Sustainability in Wireless Mobile Communication Networks through Alternative Energy Resources

[1]Amit Kumar; [2]Dr. Yunfei Liu; [3]Dr. Manu Sood; [4]Tanvir Singh; [5]Sunder Gopal Singh
[1,2]College of Information Science and Technology, Nanjing Forestry University, Nanjing, China
[3]Deparment of Computer Science, H.P. University, Shimla, India
[4]Department of ECE, I.E.T. Bhaddal, Ropar, Punjab, India
[5]Department of I.T., G.G.D.S.D. College, Sec-32, Chandigarh, India
E-mail : amitmehta66@gmail.com

Abstract

The combination of rising energy costs and our insatiable appetite for technology advancements will lead to significant environmental impact unless aggressively addressed by a unified strategy. The explosive development of ICT (information and communication technology) industry has emerged as one of the major sources of world energy consumption. In fact ICT industry ranks among the top energy consumers, with 2% to 10% energy consumption in the world. This paper addresses the energy optimization of wireless mobile networks through alternative energy resources in wireless mobile communication to tread the path of energy sustainability. The study includes the overview of alternative energy resources like wind power, solar power, including their economic, environmental and social impact on wireless mobile communication networks.

Keywords

Sustainable Mobile Communication, ICT, Energy Efficiency, Alternative Energy Resources, PV, Wind Energy

I. Introduction

The continuously growing demand for ubiquitous information access triggers the rapid development of the ICT (information and communication technology) industry and service uptake resulting in more than 5 billion mobile cellular subscriptions worldwide, translating into a penetration rate of more than 65 per cent (see Fig. 1). The ICT industry ranks among the top energy consumers with 2% to 10% energy consumption in the world, which is expected to get more demanding in the future due to increase in the density of base stations in 4G wireless communication networks. Every year, 120,000 new base stations are deployed servicing 400 million new mobile subscribers around the world [13]. Also, with the introduction of the iPhone and other software driven smart phones the Internet is now accessible from a mobile platform which will place even greater demand for broadband. As a result, energy saving approaches are urgently required by both the government and network venders [1,8]. Toward realizing ubiquitous computing environments, Wireless technology is enhancing the mobility of ubiquitous devices, but this mobility creates a power management problem [3]. Consequently reducing the energy consumption of wireless networks is considered vital for the future [4]. Also, the implication of cellular usage on human health surfaces the dark side of the technology [2].

In the mobile cellular networks, the Base Stations (BSs), backhaul routers and data servers are the major energy consumers in a mobile access network. Due to spectrum scarcity and high bandwidth requirements of the users, the BSs will be deployed more densely in the future 4G networks.

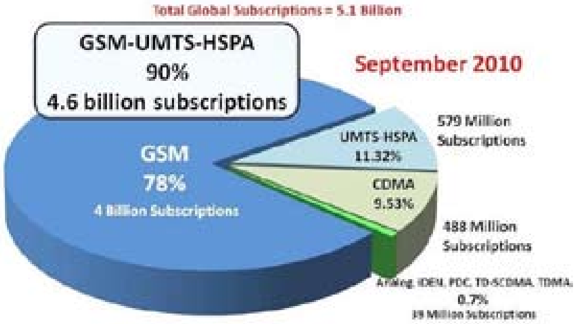

Fig. 1: Global Mobile Subscriptions September, 2010 [8]

The large number of BSs will contribute a significant portion of the whole network energy consumption. Therefore, it will be very valuable if the energy consumption of the BSs can be greatly reduced by using more energy efficient BS hardware or software. Also, the inefficient fuel sources, such as diesel generators, will significantly grow the carbon footprint of telecommunications [1]. In this paper we have particularly discussed some important Renewable Energy Sources (RES) like photovoltaic cells and wind turbines, as a possible solution for achieving the energy optimization and sustainability in wireless mobile networks.

II. Alternative Energy Resources: A viable Choice

According to International Energy Agency (IEA), "Renewable Energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly or indirectly from the sun, or from heat generated deep within the earth. Included in the definition is energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, and bio-fuels and hydrogen derived from renewable resources" [10].

A. Photovoltaic (PV)

According to US National Renewable Energy Laboratory, "The amount of solar energy that hits the surface of the Earth every minute is greater than the total amount of energy that the world's human population consumes in a year". Thus, sun energy is available to us in great abundance [6]. There are two basic categories of technologies that convert sunlight into useful forms of energy, aside from biomass-based systems that do this in a broader sense by using photosynthesis from plants as an intermediate step. First, solar photovoltaic (PV) modules convert sunlight directly into electricity. Second, solar thermal power systems use focused solar radiation to produce steam, which is then used to turn a turbine producing electricity [12].

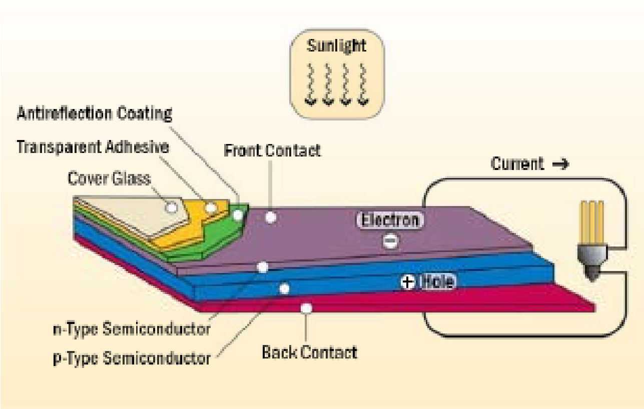

Fig.2: Typical PV Cell [15]

Solar PV modules/cells are solid-state semiconductor devices with no moving parts that convert sunlight into direct-current electricity (see Fig.2). Basically, when light strikes the cell it will absorb photons of radiation in the visible region of the electromagnetic spectrum. Each photon of light energy is absorbed by an electron within the solid material. In absorbing the energy, the electron acquires an electrical potential. This potential can be made available as electrical energy, as an electric current. The current is produced at a specific fixed voltage called the cell voltage. For silicon it is around 0.6 V [9].

Though, the price remains high, but still large photovoltaic installations exist around the world. PV does not produce any negative environmental effects by way of pollution to the air, land or water. It makes no noise, and does not consume any non-renewable resources. Its 'fuel' is an inexhaustible source: the sun. PV probably offers the best deal for the environment among non-conventional sources, perhaps being challenged only by mini hydro power plants. It provides thousands of jobs for the construction and installation of solar panels. PV constitutes an ideal alternative for remote locations or as back-up systems when problems develop in the grid. For instance, when electrical service is interrupted by storms, falling poles, cable failures, sabotage, etc. [6]. The potential reductions in cost, combined with the simplicity, versatility, reliability, and low environmental impact of PV systems, should help them to become increasingly important sources of economical premium-quality power over the next few years [12].

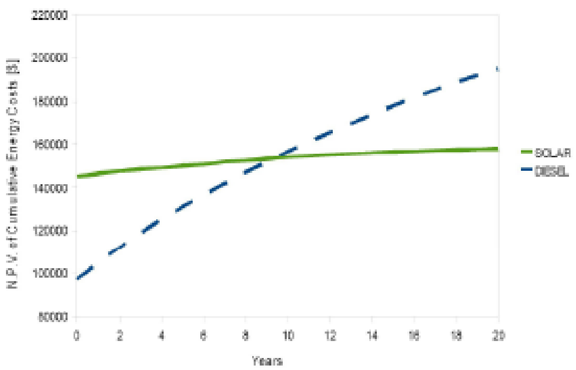

Fig.3: Cumulative Cost of Energy System for Off-Grid Cell Site (Solar v/s Diesel) [11]

Fig. 3 shows that the capital cost of the DC power plant, including batteries and charging equipment, is 50% more ($48k) with solar than with diesel (all figures in US dollars). The investment in solar pays for itself in less than five years, or eight years considering a 9% cost of capital. The solar panels have a 20-25 year lifespan [11].

B. Wind Energy

Wind energy is a form of solar energy because wind is the movement of air in response to pressure differences within the atmosphere and such pressure differences are caused primarily by differential heating effects of the sun on the surface of the earth. Annually, over the earth's land masses, around 1.7 million TWh of energy is generated in the form of wind [9]. Wind has considerable potential as a global clean energy source, being both widely available, though diffuse, and producing no pollution during power generation [12]. Wind turbines are usually mounted on conical steel or concrete towers of different heights (of an average of 50 metres), depending on the area and the output. Smaller wind turbines use a steel pole supported by guy wires. The blades are attached to a shaft that drives an electric generator usually through a gearbox to increase the generator's rotatory speed. The relationship between wind velocity and electrical output is not linear but cubic; that is, the energy produced increases proportionally to the cube of the wind's speed. These devices are subject to the variable intensity of winds; consequently, electricity production is intermittent. However, this does not appear to be a problem because electricity from small units can be stored in lead-acid batteries, as direct current (see Fig. 4), and since modern units can level off power produced at their rated capacity. From the economic point of view, wind turbines are competitive with the producing energy from coal-fired power plants. Without doubt, these units bring considerable benefits in saving fossil fuels, and in the cost of their extraction, refining and transportation. They do not pollute. Thus, Wind turbines are a sustainable way of generating energy and are currently one of the most cost-competitive renewable energy technologies [6].

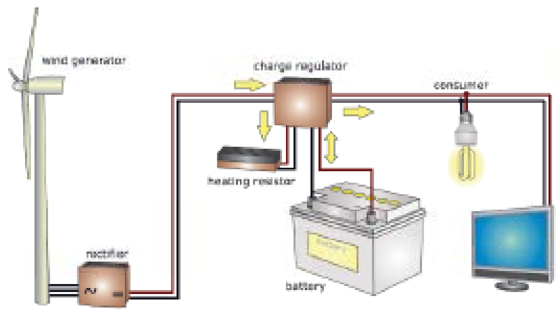

Fig. 4: Principle of Wind Power System [11].

The primary issue for more widespread use of wind power is not the cost of the wind turbines. Issues are (1) high maintenance costs because of the large number of wind turbines needed to generate as much power as a typical coal-fired power plant,(2) environmental impact (noise pollution and poor aesthetics), and (3) dependable power on demand. (The wind doesn't always blow) [9].

The dependability issue is the ability of wind power to supply continuous electrical power. The ability of a facility to provide electricity is characterized by its capacity factor. This factor is the actual energy supplied by a wind turbine compared to the theoretical power supplied if it operated continuously at its design capacity. Wind power suffers from low-capacity factors because of the lack of wind at night and the lack of power demand when the wind is blowing. Storing wind energy as it is

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available for use during peak demand times will increase the value of the wind energy and would increase capacity factors. This could increase the value of wind energy from a wind farm and hence change the economic outlook of wind power from marginal to profitable [9].

C. Solar & Wind Hybrid System

The intermittent nature of solar and wind power can be effectively mitigated by using a solar and wind hybrid system. Energy storage on-site (batteries) ensures that power is available when the sun isn't shining or the wind isn't blowing. Pairing solar and wind collection systems at one site can provide diversity protection against the variable natures of both energy sources. Expert system design and dimensioning with consideration of the local sunlight and/or wind patterns maximizes energy capture through a broad range of common conditions.

Fig.5: Solar and Wind Hybrid System [11]

Solar and wind power generation offer several advantages such as reduced OpEx in terms of no fuel costs, no fuel deliveries, reduced maintenance requirements, reduced environmental and safety liability as no on-site fuel storage is required, corporate social responsibility in terms of no pollution, noise or GHG emissions. Also, they become an additional source of income in terms of GHG offset credits2 and there is no exposure to risks of rising fuel costs and emissions costs. Solar and wind power can meet the strict requirements of a carrier-grade solution.

The rising costs of energy and green-house gas emissions must now receive full consideration in the design and purchase decisions of every business. Telecommunications operators can design and build radio access networks that minimize OpEx and exposure to cost risk, even where utility grid power is unavailable or unreliable. Carrier-grade solar and wind power systems (see Fig. 6) are now available that offer the reliability, remote configurability, alarms and monitoring that the top operators demand. Renewable energy systems can meet the

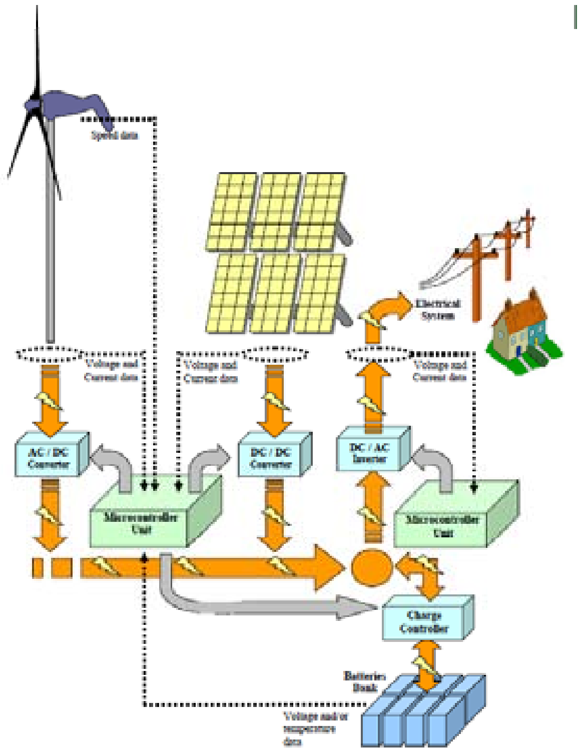

Fig. 6: Hybrid system block diagram [17]

stringent requirements of world-class carriers, and achieve payback versus diesel generators in as little as six years. As a bonus, deploying solar panels and small wind turbines allows a company to demonstrate its concrete commitment to environmental responsibility [11].

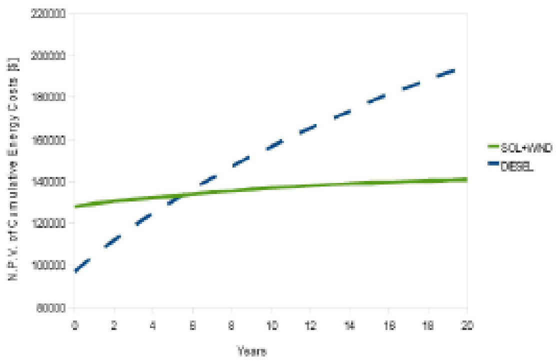

Fig.7: Cumulative Cost of Energy System for Off-Grid Cell Site (Solar+Wind v/s Diesel) [11]

Fig. 7 shows that the capital cost of the DC power plant, including batteries and charging equipment, is 32% more ($30k) with solar and wind together than with diesel (all figures in US dollars). The investment in renewables pays for itself in the fifth year, or in the sixth year (breakeven point) considering a 9% cost of capital [11].

III. Sustainability Issues of Renewable Energy Resources

"Sustainable Development" is the key word which sets the path to be tread in the foreseeable future for our survival on the planet earth. According to World Commission on Environment and Development, 1987; Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. When the word 'development' is mentioned, one reflexively thinks of economic development but when it comes to sustainability issues, development means advancement in every area (see Fig.8), including [6,10]:

- Economic growth
- Social progress
- Environmental protection

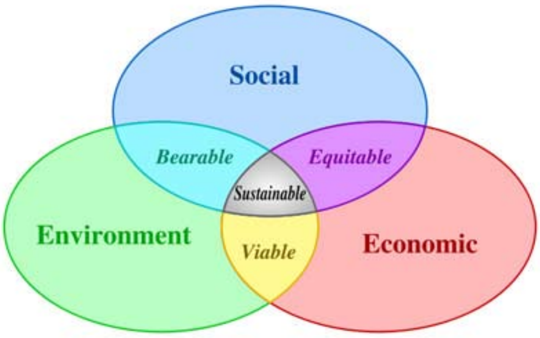

Fig.8: The Three E's of Sustainability: Environment, Social Equity, and Economy [18]

A. Economic Progress

Economic factor is the one we are being considering since we have started the development in any field. Always we want to have the cheapest resources at any cost either that's the contamination of our environment. Though renewable energy resources are not economically cheaper than the conventional one but yet we have several other benefits to cope up with this factor. Mainly installation cost of renewable energy resources is more and after that we can utilize its energy produced in an efficient way at just the little cost of maintenance [6,10]. Moreover, the fact is that the cost of conventional sources of energy (particularly Fossil Fuels) is constantly increasing and due to recent innovations and research endeavors, the cost of Renewable Energy Sources (RES) is constantly decreasing. Moreover, solar power and wind power uses a free renewable energy source and there are no re-occurring costs from consuming power. Particularly, in case of PV cells/panels in many areas an installation on a pole will be subject to pole attachment & utility infrastructure costs. These are fees that are charged whether you actually use any power or not and are governed by State tariffs. All utilities such as the telephone company and cable operators making attachments to utility poles pay a uniform fee for attachment to a pole. Furthermore, by using solar power you can avoid the cost of actually running power lines to areas that don't have existing power. In some cases meters must be installed, thereby increasing costs. Connections to existing light pole timing systems could mean a lack of power during daylight hours. Battery charging systems may provide a solution to gang switched street lights. Solar power systems are installed once and require very little, if any, maintenance. Often, the cost to install solar is less then installing electrical power at a site. Also, their relocation is very easy as they are not tethered to the power grid sites [16]

B. Social Growth

Social factor is of extreme importance as many of the countries are facing challenges of unemployment and by implementation of renewable energy plants this problem can be decreased up to a certain level. Different plants like photovoltaic, wind energy plants create jobs for thousands of people engaged in their manufacture, sale, installation and maintenance. Thus, alternative energy resources provide commercially attractive options to meet specific energy service needs helping to create new employment opportunities predominantly among the small and medium sized enterprises which are so central to the Community economic fabric, and indeed themselves form the majority in the various renewable energy sectors. Deployment of renewable energy sources can be a key feature in regional development with the aim of achieving greater social and economic cohesion within the Community [12,14].

C. Environmental Protection

The increasing concentration of CO2 in atmosphere which has created global warming on the earth, over and above caused the depletion of ozone layer. Besides this we are also suffering from the problem of acid rain, urban smog and various others. The Gross Domestic Product (GDP) is an indicator measuring the economic progress of a country considering the sale of its products, the value added, etc. Any industry do not take into account what are called the 'hidden costs', that is, those social and environmental costs that are not part of the typical cost/benefit equation and are not incorporated in the economics of a project. These costs end up being borne by society at large or specific organizations [6,10].

As the production and utilization of solar power or wind power does not emit any greenhouse gases, the development and use of renewable energy sources can enhance diversity in energy supply markets, contribute to securing long term sustainable energy supplies, help reduce local and global atmospheric emissions. These are compelling reasons for choosing these alternative energy resources as an environmentally friendly method of powering the future wireless networks [16].

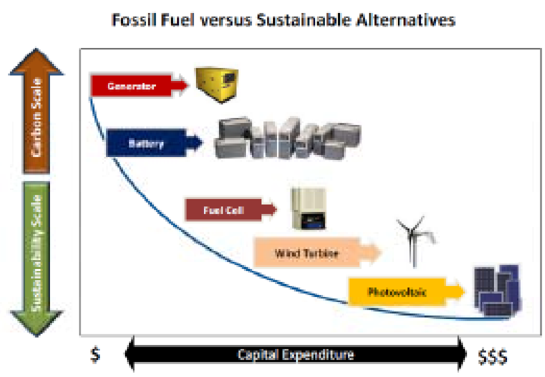

Fig. 9: Fossil Fuel versus Sustainable Alternatives (ATIS Report)

Fig.9 shows a comparative graphical representation of the Alternative Energy Resources (AERs) and fossil fuels as specified in ATIS Report on Wireless Network Energy Efficiency. Policies should be implemented for the replacement of conventional sources by non-conventional ones even if the cost per kWh is higher than in conventional plants. This way, the conservation of the environment can take precedence over the economy, and people can still grow but through better development [6,10].

D. Conclusion

Wireless telecom operators are coming to realize that energy costs can no longer be dismissed as a minor factor in the cost of doing business. Also, protecting the environment and combating climate change are two of the most pressing challenges facing humankind. Therefore, being sustainable is becoming the most important factor for any technology in order to achieve various dimensions of sustainability, such as social, economical and environmental. The non-conventional or alternative energy resources are sustainable due to being renewable and not amenable to depletion even with irrational levels of consumption. Optimizing energy efficiency through alternative energy resources will not only reduce environmental impact, it will also cut costs and help to make wireless mobile technology more affordable for everyone. This paper provides an overview of various alternative energy resources like fuel cells, wind power, solar power which serve as the efficient sustainable energy resources for the future generations of wireless mobile communication networks.

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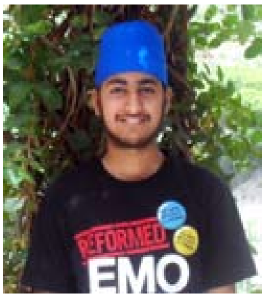
Amit Kumar received his bachelor's degree in Mathematics from the Himachal Pradesh University, Shimla, India, in 2002 and Masters degree in Computer Application from Kurukshetra University, Kurukshetra, India, in 2006. He completed his M.Phil. in Computer Science from Annamalai University, Annamalainagar, Tamilnadu, India, in 2010. He is currently working as a Lecturer in the Department of Computer Science, College of Information Science and Technology, Nanjing Forestry University, Nanjing, China. He has many publications in National /International Conference proceedings and International Journals. He is a reviewer for many international Journals. His current interest includes Techno-Economic Analysis of Broadband Wireless Networks viz. WiMAX, HSPA, EV-DO and LTE. His future focus is to explore the Green Wireless Technologies and Sustainable development.

Yun-fei Liu was born in Nanjing, China, on December 20, 1962. He received the B.S. degree in physics from Zhenjiang Normal College, Zhenjiang, China, in 1984, the M.S. degree in optics from Sichuan Normal University, Chengdu, China, in 1991, and the Ph.D. degree in testing measuring technology and instrument from Nanjing University of Aeronautics and Astronautics, Nanjing, China, in 2005. He was a teaching assistant, lecturer, associate professor, with Department of Basic Courses, Nanjing Forestry University, in 1991, 1994 and 2000 respectively. He was an associate professor, professor, College of Information Science and Technology, Nanjing Forestry University, in 2000 and 2007 respectively. His research interests include digital signal processing, electronic measurement techniques, microwave and optical technique. At present, He is engaged in Gaussian optics and terahertz technique in forestry application.

Tanvir Singh is pursuing his bachelor's degree in Electronics and Communication from I.E.T., Bhaddal, Ropar (Punjab Technical University), Punjab, INDIA. He is working as a budding researcher in field of research on topics Green Computing and Sustainability with a dream to create a Technical Advanced and eco- friendly world.



Sunder Gopal Singh is pursuing his Bachelor Degree in Computer Application form GGDSD College, Punjab University, Chandigarh, India. He has publications in International Journal and International Conference to his credit. His current research interest is sustainability of Wireless Technologies through Renewable Energy Resources.