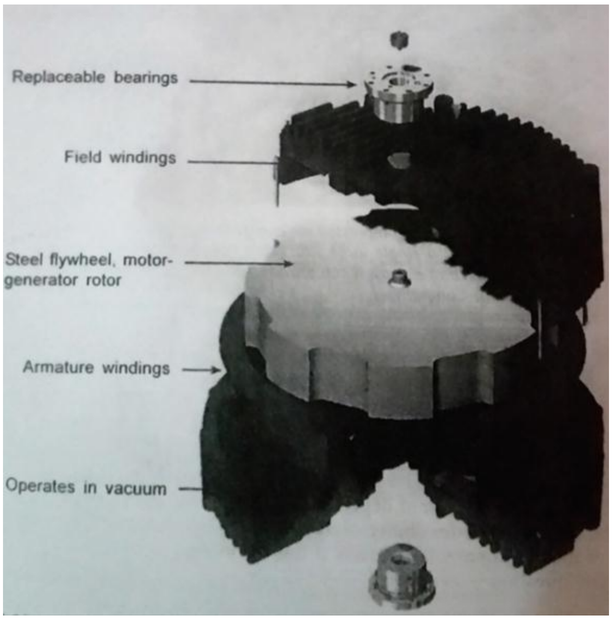

Figure 2.10: Inside of a Typical FES (Reproduced With Permission From Active Power, USA)

Even if FES systems are designed to minimize energy loss, laws of mechanics, thermodynamics, and electrostatics dictate that FES systems incur energy losses due to friction, hysteresis, and eddy currents. These aspects limit the time up to which energy can be economically stored in an FES system. Further improvements in superconductors may help in eliminating eddy current losses in existing magnetic bearing designs as well as raise overall operating temperatures. However, the costs and the complexity associated with such systems may delay their commercial exploitation.

load rundown time' or how long it takes for the FES to come to a standstill when it is not connected to any other device. Modern flywheels can have a zero-load rundown time measurable in years.

The advantage of FES systems are that they are not affected by temperature changes as are chemical chargeable batteries, nor do they suffer from memory effect. They are also less potentially damaging to the environmental being made of largely inert or benign materials. Another advantage of flywheels is that by a simple measurement of the rotation speed it is possible to know the exact amount of energy stored. However, there is a hazard associated with flywheel accumulators the danger of explosive shattering of the massive wheel due to overload. If tensile strength of a flywheel is accidentally exceeded, the flywheel will shatter, releasing all of its stored energy at once, this is commonly referred to as flywheel explosion. In it, the wheel fragments can reach kinetic energy comparable to that of a bullet. Experts associate with the FES production and marketing for the US company Active Power insist that the probability of flywheel explosion occurring is too low to be of significance and that even in more than 55 million hours of field time none of their FES-based UPS has 'experienced a flywheel explosion' .it is possible that the risk of a 'flywheel explosion' may be lesser in composite materials which tend to disintegrate quickly to red-hot powder once a broken, instead of large chunks of high-velocity shrapnel. Still, many customers of modern flywheel energy storage systems prefer to have them embedded in the ground to halt any material that might escape the containment vessel.

2.8.5. Storage as Chemical Energy

- **Fuel Cell Storage**

In the electrolyze fuel cell storage option, water is electrolyzed to hydrogen source such as solar, wave or wind see Figure 2.11. Hydrogen (and optionally, oxygen) is stored in a suitable storage reservoir. At times of a high demand, hydrogen and air (optionally, oxygen) electrochemically react in the FC producing electricity. A reversible FC can be used instead of the electrolyzer fuel cell (FC) combination (since the electrochemical reaction is reversible). Standby losses for this energy storage are low, because the product of the reaction (hydrogen and oxygen or air) are stored separately. The storage capacity of this system is determined by the size of the hydrogen storage.

hydrogen are similar to those for air reservoir the options envisaged for gaseous hydrogen (e.g. underground caverns abandoned mines, aquifers, etc.) but the risks associated with the storage of a highly flammable gas like hydrogen in this manner are enormously greater than the risks associated with the storage of compressed air. Hydrogen can, of course be liquefied and stored in very large cryogenic insulated vessels with a high volumetric density, but it involves expenditure of energy in liquefying hydrogen that is as much as a third of the energy content of hydrogen.

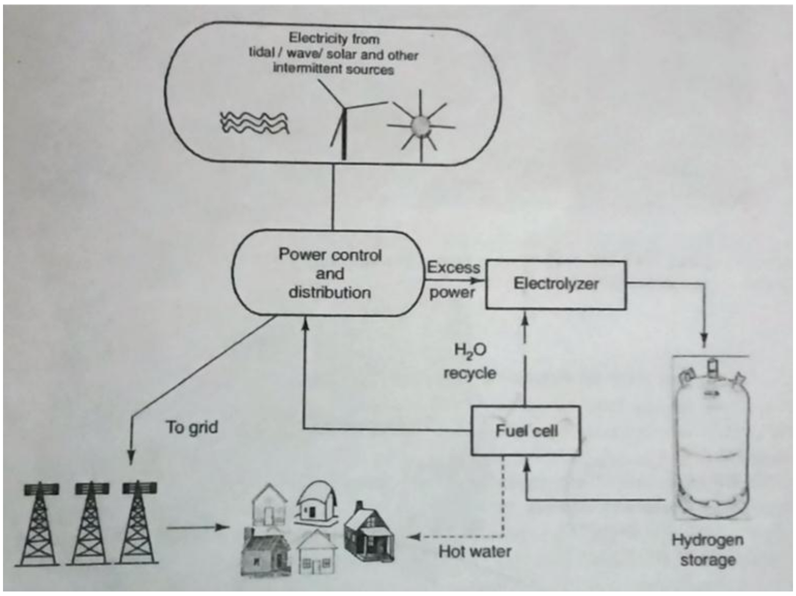

Figure 2.11: Schematic Diagram of Fuel Cell-Based Energy Storage/ Recovery System

- **Thermochemical Energy Storage**

In thermochemical energy storage systems, energy is stored in chemical bonds by means of reversible thermochemical reactions. Depending on the targeted application, these reversible chemical reactions can be used for long-duration energy storage, or long-distance energy transport, such as a chemical heat pump storage. One example of thermochemical energy storage is the reversible reforming machination system, also known as *Adam/Eve concept*, where the reaction $CH_4 + H_2O \leftrightarrow 3H_2 + CO$ is driven to the right by heating the reactor to 900°C by a solar concentrator.

The reaction products are stored or transported at ambient temperature over long distances to the point of use. When needed, the reaction is driven to the left, in the presence of a catalyst, releasing stored thermal energy. Another example of thermochemical energy storage/recover system is the one based on ammonia see Figure 2.12.

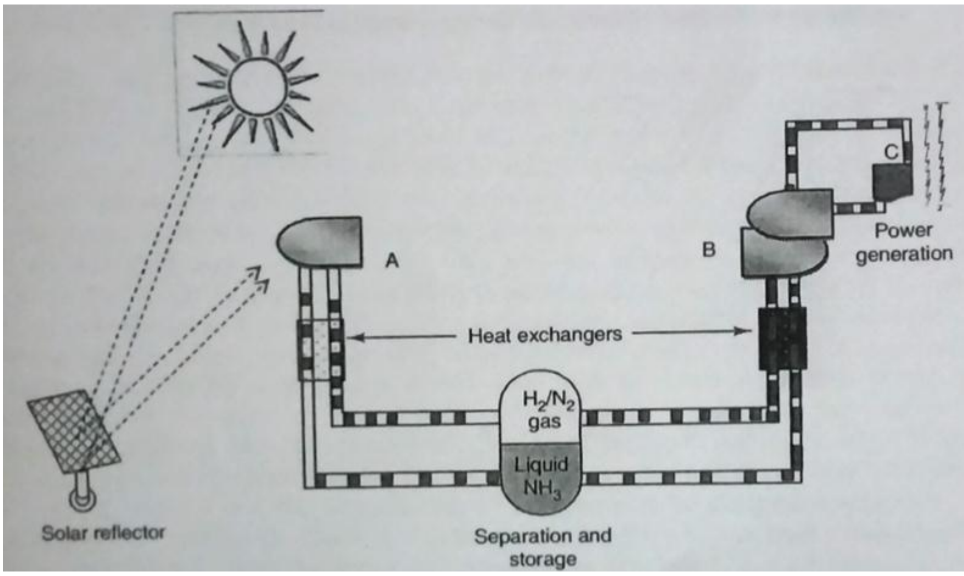

Figure 2.12: Concept of Thermochemical Energy Storage System Using Ammonia. Heat Drives The Endothermic Dissociation of Ammonia. (A) Part of Energy is Recovered in The Endothermic Reactor (B) Which Regenerates Ammonia. The Energy Can be Converted to Electricity Via Steam (C) .

Attempts are underway for developing novel and more energy-efficient thermochemical systems .

- **Hydrogen**

2.8.6. Storage as Thermal Energy

Thermal energy-based storage systems aim at storing high temperature solar heat, e.g. from solar concentrators, and involve several types of storage media, predominantly, thermal oil and molten salts see Figure 2.12. Thermal oils have a disadvantage of relatively low decomposition temperature (300°C) and inflammability.

The concept of solar energy-based thermal energy storage-recovery system is presented in see Figure 2.13 which also shows an actual system based on this concept installed near Las Vegas, USA .

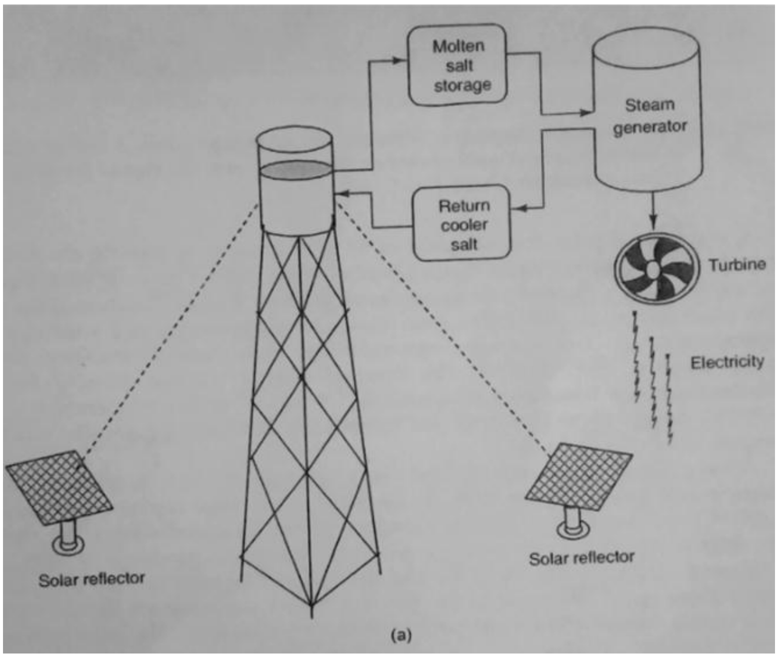

Figure 2.13 : Contd.

A commercial solar thermal plant of 50 MW capacity to incorporate molten salt storage is under construction in Spain. Currently ionic liquids are being explored as a thermal storage medium and heat transfer fluids in solar thermal Power plant The ionic liquids have advantage of a wide operational temperature range, low viscosity, non-volatility, high chemical stability, and high storage density. For example, the thermal energy storage density for octylmethylimidazolium hexafluorophosphate is 378 MJ/m^3 , the temperature range of 210-390°C, compared to 59 MI/m^3 for thermal oil. But ionic liquids are much more Expensive than salts and oils .

Among novel, unproven, thermal energy-storage concepts is the one based 'isentropic heat pump' see Figure 2.14 It comprises of two large containers of gravel, one hot (500°C) and one cold (-150°C).

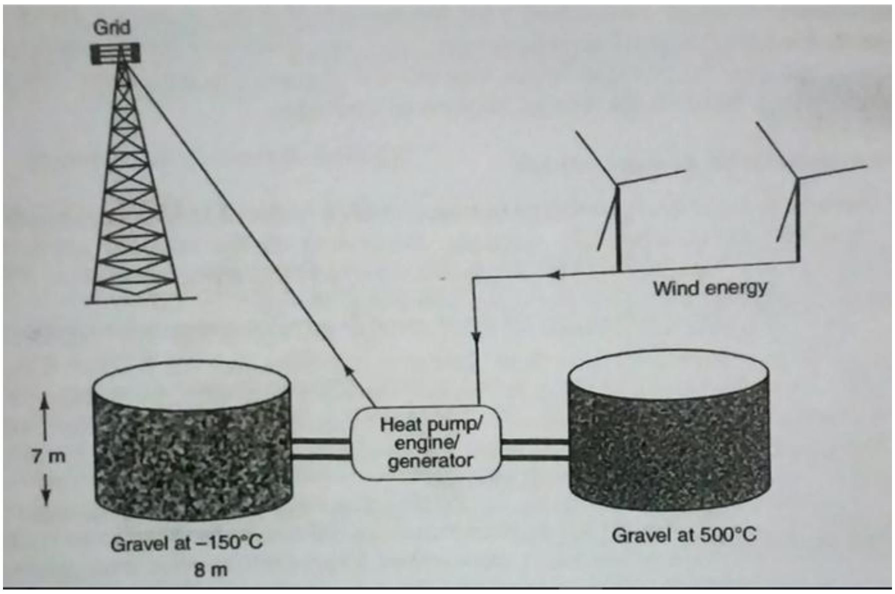

Figure 2.14: Concept of Isentropic Energy Storage System Using Argon Gas and Rocks.

Electrical Power generated with wind and other renewables is supplied to the machine which compresses/expands air to 500°C on the hot side and -150°C on the cold side. The air is passed through the two piles of gravel where it gives up its heat/cold to the gravel. In order to regenerate the electricity, the cycle is simply reversed. The temperature difference is used to run the isentropic machine as a heat engine[36].

CHAPTER THREE

WIND ENERGY

3.1. Introduction

Wind is air in horizontal motion across the Earth's surface. All winds are produced by differences in air pressure between two regions. Differences in pressure result from differential heating of the surface of the Earth. Heating, of course, is caused by sunlight striking the Earth's surface. Like most other forms of energy in use today, even coal, oil and natural gas, wind is a product of sunlight solar energy. Some wind advocates, refer to wind as "the other solar energy" or "secondhand solar energy." Let's begin by looking at two types of local winds: (1) offshore and onshore winds and (2) mountain-valley breezes[11].

Wind, which is essentially air in motion, carries with it kinetic energy. The amount of energy contained in the wind at any given instant is proportional to the wind speed at that instant. The temperature of the wind also influences the energy content of the wind but is not important in the context of wind-based energy production systems.

The obvious power of wind caught man's attention thousands of years ago and he has been using wind energy to propel ships, and to provide rotary windmill power for pulling up water from wells and grinding agricultural produce. The windmill is an invention that dates from the earliest times of recorded history. There is evidence that the ancient Egyptians used windmills as early as 3600 B.C. to pump water for irrigating their arid field and to grind grain. The early Persians ground grain with a vertical-axis sail mill . Europeans imported the technology from the east and were probably the first to introduce sill around the 12th century. Almost all subsequent developments have taken place with this latter type, primarily because of the low rotational speeds and greater efficiency of the horizontal-shaft mill Up to the 19th century, the millwright's Craft was highly regarded in Europe, and mills were built that would work without failing for centuries, although their sails had to be replaced every 15-20 years Traditionally, rural populations used windmills for the following applications:

- To perform agricultural tasks such as grinding corn, crushing sugar cane, threshing and wood cutting .
- For specialty applications such as moving saline water in salt works.
- For the generation of electricity (in more recent times).

The mechanical use of wind for driving ships, pumping water, grinding grain, turning the machines of factories, and doing a large variety of other tasks advanced steadily over the centuries. The use of wind as a source of the most widely utilized form of energy-electricity began in the nineteenth century. Indeed, the windmills had a major role in sparking off the industrial revolution[36].

3.2. Using The Wind

Wind as a power source has the same inherent disadvantage as all other solar energy- derived sources have namely it is dispersed source of power. This dispersed availability of energy makes the harnessing and utilization rather difficult, thereby limiting its utilization In order to obtain substantial amounts of power from wind, massive wind machines must be used. But it has been learnt from experience that instead of generating enormous amounts of power from a single giant machine, it is more practical to use several smaller wind machines.

In the People's Republic of China, windmills are extensively used for irrigation on small holdings, using windmill driven, scoop-bucket systems. The windmills are always constructed of locally available materials, e.g. bamboo and wood and are generally built by the user, although perhaps, long ago they were produced by craftsmen for distribution to others. With minor modifications, the same device is used to grind beans and rice and for shelling crops, as well as for pumping. Indeed, the Chines too have a long history of utilization of wind power. The horizontal windmill seems to have been introduced into China during the Sung period (960-1280). Eventually, it evolved into something quite different from the Persian type, using the principle of the luffing sail adapted from the junk for its vanes[36].

In Thailand, simple windmills constructed locally, using wooden or bamboo poles with cloth sails, have been used for many years to move water. More recently, a two-bladed, wooden-propeller type of windmill has been introduced. Here, the water is lifted by scoop-buckets attached to an endless belt, or by water ladder. The buckets scoop water from shallow wells and raise it to the top of the rotating wheel. Each bucket, in turn, turns over on its downward journey, discharging its water into a wooden chute. The Water is then lifted up the water ladder to a point well above ground level and flows to channels dug in the ground to water crops. The ladder consists of a series of wooden flights fitted to an endless chain driven by mechanical linkage to the windmill The flights are closely fitted to an inclined wooden trough and are able to 'scrape' water up the trough, elevating it about 1 m The windmill, as we know it, was derived from watermills in the west the mechanism is basically that of a watermill turned upside down. Unfortunately, no early designs have survived , for in the earliest days full size parts were set out on the workshop floor for making their templates, much as it is done today.

In Europe, the earliest machines made to utilize the wind, dating back to the 12th and 13th centuries, were produced in Holland and England. Constructed of wood, iron and stone, these machines were made by unknown millwrights who designed and built the mills empirically, yet they did excellent jobs of design and execution. Subsequently well-known engineers, including John Smeaton, Sir William Cubitt and Sir William Fairbaimn became interested in the practical use of windmills. These early windmills in England were used for grinding corn, whereas the Dutch machines were used for pumping to reclaim land. Later, in England, windmills for pumping water in Fens-Norfolk and Suffolk came into general use. Farmers have used similar windmills in Russia for hundreds of years[36].

2.3. Met Tower

Met towers are 50–80 meter (160–260 feet) guyed meteorological towers that measure wind speed, air pressure, and temperature. Anemometers provide wind readings at several heights on the tower. The towers are generally unlit, unless they exceed the Federal Aviation Administration (FAA) height requirement[37].

3.4. University of Wyoming

Concerns about the long-term environmental effects of consuming fossil fuels, together with the rising costs of oil and natural gas, have led to rising interest in renewable energy sources. Wind power in particular has been experiencing rapid growth. In 2007, the U.S. led the world in new wind capacity installed .The U. S. also led the world in new capacity installed in

2006. Total U. S. installed capacity at the end of 2007 was 16,818 MW, second only to Germany. Wind is generally considered the lowest cost renewable energy source for the Midwest region, and both a federal production tax credit (PTC) and state renewable portfolio standards (RPS) have favored expansion in recent years[38].

Wind power provides electricity without polluting the air or depleting nonrenewable resources. Wind power relies on steady winds to turn the blades of power generating turbines. Because these turbines generally are located on rural lands, wind power could also provide economic benefits to farmers and rural communities. The 2002 farm bill created a renewable energy program and authorized $115 million for the U.S. Department of Agriculture (USDA) to provide assistance for renewable energy projects, including wind power[39].

To overcome wind energy integration challenges, the Department is developing tools and strategies, such as wind forecasting techniques, which will improve the integration of wind energy with the electrical grid. The Department is funding two state-of-the-art high penetration wind integration studies, the Eastern Wind Integration and Transmission Study and the Western Wind and Solar Integration Study that evaluates the impact of integrating up to 30% wind energy into the U.S bulk power system[40].

When connecting wind parks at various locations across the country, the transmission reinforcement cost needs to be considered. Wind power integration should be assessed at the international level, to identify the needs and benefits of interconnection of national power systems. For high penetration levels of wind power, the optimization of the integrated system should be explored[41].

3.5. Technology and Applications

Modern, commercial grid-connected wind turbines have evolved from small, simple machines to large, highly sophisticated devices. Scientific and engineering expertise and advances, as well as improved computational tools, design standards, manufacturing methods and (operator and management) O&M procedures, have all supported these technology development.

Generating electricity from the wind requires that the kinetic energy of moving air be converted to electrical energy, and the engineering challenge for the wind energy industry is to design cost-effective wind turbines and power plants to perform this conversion. Though a variety of turbine configurations have been investigated, commercially available turbines are primarily horizontal-axis machines with three blades positioned upwind of the tower. In order to reduce the leveled cost of wind energy, typical wind turbine sizes have grown significantly see Figure 3.1. with the largest fraction of onshore wind turbines installed globally in 2009 having a rated capacity of 1.5 to 2.5 MW. As of 2010, onshore wind turbines typically stand on 50 to 100m towers, with rotors that are often 50 to 100 m in diameter; commercial machines with rotor diameters and tower heights in excess of 125m are operating, and even larger machines are under development. Onshore wind energy technology is already being commercially manufactured and deployed at a large scale[10].

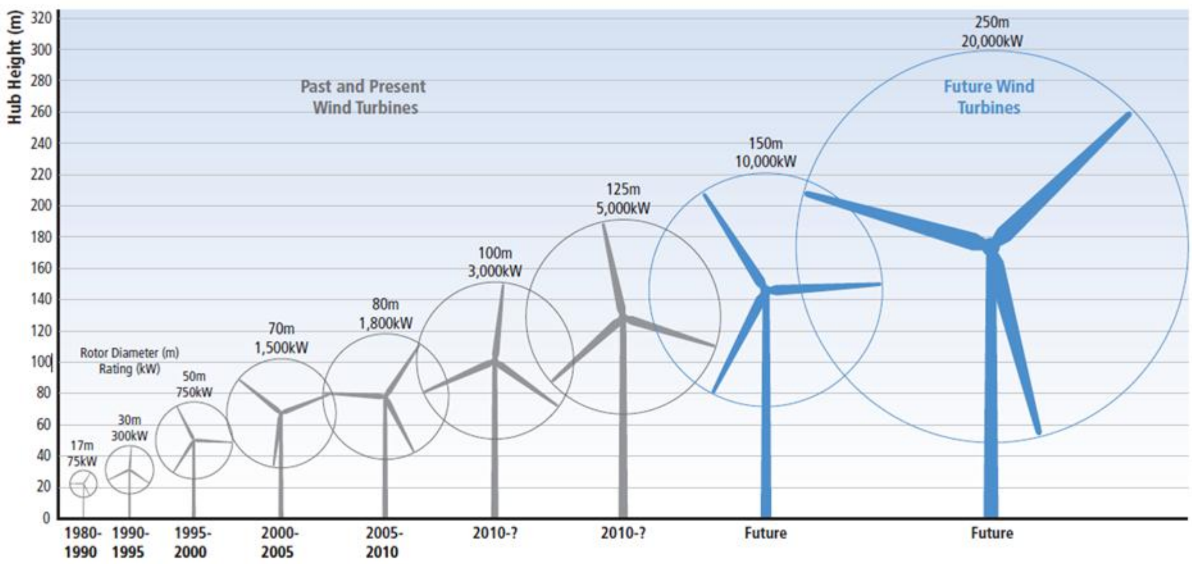

Figure 3.1 : Growth in Size of Typical Commercial Wind Turbines.

Offshore wind energy technology is less mature than onshore, with higher investment costs. Lower power plant availabilities and higher O&M costs have also been common both because of the comparatively less mature state of the technology and because of the inherently greater logistical challenges of maintaining and servicing offshore turbines[10].

Nonetheless, considerable interest in offshore wind energy exists in the EU and, increasingly, in other regions. The primary motivation to develop offshore wind energy is to provide access to additional wind resources in areas where onshore wind energy development is constrained by limited technical potential and/or by planning and siting conflicts with other land uses. Other motivations include the higher-quality wind resources located at sea, the ability to use even larger wind turbines and then potential to thereby gain additional economies of scale, the ability to build larger power plants than onshore, gaining plant-level economies of scale, and a potential education in the need for new, long-distance land-based transmission infrastructure to access distant onshore wind energy. To date, offshore wind turbine technology has been very similar to onshore designs, with some modifications and with special foundations. As experience is gained, water depths are expected to increase and more exposed locations with higher winds will be utilized. Wind energy technology specifically tailored for offshore applications will become more prevalent as the offshore market expands, and it is expected that larger turbines in the 5 to 10 MW range may come to dominate this segment.

Alongside the evolution of wind turbine design, improved design and testing methods have been codified in International Electro technical Commission standards. Certification agencies rely on accredited design and testing bodies to provide traceable documentation demonstrating conformity with the standards in order to certify that turbines, components or entire wind power plants meet common guidelines relating to safety, reliability, performance and testing.

From an electric system reliability perspective, an important part of the wind turbine is the electrical conversion system. For modern turbines, variable speed machines now dominate the market, allowing for the provision of real and reactive power as well as some fault ride-through capability, but no intrinsic inertial response (i.e., turbines do not increase or decrease power output in synchronism with system power imbalances) wind turbine manufacturers have recognized this latter limitation and are pursuing a variety of solutions[10].

3.6. Design and Dimensions

Most commercial-scale wind turbines consist of a three-bladed rotor that rotates around a horizontal hub facing upwind in front of the generator and tower figure 3.2 Most towers these days are of tubular steel construction and are bolted to a concrete foundation. Blades are made of fiberglass or wood epoxy. The hub is connected to a gearbox and generator, which are all located in the nacelle. The tower of a large wind turbine may have an internal elevator to transport workers to the nacelle for maintenance. The nacelle on top of the tower contains a generator turned by the blades, which in turn produces electricity[42].

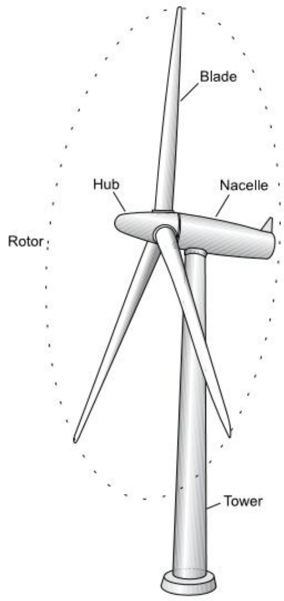

Figure 3.2: Basic Features of The Wind Turbine.

3.7. Turbine Size

Over the past 20 years, average wind turbine ratings have grown almost linearly Figure 3.3 with current commercial machines rated at 1.5 MW. Each group of wind turbine designers has predicted that their machines are as large as they will ever be. However, with each new generation of wind turbines, the size has increased along the linear curve and has achieved reductions in life-cycle cost of energy. The long-term drive to develop larger turbines stems from a desire to take advantage of wind shear by placing rotors in the higher, more energetic winds at a greater elevation above ground (wind speed increases with height above the ground). This is a major reason that the capacity factor of wind turbines has increased over time, as documented by Wiser and Bolinger. However, there are constraints to this continued growth to larger sizes as in general it costs more to build a larger turbine. The primary argument for a size limit for wind turbines is based on the “squarecube law”. Roughly stated, it says that “as a wind turbine rotor increases in size, its energy output increases as the rotor-swept area (the diameter squared), while the volume of material, and therefore its mass and cost, increases as the cube of the diameter.” In other words, at some size the cost for a larger turbine will grow faster than the resulting energy output revenue, making scaling a losing economic game. Engineers have successfully skirted this law by changing the design rules with increasing size and removing material or by using material more efficiently to trim weight and cost. Studies have shown that in recent years, blade mass has been scaling at roughly an exponent of figure 3.3 instead of the expected, as shown by the Wind PACT (Wind Partnership for Advanced Component Technology) blade scaling study[43].

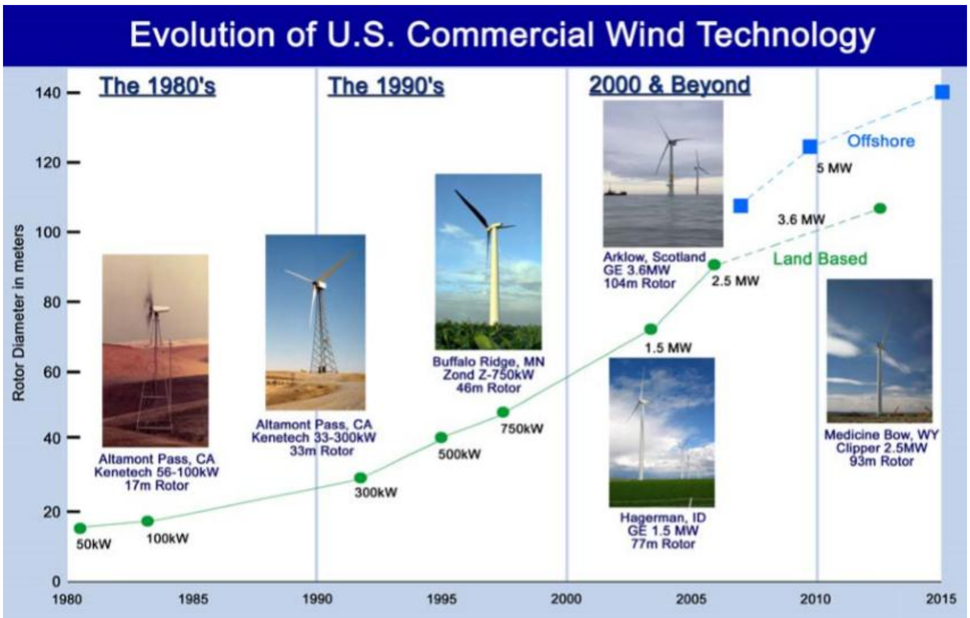

Figure 3.3 The development path and size growth of wind turbines.

Alameda and Contra Costa Counties have initiated a repowering program at the Altamont Pass WRA (Alameda County 1998). Repowering refers to the replacement of existing, less-efficient turbines with a smaller number of larger, more-efficient turbines, see Figure 3.4.[29]

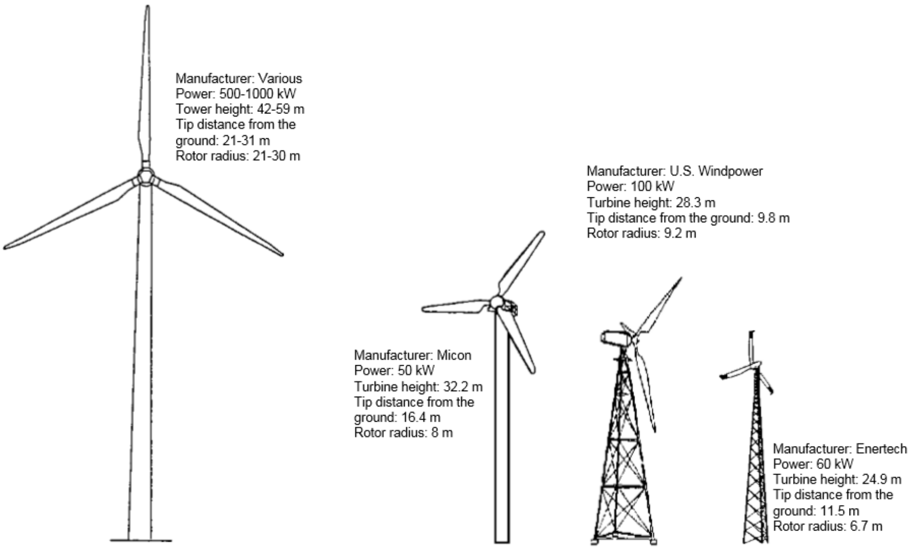

Figure 3.4 Comparison of Size and Other Characteristics of Three Wind Turbine Types Currently in Operation at The Altamont Pass Wind Resource Area With A Representation of Proposed New and Larger Turbine That Would Replace Them.

3.8. Measures of Performance

Capacity factor: Capacity factor is the average power, which is equivalent to an average efficiency factor.

$$CF = average\ power/rated\ power$$

In general, capacity factors are calculated from the kilowatt-hour produced during a time period, since power energy/time. The time periods vary; however, the most representative time period would be 1 year, although capacity factors for a month and a quarter have been reported. Capacity factors of 0.3 would be good, 0.4 would be excellent, while those of 0.10 would be too low. For wind sites and wind farms with class 4 and above winds, annual capacity factors should be 0.35 or greater, and during windy months, the capacity factors can exceed 0.50. Capacity factors are somewhat arbitrary because of the different sized generators for the same rotor diameter. For the month of February 2002, Lake Benton I, Minnesota, reported a capacity factor of 0.49, and Lake Benton II, Minnesota, reported a capacity factor of 0.60. The difference was the wind turbines at Lake Benton II had a larger diameter, more swept area, for the same size generator. Availability: The availability is the percentage of time the unit is available to operate and is a measure of reliability. For prototypes and early production models, the availabilities were low, 0.50 or even lower. Third-generation models have availabilities of 0.95–0.98. Manufacturers may define availability differently, so be careful in comparing availability of different wind turbines. Reliability and operation and maintenance affect the system performance[44].

3.9. Wind Farm Performance

Capacity factors have improved with the newer and larger wind turbines, so it is expected that wind farms installed from 2000 on will have better capacity factors than the older installations The early wind farms in California had average capacity factors below 20%, while wind farms in good to excellent wind regimes with new wind turbines should have capacity factors from 35 to 40%. Availability and capacity factor are related, because if the wind turbines are having operational problems, availability and capacity factors will be low. For example, for the first year, there were problems at Horns Rev, an offshore wind farm in Denmark, so the capacity factor was only 26%; however, the next year it reached the expected value. At the offshore wind farm Scroby Sands (thirty wind turbines, 60 MW) in the United Kingdom, energy production was limited in the first year of operation. There were numerous mechanical problems, with 27 intermediate-speed and 12 high-speed gearbox bearings replaced, along with four generators. So the capacity factor for the first year was 29%, rather than the predicted 40%. Another example is a 38 turbine, 80 MW wind farm where there were software problems and then blade problems. One year after installation thirteen turbines were still not operational. All were expected to be operational in the second year[44].

The winds of the world amount to an average power of 2.5 Wm^2 of the earth's surface At many windy sites throughout the world, the flow of wind through a vertical square meter, at a height of about 25 m, may reach a yearly average of 500Wm^2. An efficient windmill has about 175 Wm^2 equivalent of area swept by its propeller. Theoretical considerations show that the ideal windmill could extract only about 59% of the kinetic energy of the wind passing through the area of its blades. Even good aerodynamic design would achieve less than 70% of the theoretical maximum .The proponents of wind power suggest that large array of wind machines may be arranged in a windy site to make a 'wind farm'. They then calculate the total energy that might be extracted from such farms get impressive figures. A typical such calculation shows that if only 10% of the wind energy available can be extracted. $2x10^{12}$W can be generated in the United States alone. This amounts to 3900 quads of energy, or over 15 times the present energy demand of the whole world! But these theoretical calculations for wind energy potential can be as misleading as similar calculations for other renewable energy source because the utilizable fraction is much smaller, and serious technological problems have to be surmounted to realize even this fraction. For example, in the United States the available sites have to be cluttered with 2 million 1 MW wind machines in order to achieve the necessary energy extraction, far beyond the realms of practicality[45].

The limitations on the extraction of energy from the wind include the practical size of wind machines, their density, friction losses in the rotating machinery, and efficiencies of conversion from rotational energy to electrical energy. These merits and limitations are listed in Table 3.1.

TABLE 3.1: The Merits and Limitations of Wind Energy

Merits of wind energy	**Limitations of wind energy**
Important renewable energy, available free of cost available	Has low-energy density; favorable in geographic locations, away from cities, forests
Available in many offshore, onshore remote areas; helpful in supplying electric power to remote areas	Variable, unsteady, irregular, intermittent, erratic sometimes dangerous
cost-effective and reliable in wind power generations	Wind turbine design, manufacture and installation have proved to be complex due to widely varying atmospheric conditions in which they have to operate
Supplies energy in rural areas	Small units are more reliable, but have higher capital cost per kWh; large units require high-tech even if they have less capital cost per kWh
No pollution during energy	Requires energy storage batteries

generation	which indirectly and substantially contribute to environmental pollution
Economically competitive	Wind farms can be located only in vast open areas in locations of favorable wind. Such locations are generally away from load Centre's

Wind power profiles are location specific. The data show that different regions have different daily, monthly, and seasonal wind power profiles. Wind power data from one region can be used to predict fluctuation behavior from second-to-second up to hourly, but they are not good indicators to daily and monthly performance of wind power plants in other regions. Utility system load follows predictable daily, weekly (weekdays and weekends), and seasonal (summer cooling, winter heating, on-peak, off-peak) patterns. With long-term wind power data, it is possible to assemble seasonal average output profiles for the region, but they may not be applicable to other regions. In addition, the available data do not show that wind power has any distinctive weekday and weekend profiles.

Utility planners usually compile some representative load profiles for system analysis and planning. A different approach may be necessary with wind power. The stochastic nature of wind power series makes it difficult to compile representative daily or seasonal profiles for a specific region. The critical issue is that the wind power profiles capture the characteristic wind power variations. Again, this issue could be addressed with the weather model approach[45].

To realize the potential of wind power, we must met the three challenges of technology, supply chain, and policy. Technological advances have been central to the growth of wind. Innovations in turbine design have lowered wind's cost of electricity by more than 80%since 1985, primarily through increases in power output and rotor size to optimize energy capture. In 1985, the average US wind turbine was 100 kw with a 17-meter rotor diameter. When General Electric GE entered the wind industry in 2002, we inherited a 1.5 megawatt turbine with a 70.5-meter rotor.

Since 2002, we have made major technology and supply chain investments to further improve turbine efficiency by increasing the rotor diameter of our 1.5-megawatt turbine to 77 and 82 meters. This has increased capacity factor, or turbine efficiency[46].

3.10. Future of Wind Power

A study by an advisory committee to the U.S. Department of Energy in 1980 showed that wind power was the most promising source of alternative energy for the near and intermediate term. There is no doubt that wind power has the potential to produce prodigious amounts of energy. One of the problems is to build wind machines large enough to make the electrical power output worthwhile. Another problem is to regenerate electricity, reliably, despite uncertain and highly variable wind The advantages are that wind power is continually regenerated in the atmosphere under the influence of solar. heating and that wind is a clean and cheap power source. There is no waste product to dispose of, except during the manufacturing of the materials going into the wind machine.

In 1972 Professor William E. Heronemus of the University of Massachusetts proposed a gigantic scheme of hundreds of huge windmills strung out across the great plains of mid-America. Heronemus planned to mount 20 wind turbines on a 115 m tall tower.

Originally, Heronemus visualized, some his 300000 towers strung out from Texas to the Canadian border. Now, to conserve land, his plan calls towers for strung 240 m tall towers and straddling the highways at half-mile intervals, with the 20 turbines slur from cables strung between the towers .

He visualizes 2000 windmills pumping an annual 1.5 trillion kilowatt-hour per year into the national power grids. This is nearly as much as the yearly amount of electricity generated in the United States today. Whether this ever comes about remains to be seen. However, people are taking the idea more seriously as other energy sources become more expensive and more difficult. Within a decade or so, we may see the development of very large arrays of wind turbines to generate electricity[36].

3.11. Land Requirements and Environmental Impacts

Most of the arguments on renewable energy technologies focus on their land requirements and the potential environmental and social impacts. Although renewable energy technologies often cause fewer environmental problems than fossil energy systems, they introduce new conflicts. At a global scale the environmental benefits of renewable energy are largely, and undisputed with major contributions in reducing global emissions of greenhouse gases. However, the benefits are less clear and far more disputed at a local scale. Due to tapping more diffuse forms of energy, these technologies require greater areas of land. Because of that, the general belief on renewable energy technologies is that they are land hungry. Therefore, land availability is one of the basic parameter. Since they require large amounts of land, the utilization of renewable energy sources competes with agriculture, forestry, and other essential land use systems. In relation to that, the availability of required land is seen as a potential constrain on renewable energy developments, and considered as an essential factor also in assessing the resource capacity of any region[4].

3.12. The Theoretical Model

the power generated by wind is given by

$$VI = P = \frac{\pi}{\delta} K_{\circ} \rho D^2 v^3 \quad (3.1)$$

With

$\pi = 3.14$

$\delta = function\ in\ the\ integral$

$K_{\circ} = conversion\ coefficient$

$\rho = air\ density$

$D = fan\ blade\ diameter$

v = wind speed

$V = generated\ voltage$

$I = generated\ current$

The air density ρ is known to decrease upon increasing temperature T. this physical fact can be theoretically realized by bearing in mind that the decrease in density due to the temperature effect is related to the fact that, increasing temperature T, increases the spacing x between successive atoms or molecules according to the phonon model relation[47].

$$x = \frac{gkt}{c^2} \quad (3.2)$$

Where the restarting force F takes the form

$$F = -cx + gx^2 \tag{3.3}$$

With K standing for Boltzmann constant, whereas c and g are stiffness parameters respectively.

In view of equation (3.1) and (3.2), the density ρ and generated voltage V are given by

$$\rho = \frac{m}{x^3} = \frac{mc^3}{g^3k^3T^3} \approx C_1T^{-3} \tag{3.4}$$

Where m is the air mass enclosed in a volume x^3[48].

Thus

$$V = \frac{\pi}{8I} k_\circ (c_1T^{-3})D^2v^3$$

$$= c_2T^{-3} = \frac{c_2}{T^3} \tag{3.5}$$

Where all parameters other than temperature are assumed to be constant. Thus the $V - T$ curve can be displayed in Fig. 3.5

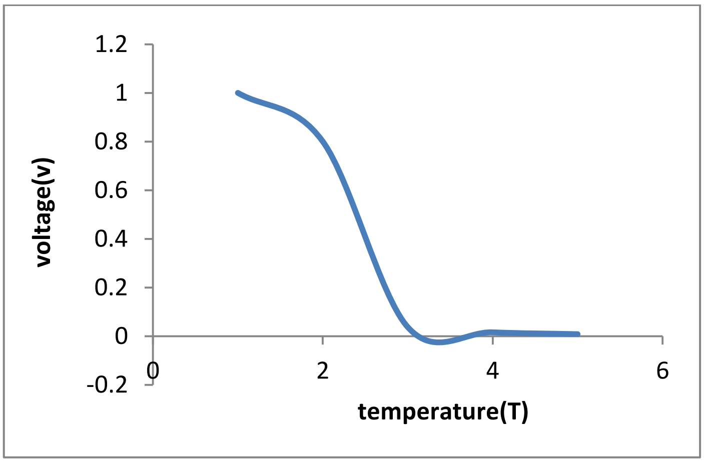

Figure 3.5 Relation Between Applied Voltage V and Air Temperature T

The relation between speed v and voltage V, can be found from equation (3.1) to be

$$V = \frac{\pi}{8}\frac{k_\circ \rho}{I} D^2 v^3$$

$$= c_2 v^3 \qquad (3.6)$$

Where the parameters other than v are assumed to be constant this relation can be displayed graphically in Figure 3.6 to get

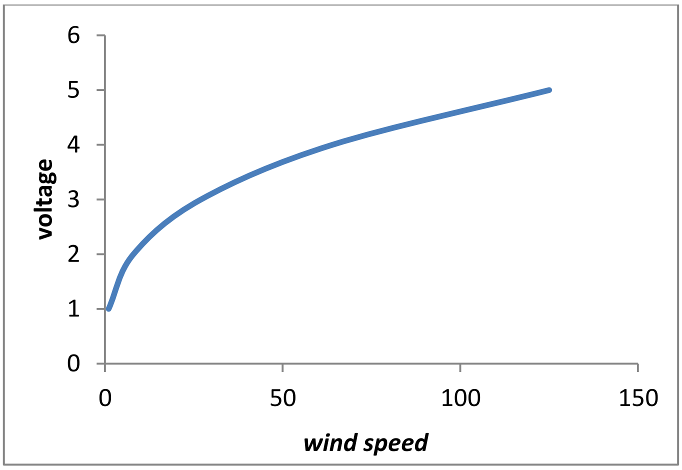

Figure 3.6 Relation Between Wind Speed v and Generation Voltage V.

3.12.1. Power Output of a Wind Turbine:

The procedures of equation deduction below are from[21], and they are used to introduce how to calculate the rated power of wind turbine. Actually, this final equation is same to the equation of power in the wind.

$$E = W = Fs \qquad (3.7)$$

Equation (3.7) is based on Work Done, where " E " is kinetic energy, " W " is work done on the object, " F " is force and " s " is distance.

$$F = ma \qquad (3.8)$$

Equation (3.8) is based on Newton's Law, where " m " is mass, and " a " is accelerated velocity.

$$v^2 = u^2 + 2as \tag{3.9}$$

Equation (3.9) is based on Motion Equation, where " u " is initial velocity. Because of the initial velocity " u " here is zero, following equation could be achieved:

$$v^2 = 2as \tag{3.10}$$

$$a = \frac{v^2}{2s} \tag{3.11}$$

Finally, put the value of $a = \frac{v^2}{2s}$ into the Equations (3.7) and (3.8), then:

$$E = \frac{1}{2} m v^2 \tag{3.12}$$

Equation (3.12) is based on Kinetic Energy, then the power in the wind is given by the rate of change of energy below:

$$P = \frac{dE}{dt} = \frac{1}{2}\, v^2 \frac{dm}{dt} \tag{3.13}$$

$$\frac{dE}{dt} = \rho A \frac{dm}{dt} \tag{3.14}$$

Equation (3.14) is based on mass flow rate, where "ρ " is density, and "A" is the mass area.

$$\frac{dx}{dt} = v \tag{3.15}$$

Equation (3.15) is based on the rate of change of distance. Then the power in the wind could be written as Equation (3.8) by combining the Equations (3.13) (3.14) and (3.15).

$$p = \frac{1}{2}\,\rho A v^3 \qquad (3.16)$$

Here it is found that this Equation (3.16) is the maximum theoretical power in the wind, where " ρ " is air density of wind, " A " is the area of wind pass, and " v " is the wind speed. If this equation is used in the calculation of power of wind turbine. The " A " should be swept circle area of blade of wind turbine. $A = \pi r^2$ (3.17)

Equation (3.17) is based on the area of a circle, where "π" is mathematical constant of circle, and " r " is blade radius[49].

The total amount of energy extractable from a wind turbine can be calculated theoretically, using translational momentum theory. Power extractable from the wind passing across an area A, when the wind speed is v can be expressed as,

$$p_w = \frac{1}{2}\rho A v^3 \qquad (3.18)$$

Here, ρ is the density of air, which depends on the pressure and moisture levels of air. Betz's law states that the maximum fraction of power extracted by a wind turbine would be theoretically 16/27 of p_w. However in practice, turbines would extract a significantly lesser portion of wind power. Even modern commercial wind turbines extract about 0.45 of p_w. Thus, a coefficient is defined to express the useful mechanical power extracted from the wind by the turbine. It is called the power coefficient or the Betz factor, c_p, and defined as,

$$\text{Power coefficient, } c_p = \frac{turbine\ power}{power\ of\ wind} \qquad (3.19)$$

Power coefficient, c_p, is a function of two variables, namely, tip speed ratio, λ, and pitch angle, β. Tip speed ratio, λ, is the ratio between the speed of the tip of the blade, ωR, and the velocity of wind, v. Here, ω is the rotational speed of the turbine rotor and R is the radius of the turbine blade

$$\lambda = \frac{\omega R}{v} \tag{3.20}$$

Moreover, c_p is also a function of the pitch angle, β but for a fixed pitch wind turbine, β, is generally zero. Then the turbine power extracted by a fixed pitch wind turbine can be expressed as,

$$p_t = \frac{1}{2}\rho A v^3 c_p(\lambda) \tag{3.21}$$

In Equation (3.21), the circular swept area of the turbine is given as A. Further it can be seen that for a given wind speed, tip speed ratio, λ, is a function of ω only and hence, c_p becomes a function of ω only. Therefore, the power extracted by a fixed pitch wind turbine, P_t, is a function of its rotor speed, ω, only, provided that the wind speed remains constant. Similarly, a coefficient can be defined for the torque extracted as c_t, and the torque output of a fixed pitch wind turbine can be given as[50],

$$\tau_t = \frac{1}{2}\rho A v^2 c_t(\lambda) \tag{3.22}$$

Torque of the turbine can also be expressed as,

$$\tau_t = \frac{1}{2}\rho A v^3 c_p(\lambda)/\omega \tag{3.23}$$

Furthermore,

$$c_t(\lambda) = \frac{c_p(\lambda)}{\lambda} \tag{3.24}$$

CHAPTER FOUR

Materials and Methods

4.1. Introduction

Researchers have registered a patent for a wind energy capturing device for moving vehicles including a wind turbine powered electrical power generator for installation on the roof of a moving vehicle such as a truck cab or tractor. The invention takes advantage of the powerful wind force generated by the vehicle moving on the road at moderate to high speed impinging against the wind deflector mounted on the truck cab or tractor. This otherwise "wasted" wind energy is captured and directed to the face area of the rotor blade, rotating the turbine, which, in turn, drives the generator to generate electricity[51].

Electric cars are a variety of electric vehicles. The term "electric vehicle" refers to any vehicle using electric propulsion motors. The maximum speed of travel on public roads and city streets varies by country. Electric cars need to charge their batteries every 300 km or 400 km, we propose to add wind turbines to an electric car for using wind energy neglected during the movement of the vehicle to produce electricity.

Only 30% of an engine's fuel combustion energy is converted into useful work to driving. The remainder is engine waste heat dissipated by the engine exhaust system, the cooling system, and convection as well as radiation from the engine block. Nearly 40% of thermal energy is wasted by using exhaust gas. If this portion of waste thermal could be harnessed, energy efficiency will be enhanced, as vehicles around the world can save a lot of energy[16].

Several investigations about possible applications of thermoelectric power generation are a recovery of waste heat in the vehicle to improve fuel economy. In this idea, the heat of vehicle waste, usually from the exhaust to produce electricity. More drive-train power is available to move the vehicle, and electricity is still available[52].

we used the waste of wind energy during the vehicle movement. The wind turbine having blades which are joined to a rotor generator leading to produce electrical energy as moves by the flow of wind. The electrical energy produced by the system needs to be either utilized completely or stored. So, it should be stored rather than wasted. Electrical batteries are the most relevant, low cost, maximum efficient storage of electrical energy in the form of chemical reaction[53]. In this research one select wind turbines with different specifications and conducted indoor and outdoor experiments, These experiments propose to avail from wind energy to generate electricity for electric vehicle.

4.2. Methodology

4.2.1. Apparatus and Equipment

The three experiments was carried out in which was used apparatuses and equipment's: Wires, five fans, a car, trestle "support", Avometer see figure 4.1, thermometer, heater, a pump of air 750w, first transducer12 volts 50 ampere/DC see figure 4.4, second transducer 12 volt/Ac see figure 4.3, and a battery 12volt see figure 4.2

The following are records of the experiment, where the table shows the dimension records of the used fans, and the followed five graphs show the power generation in the different speed of the car.

Figure 4.1: The Multimeter

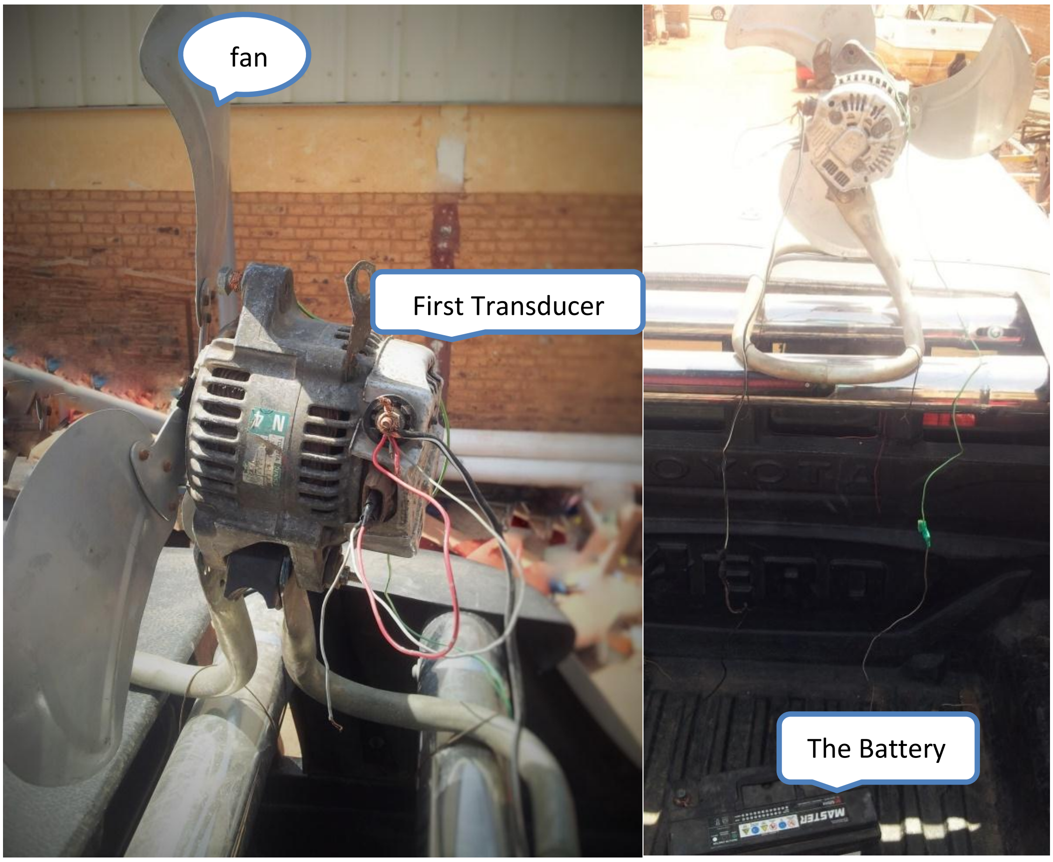

Figure 4.2: Plumb of Device

Figure 4.3: The Second Transducer

4.3. The Results

Table 4.1: Specifications of The Fans.

Number - of the fans	Number of the blades	The length/cm ±0.01	Maximum of width/cm ±0.01	Minimum of width/cm ±0.01	The weight of the fans/g ±0.001
1	3	17	16.3	6	402
2	3	16.9	17	4.5	196
3	3	16.9	16	4.5	302
4	3	17.4	8.6	7.5	172
5	4	14	16.8	8	454

1) **The First Experiment** which it explain in table 4.2 the car speeds, voltage and direction of the car's move while wind speed move from the West to the East for the first transducer with the first fan.

Table 4.2: Relation Between Speed, Voltage and Direction of The Car For The First Transducer With The First Fan:

Speed (Km/h) ±1/260	V /volt ±1/600	Direction of car
20	13	East
25	13	East
30	13	West
35	12.6	East
40	12.5	East
45	12.7 – 12.6	West
50	12.5	East
55	12.5	West
60	12.6	East

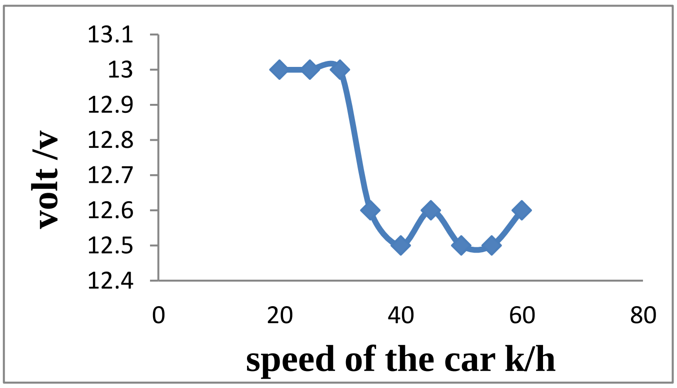

Figure 4.4: The Speed Against The Volt for The First Transducer With The First Fan

2) The Second Experiment which it explain in table 4.3 the car speeds, voltage, currents and power for the first transducer with the first fan.

Table 4.3: Relation Between Speed, Voltage, Current and Power For The First Transducer With The First Fan.

Speed (km/h) ± 0.0038	V/volt ± 0.0016	Current/ampere ± 0.001	Power /watt
0	10.16	0	0
30	10.18	0.42	4.27
35	10.17	0.44	4.47
40	10.17	0.44	4.47
45	10.19	0.49	4.99
50	10.00	0.57	5.7
55	10.00	0.90	9
60	10.00	1.0	10
65	10.21	1.3	13.27
70	10.20	1.6	16.32
75	10.23	2.0	20.46

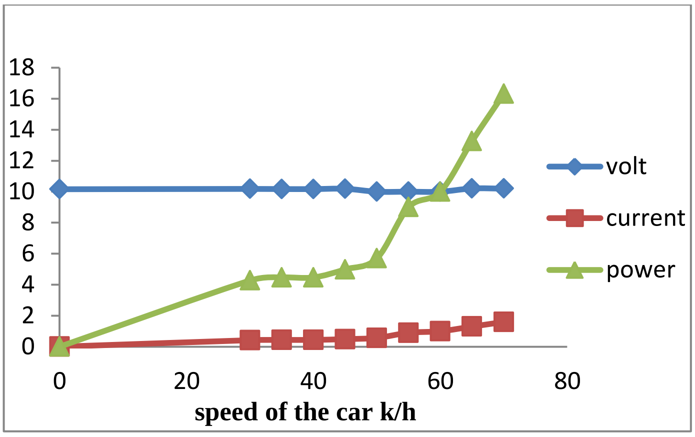

Figure 4.5: The Speed Against The Volt, Current and Power Progressively for The First Transducer With The First Fan

3) **The Third Experiment** which it explain in table 4.4 the car speeds, voltage, currents and power for the first transducer with the first fan.

Table 4.4: Relation Between Speed, Voltage, Current And Power For The First Transducer With The First Fan.

Speed km/h ± 0.0038	**V /volt ± 0.0016**	**A/ampere ± 0.001**	**Power / watt**
75	10.4	1.7	17.68
70	9.8	1.3	12.74
65	10.1	1.3	13.13
60	9.8	1.0	9.8
55	9.6	0.92	8.83
50	9.7	0.92	8.92
45	10.7	1.2	12.84
40	10.0	1.7	17
35	10.1	0.49	4.94

30	10.1	0.48	4.84
25	10.1	0.44	4.44
20	10.1	0.44	4.44

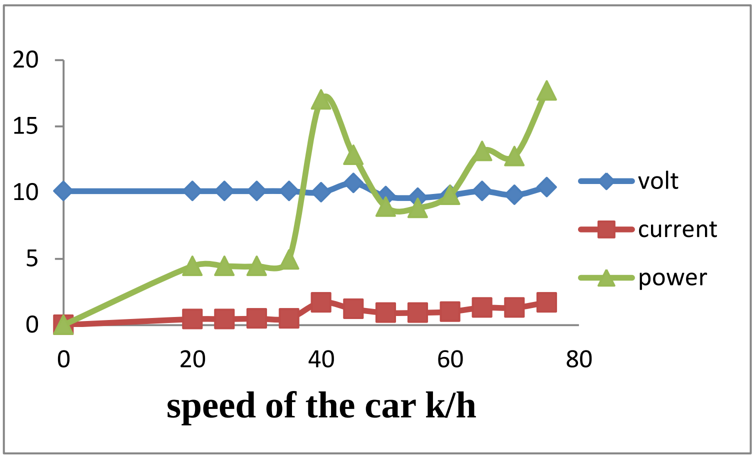

Figure 4.6: The Speed Against The Volt, Current and Power Receding for The First Transducer With The First Fan

4) **The Forth Experiment** which it explain in table 4.5 the car speeds, voltage, currents and power for the first transducer with the second fan.

Table 4.5: Relation Between Speed, Voltage, Current and Power For The First Transducer With The Second Fan

Speed km/h ± 0.0038	V /volt ± 0.0016	A/ampere ± 0.001	Power / watt
0	11.56	0	0
20	11.56	0.95	10.98
25	11.55	0.94	10.85
30	11.55	0.90	10.40
35	11.58	0.85	9.84
40	11.62	0.90	10.46

45	11.66	0.92	10.72
50	11.64	0.91	10.59
55	11.70	0.98	11.47
60	11.73	0.95	11.14
65	11.83	1.50	17.75
70	12.10	2.00	24.00

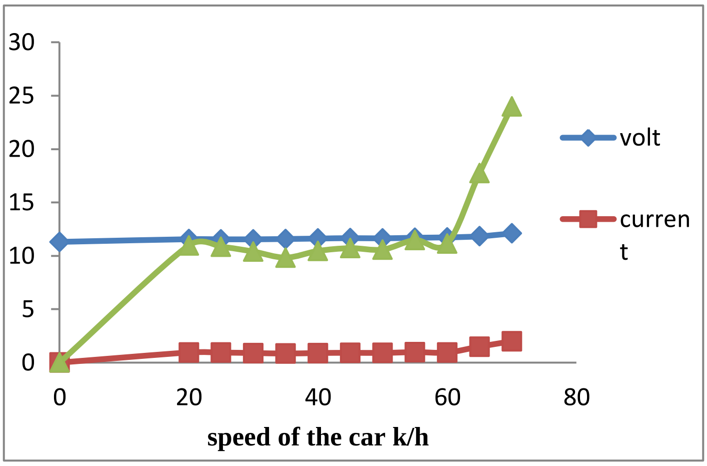

Figure 4.7: The Speed Against The Volt, Current and Power for The First Transducer With The Second Fan

5) **The Fifth Experiment** which it explain in table 4.6 the car speeds, voltage, currents and power for the first transducer with the third fan.

Table 4.6: Relation Between Speed, Voltage, Current and Power for The First Transducer With The Third Fan

Speed km/h ± 0.0038	V /volt ± 0.0016	A/ampere ± 0.001	Power / watt
0	11.54	0	0
20	11.54	0.80	9.23
25	11.53	0.82	9.45

30	11.56	0.83	9.59
35	11.50	0.86	9.89
40	11.59	0.88	10.20
45	11.70	0.84	9.82
50	11.83	0.87	10.29
55	11.84	0.87	10.30
60	11.92	0.97	11.56
65	11.93	0.90	10.74
70	12.00	0.94	11.28

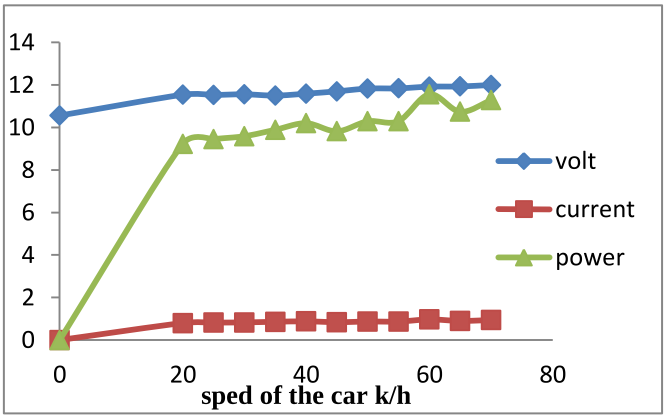

Figure 4.8: The Speed Against The Volte, Current and Power for The First Transducer With The Third Fan

6) **The Sixth Experiment** which it explain in table 4.7 the car speeds, voltage, currents and power for the first transducer with the fourth fan.

Table 4.7: Relation Between Speed, Voltage, Current and Power for The First Transducer With The Fourth Fan

Speed km/h ± 0.0038	**V /volt ± 0.0016**	**A/ampere ± 0.001**	**Power / watt**
0	11.02	0	0
20	11.02	0.96	10.58
25	11.30	0.86	9.72
30	11.50	0.81	9.32
35	11.50	0.84	9.66
40	11.40	0.88	10.03
45	11.50	0.94	10.81
50	12.10	1.30	15.73
55	11.99	1.10	13.20
60	12.40	1.70	21.08
65	12.70	1.60	20.32
70	13.10	1.70	22.27

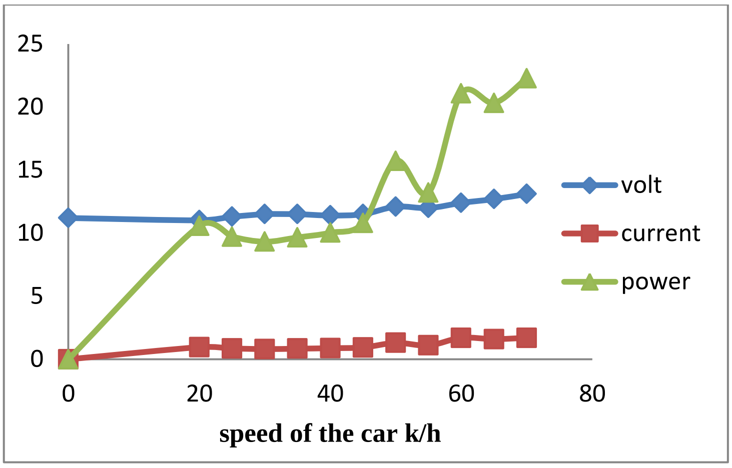

Figure 4.9: The Speed Against The Volt, Current and Power for The First Transducer With The Fourth Fan

7) **The Seventh Experiment** which it explain in table 4.8 the car speeds, voltage, currents and power for the first transducer with the fifth fan.

Table 4.8: Relation Between Speed, Voltage, Current and Power for The First Transducer With The Fifth Fan

Speed km/h ± 0.0038	V /volt ± 0.0016	A/ampere ± 0.001	Power / watt
0	10.80	0	0
20	10.80	0	0
25	10.80	0.90	9.72
30	10.78	0.90	9.70
35	10.80	0.82	8.86
40	10.82	0.94	10.17
45	10.80	0.96	10.37

50	10.80	0.96	10.47
55	10.90	0.95	10.36
60	10.92	0.95	10.37
65	10.84	0.95	10.30
70	10.99	0.94	10.33

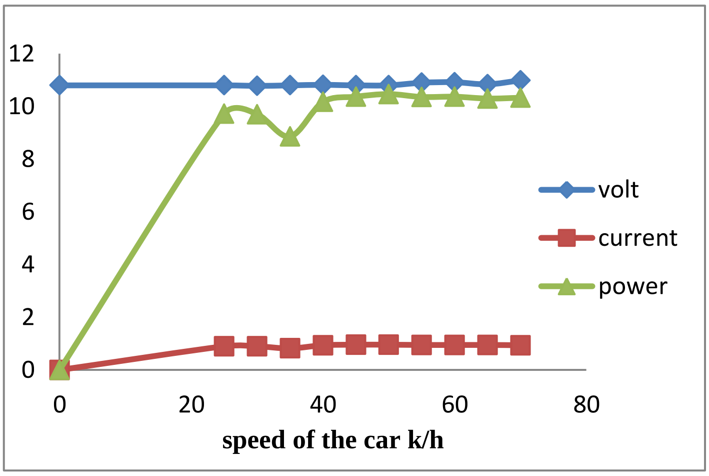

Figure 4.10: The Speed Against The Volt, Current and Power for The First Transducer With The Fifth Fan

8) **The Eighth Experiment** which it explain in table 4.9 the temperature and voltage for the second transducer with the second fan.

Table 4.9: Relation Between Temperature and Voltage For The Second Transducer With The Second Fan

Temperature/ c°	Voltage / volt
35	2.6
36	2.3
37	2.3
38	2.1
39	1.9
40	1.9
41	1.4
42	1.2
43	1.00
44	1.00
45	1.01
46	0.9
47	0.9
48	0.9

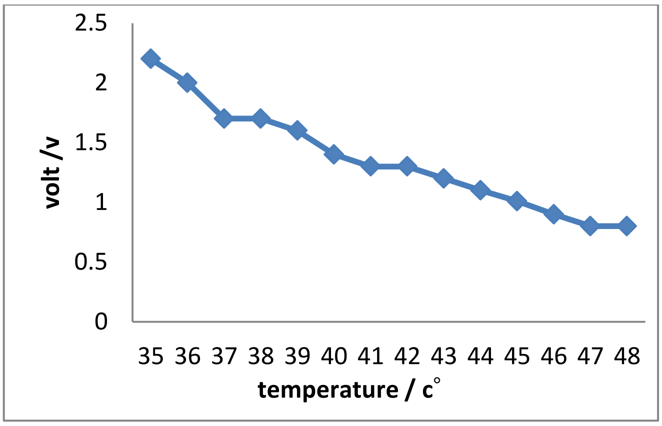

Figure 4.11: The Temperature Against The Volte for The Second Transducer With The Second Fan

9) The Ninth Experiment which it explain in table 4.10 the temperature and voltage for the second transducer with the fourth fan.

Table 4.10: Relation Between Temperature and Voltage For The Second Transducer With The Fourth Fan

Temperature/ c°	**Voltage / volt**
35	2.2
36	2.0
37	1.7
38	1.7
39	1.6
40	1.4
41	1.3

42	1.3
43	1.2
44	1.1
45	1.01
46	0.9
47	0.8
48	0.8

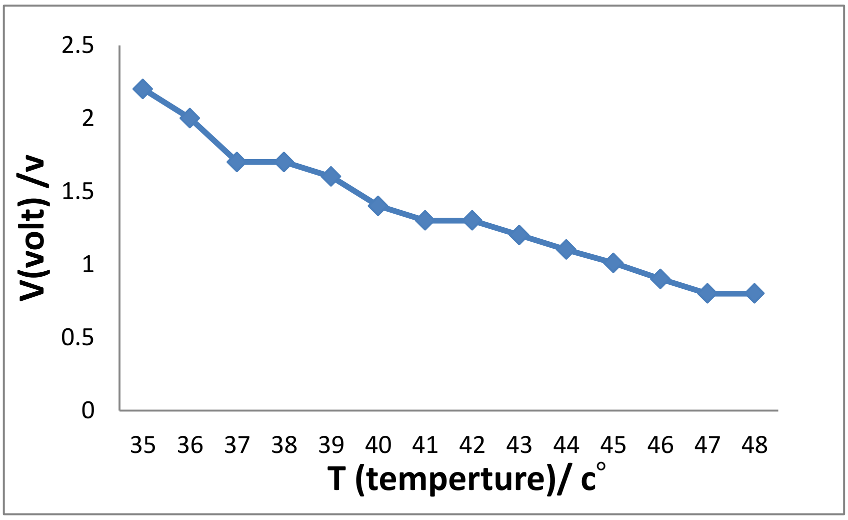

Figure 4.12: The Temperature Against The Volte for The Second Transducer With The Fourth Fan

9) **The Tenth Experiment** which it explain in table 4.11 the car speeds and voltage for the second transducer with the second fan.

Table 4.11: Relation Between Speed and Voltage for The Second Transducer With The Second Fan

Speed km/h ± 0.0038	V /volt ± 0.0016
0	2.2
20	5.6
25	6.2
30	6.5
35	6.7
40	6.8

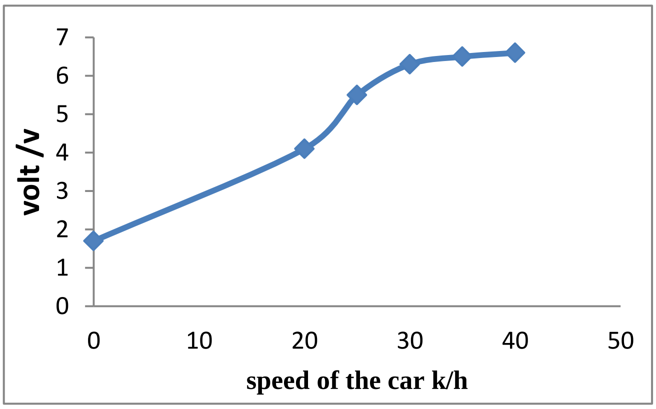

Figure 4.13: The Speed Against The Volte for The Second Transducer With The Second Fan

4) **The Eleventh Experiment** which it explain in table 4.12 the car speeds and voltage for the second transducer with the fourth fan.

Table 4.12: Relation Between Speed and Voltage for The Second Transducer With The Fourth Fan

Speed km/h ± 0.0038	V /volt ± 0.0016
0	1.7
20	4.1
25	5.5
30	6.3
35	6.5
40	6.6

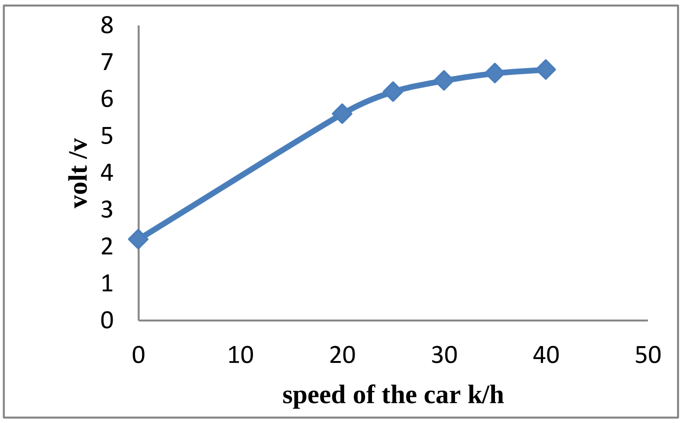

Figure 4.14: The Speed Against The Volt for The Second Transducer With The Fourth Fan

4.4. Dissociation

In the previous result section Table 4.1 showed measurements of blade dimensions for five fans; different dimensions and different weights mean different resistant to air that affects voltage generation of the wind turbine.

In the first experiment, the relationship between speed of the car and voltage was inversely proportional because the blades of the first fan were friction with the holder, and increase friction as the car speed increase see figure 4.4. In figure [4.5, 4.7, 4.8, 4.9, 4.10] the plot of speed of the car against volt, current, and power for the five fans power was calculated from equation (3.1), respectively were shown, and direct proportionality relation between voltage, current, and power with speed of the car has been observed, this is relation agree with the theoretical relation according to equation (3.1). Some values were irregular because the car slowed for a bystreet curved. The experiment was carried out while the speed of the car was decrease from 75-20kh, and observed direct proportionally between speed of the car with voltage, current and power see figure 4.6. When usage first and fifth fans the blades didn't move before the car reaches25k/h and 30 k/h respectively, moreover, the fifth fan has four blades due to the weight of the fans. Got maximum power 24 watts when used the third fan are provided in figure 4.7 the voltage value of the battery before the experiment was equal 10.16 volt and after the finish it was equal to 13.10 volt.

In figure 4.11 and figure 4.12 the plot of voltage against temperature/c° for the two fans, respectively were shown, and an inverse proportionality relation between voltage and temperature/c° has been observed. these empirical relation conforms with the theoretical relation displayed in Figure 3.5 It is also interesting to note that large blade fan voltage is higher than small one. This come from the proportionality of voltage V with blade diameter D. In figure 4.13 and figure 4.14 the plot of voltages against speed of car for two fans, respectively were shown, and a direct proportionality relation between voltage and speed of a car has been observed. This relation agrees with the theoretical relation display in Figure

3.6 When using the fan with large blade dimensions at the second fan, the voltage value was found to be equal to: 2.2 v, i.e. When the vehicle was in static state. This voltage results from free wind speed. It however when the vehicle started to move the value changed to: 5.6v for vehicle speed of 20k/h. This results from the fact that the wind speed increases due to the car motion. Thus v increase according to equation (3.1) at higher speed the voltage tend to remain fixed. this is similar to what happened in a small blade dimension at the fourth fan. It is also very interesting to note that the voltage of large blade is higher than that of the smaller are due to the effect of radius according to equation (3.1).

4.5. Conclusion

A comparison between five fans with first transducer showed that: the fan with large dimension blade and lightweight was the best one to generate voltages. These results agree with theoretical model reveal that one avail from wind energy to charge the battery to vehicles as long as vehicles move along the way.

At (eighth, ninth, tenth, eleventh) experiments a comparison between the two fans showed that the fan with large dimensions blade was the best one to generate voltages, moreover, fans can generate high voltage at low temperatures. These results agree with theoretical models. It also reveal that one avail from wind energy to supply more electricity to vehicles as long as vehicles move along the way.

4.6. Recommendations

One recommend that this experiment should be done using more fans and connect them with different transducers and connect them with batteries and take values of voltages and currents. The effect of change of dimensions of fans' blades, on the wind energy transducer performance, should be studied also. Future work of research will aim at addressing the comparison and different combinations of the wind turbine and this experiment should be done connect the wind turbine to the vehicle battery directly and compare the consumption time with battery charge time.

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