A Study on Research, Development and Demonstration Of Renewable Energy Technologies

K.A. Khan[1] & M. Abu Salek[2]

[1]Department of Physics, Jagannath University, Dhaka-1100, Bangladesh
&
[2]Department of Chemistry, Adamjee Cantonment College, Dhaka-1206, Bangladesh.

Abstract

In this research work a study on Research, Development and Demonstration (RD & D) Of Renewable Energy Technologies has been conducted. The pace and extent of the contribution of new and renewable sources of energy and related technologies will depend, to a large extent, on scientific research directed towards their development and widespread utilization. The present R&D expenditure on renewable-energies is 6-8% of the total expenditure on Research & Development in Energy, of which about half goes to nuclear energy. While such research is expanding rapidly world-wide, the coordination and information-sharing is poor; duplication is widespread, and certain important aspects are relatively neglected and receive little attention. Moreover, currently the bulk of research is being carried out in developed countries; much of it will later on be extensively re-adapted for use in developing countries. A similar pattern is emerging for nuclear energy and also appears likely in future for the newer renewable-energy technologies (peaking after 2100 A.D). Accordingly, there has to be a more or less continuous effort for development of new renewable forms of energies. This effort should be at national, as well as regional and international levels, and an action plan upto year 2020 or 2030 should be worked out for every developing country.

Keywords: *Renewable Energy, Development, Research, Developed Country, Technology*

I. Introduction

National policies and plans should be developed and are urgently needed, in order to enhance the indigenous scientific and technological capabilities of developing countries, so as to enable them not only to fully and independently exploit their own resource-potential , but also to enter into collaborative research, development and demonstration effort, which should be closely coordinated with the related education and training programmes. The following are some basic steps and activities that shall be given consideration:

i.Select promising technologies, with a view to launch concerted efforts to accelerate their development, increase cost-effectiveness and widen their applicability;

ii. Identify the area and need of research, with special reference to the economic, social and environmental implications of emerging technologies, such as employment-potential;

iii.Establish or strengthen institutional mechanism for (i) national Renewable Sources of Energy for developing countries; (ii) Regional capacity, including the private sector, where appropriate, for undertaking and coordinating research, development and demonstration activities, on the basis of a review initially to be undertaken at national, sub-regional and regional levels, to enable present capabilities and existing resources to respond to identified needs and priorities, in particular those of developing countries;

iv. Establish or strengthen institutional linkages between research and development activities and the production-sector (to have public investments and industrial property systems, etc.);

v.Consider undertaking testing-programmes for increasing the ability of prospective consumers, producers and investors, to make knowledge-based decisions regarding technological options;

vi. Establish criteria for technical and economic evaluation of new and emerging technologies that may help national experts to identify their potential at specific locations;

vii. Identify and implement demonstration-projects relating to new renewable-energy technologies, including those which can be undertaken on a collaborative basis, with the consideration that it will further stimulate research and development; the training of specialists, and increase industrialization.

II. Methods and Materials

II A. Proposals for developing countries Renewable Energy Electric power capacity2 (1,500,000 MW) was 45% of world electric power (3,400,000) in year 2000, the developing countries' (table-1). World's fossil-fuels account for about twothird of generating capacity, with the remaining one-third being composed of large hydro (20%), nuclear (10%) and other renewable energy (3%). Electric energy-consumption in the developing world is increasing with economic growth and the developing world will need to double its current generation-capacity. Renewable energy faces stiff competition from other generation of distributed technologies, especially those based on natural gas and gas-turbines (and perhaps natural gas supplied fuel-cells in the future). Provided a gas supply exists, gas seems to remain the fuel of choice for small self-producers, because of short construction lead-times, low fuel and maintenance costs, and modular technology. New "micro-turbines" are lowering the capacity- threshold at which natural gas fuelled self-generation becomes viable.

Table-1: Renewable Grid-Based Electricity Generation Capacity Installed, as of 2000 (megawatts) [1-13]

Technology	All countries	Developing countries
Small hydropower a	43,000	25,000
Biomass power b	32,000	17,000
Wind Power	18,000	1,700
Geothermal power	8,500	3,900
Solar thermal power Solar photovoltaic power (grid)	350 250	0 0
Total renewable Power capacity	102,000	48,000
Large hydropower	680,000	260,000
Total world electric power capacity	3,400,000	1,500,000

It is mentioned that (a)"Small hydro" is usually defined as 10MW or less, although the definition varies by country, sometimes up to 30 MW; (b) Biomass figures omit electricity from municipal solid-waste and landfill gas; commonly, biomass and waste are reported together.On the other hand, as households and business entrepreneur take more interest in distributed Solar PV, either by taking advantage of government subsidy-programs or decide to pay the extra cost themselves, "net metering" that allows "stored" kilowatt-hours over the utility connection and power sales at retail-tariff levels, is becoming more widespread. For example, 30 states in the U.S. now have net-metering laws, and California allows users with upto 1-megawatt loads to use net-metering. A net-metering law was recently passed in Thailand, in general few other developing countries have come to consider net-metering.

II B. Policies for promoting Renewable Energy

There are a number of specific ways for incorporating renewable- energy in the energy mix, which can boost its use in many countries:

Fossil-Fuels Subsidy: In developing countries, most of the fossil- fuels are subsidized. These subsidies may be reduced gradually, to make renewable-energy marketable with cost competitiveness.

Access to Transmission: An open-access transmission-system may allow power-heeling between buyer and seller that provides open access to customers. Transmission-services should not discriminate against, or give unfair advantage to, specific ownership or certain types of generation. For example, in India open-wheeling policies have been credited with helping catalyze the wind-energy industry; industrial firms may even produce their windpower in regions with good wind-resources and transfer the power over the transmissionsystem for the use in their own facilities – or for sales to a third party. Similarly, in Brazil, reduction of fees for transmission-wheeling has been credited with promoting and giving boost to the small-hydro industry.

Environmental Policy : Emissions standards, monitoring requirements, and other aspects of environmental policy can be integrated to strengthen power-sector changes. For example, enforced emission- monitoring can promote "green power" markets. Major power-sector changes occur using political leverage, to incorporate environment friendly policies. Advocates of renewable energies should anticipate this opportunity.

Renewable-Energy Pricing : The electricity feed-in laws in Germany, and similar policies in other European countries in the 1990s, required purchase of renewable-energy power at a fixed price. For instance, in Germany, power producer could sell the utility at 90% of the retail market price. Feed-in laws led to a rapid increase in installed-capacity and development of commercial renewable-energy markets in particular in Germany and Spain. Partly because retail prices have been falling with competition, making renewable-energy producers and financiers more wary, the new German Renewable Energy Law now change pricing to that based on production-costs, rather than retail prices. One of the criticisms of historical feedin approaches was that they had not encouraged cost- reductions or innovation; this new German law includes provisions for regular adjustments to prices, in response to technological and market developments (Shepherd4 1998; Wanger5 2000; Sawin6 2001).

Distributed Energy Systems : Renewables are likely to play a larger role in power-systems, dominated by the distributed model than the central station paradigm. However, successful deployment of distributed renewables in an unbundled system, requires that at least one player can capture system-benefits. Some of the ways that distributed energy can be supported are :
-Financing mechanisms for renewable energy
-Common interconnection standards
-Standard power-purchase agreements and tariffs
-"Net metering" schemes for residential consumers
-Reduced bureaucratic procedures for grid-connections and/or metering
-upgrades energy tariffs in distribution-system
Distribution change system can substantially change the economics of generation of distributed renewable-energy. Solar-photovoltaic power, is perhaps the most significant. Although only about 20% of global PV production was used on grid in 1998 (mostly for government-sponsored rooftop markets). Such policies can enhance PV application at individual, community, regional and national levels.

II C. GEF Support to Renewable Energy in Developing Countries
GEF supported renewable-energy projects in developing countries from 1991 to 2000. Seventeen [14-17] projects were implemented through World Bank, UNDP and ADB. Nine (9) projects promote a wind-power in Cape Verde, Chine, Costa Rica, India, Kazakhstan and Sri Lanka, Six promote biomass and biogas power generation in China, Cuba, Hungry, Mauritius, Slovenia and Thailand, one promote power from biomethanation in India and one promotes Geothermal power in Philippines. In general, GEF projects take five main approaches to promoting Grid-connected renewable-energy : (a) demonstratable technologies, and their commercial and economic potential; (b) build capacities of project-developers, operator and regulatory agencies; (c) develop regulatory and legal frameworks that create financing mechanisms for projectdevelopers; (d) develop national plans and programmes informed by institutional and businessmodelspiloted in projects.

II D. Some typical examples
The use of renewable technologies has increased in the developing countries and its countrywide status [18-25] (2000) is given in the Table 2.

Table-2: Renewable Energy Technologies in Selected Asian Countries as of December 2000

Country	**Solar thermal system ($1000m^2$)**	**PV system (mW_p)**	**Wind power plants (mW)**	**Small/micro hydropower plants (mW)**	**Power plants (mW)**	**Biogas plants (1000units)**	**Improved cook- stoves (1000 units)**
Bangladesh		0.15		- -	- -	1	82
China	5000	6.00	344	20,000	800	6800	180,000
India	467	50	1167	217	272.74	3000	32,000
Indonesia	- -	5	0.5	54	178	- -	- -

Japan	57	3.6	75	- -	- -	- -	- -
Korea	- -	0.48	- -	5	- -	- -	- -
Malaysia	- -	2	0.15	24	200	- -	- -
Nepal	10	1.08	0.02	11.46	- -	49.28	250
Pakistan	- -	0.44	- -	20	- -	4.13	68
Philippines	- -	0.52	0.06	70	- -	- -	- -
Sri Lanka	- -	- -	3	6	- -	4	- -
Thailand	50	5	0.2	128	1230	10	500
Vietnam	- -	0.47	0.1	95	- -	3.08	- -

China leads in solar thermal system, followed by India. In the case fo PV, India is far ahead (50 MW); China, Indonesia and Thailand are also playing a significant role. Following examples are the successful Renewable Energy projects in the developing countries and lesson learned [26-30]:

a.Wind and small hydropower in India

By 2000, almost 1200 MW of wind-capacity had been installed in India, virtually all of that by the private sector, due to favourable investment/ tax policies and a supportive regulatory framework. Domestic wind-turbine manufacturers have emerged, many of them joint-ventures with foreign partners. During 1990s, GEF and World Bank directly financed 41MW of wind- turbine installations and 45 MW of mini-hydro capacity in India, through the Renewable Energy development project. Following lessons were learnt:

i.Indian Renewable Energy Development Agency (IREDA) sponsored 35 MW of wind project and 65MW of mini-Hydro projects. Many financial institutions offered financing for Wind farms.

ii.Regulatory investment-tax credit and Government commitment, as well as GEF's role, had influenced technology-transfer and market- development.

iii.Another lesson is that more understanding is needed about the relative effectiveness of production-based incentives, relative to capacity-based incentives. In the 1990s, oneyear 100% investment tax-depreciation, provided large economic gains, for installation of wind-farm capacity, regardless of the electricity-generation from that capacity. This incentive is shifting, as capacity-based tax- incentives have decreased, due to the reduction in marginal corporate- tax rates, from 55% in 1992/93 to 35% in 2000. At the same time that power tariffs, production-based incentives, have continued to rise. In addition, IREDA offers incentives for wind-farms it has financed, to achieve higher capacity-factors and attracted investment and played role in enhancing market[31-40].

b. Bagasse Power In Mauritius

World Bank/GEF Sugar Bio-Energy project (1994-96) provided technical assistance and technology demonstration, to promote private / public sector cooperation in power-plants. Electricity-generation from bagasse increased from 70GWh/yr in 1992 to 118 GWh/yr by 1996[41-56]. This project triggered the private-sector to setup power-plants based on Baggase at their own. One of the lessons the Mauritius project has how to create an investment-climate for renewableenergy power projects, and create public/ private partnerships that can lead to supportive regulatory frameworks. In this case, the project led to the establishment of a framework for the development of independent power-producer (IPP) and an administrative focal point for private/public sector partnership in IPP development. The evaluation of project showed that the project's major accomplishment was- progress in helping to establish an institutional and regulatory framework for private power-generation in Mauritius, and the provision of technical studies and trials, to support technologies for improved bagasse production and improved environmental monitoring. Another lesson may be that technical demonstration has less influence on promoting markets for a technology than other types of project-interventions (in this case the planned demonstration bagasse-plant that was never constructed).

c. Small hydro power plant in Sri Lanka

One of the lessons from the Sri Lankan project is that variable power- purchase tariffs can hinder market development. In this case, tariffs were tied to short-run avoided utility-costs based on the international price of oil. In 1997 and 1998, tariffs were set to be equivalent to 5 cents/kWh and hereafter mini-hydro development flourished. However, because of the downturn in oil prices in 1998-99, prices were only the equivalent of 3.5 cents/kWh in 1999. And this fluctuation had seriously hurt the longer-term interests of private mini-hydro developers in Sri Lanka. “The low tariffs and unresolved dispute [on tariff calculation-methods] have caused a deep slump in mini-hydro development”, said a project-status report in 2000[57-65].

d. Wind-power in China

The emerging experience from the World Bank/GEF Renewable Energy Development project in China, highlights the pressing need to address regulatory frameworks and find ways to reduce risks to project-developers. The project was designed to finance four newly formed windfarm companies for the construction of 190 MW of wind-farms in Inner Mongolia, Hebei, Fujian, and Shanghai provinces. These companies were to be jointly owned by the State Power Corporation and subsidiary electric- power utilities (at regional, provincial or municipal levels) and were to sell power to utilities under power-purchase agreements, developed through the project. The costs of wind-generated electricity from these wind companies would be higher than those of conventional electricity generation, but utilities in three provinces (Hebei, Fujian and Shanghai) were initially willing to purchase this wind-power from the project developers. At least at small scales, the added costs of wind-power were marginal, relative to total utility-revenue for these three large utilities[66-70].

However, a planned 100-MW wind-farm in Inner Mongolia, as part of that project, was cancelled in 2000, because the smaller Inner Mongolia utility was unable to sign power-purchase agreements with neighboring provinces, for sale of wind-power, which could not be absorbed within the Inner Mongolia grid itself. Originally, the North China regional power company had agreed to purchase wind-power from Inner Mongolia, but when the North China power company was split into three provincial utilities and given an explicit mandate to operate on strictly commercial terms, Inner Mongolia was unable to persuade any of these three provincial utilities to sign power-purchase agreements with it, for the higher-cost wind- power. And being unable to use this power itself – given the small size of the Inner Mongolia grid (but abundant wind resources) – it proved unable to undertake this investment[71080]. The lesson may be that government has to provide subsidy to match it with other resources of energy as well as to enhance the economic market size.

e. Nepal’s Biogas Programme

Biogas Support Programme[8] (BSP) is an example of a successful collaboration between government and private sector and donor agencies. The BSP was initiated in 1942, by Netherlands Development Organization and funded by Dutch Development Cooperation. The programme was closely associated with Agriculture Development Bank and Gobar Gas Company of Nepal[81-90].

About 86% of 21.5 M population (estimates of 1995) reside in rural areas of Nepal; the percapita GDP in 1995 was about US$200. Annual per- capita consumption of primary-energy in Nepal was estimated at 271 Million GJ in total; out of this 90% was from wood (72%) followed by agricultural waste residue (16%), animal waste (9%), electricity (0.4%) and LPG (0.1%). The BSP in Nepal was divided into two phases. Phase-1 was implemented from 1992 to July 1994 and install 7000 Biogas plants for farmers. The second phase covered 13,000 plants from 1994 to 1997. Financial subsidy was provided to farmers through Asian Development Bank. The total of (approximately) 49000 units were constructed up to 1998 and are benefiting more than 200,000 members of rural households. Biogas plants are being efficiently used in P.R. China, where over 5 million plants are installed, as against 2.7 million in India[91-101].

f. Bio-Ethenol as an alternate fuel for transport (Brazil a role model)

Developing Countries are using Gasoline and Diesel as a fuel for transport which causes pollution, and resulting environment damages as well as a lot of foreign exchange is spent on the import. The alternate fuel for transportation can be Bio-Ethanol. In Third World countries, Brazil, Kenya and Malawi are the top three users and producers of Bio-ethanol. Brazil represents 2/3rd of global ethanol production, while Kenya uses 60% of its sugarcane produce for ethanol. In comparison Malawi produces 40% for automobile consumption.

Thermal properties of Bio-ethanol include; higher heating value of 6,400 Kcal/kg; an ignition temperature of 35 degrees centigrade and a specific heat of 0.60 Kcal/Kg °C more than gasoline. Brazil can be a role model in the Third World countries using Bio-ethanol as alternate fuel for transport which resulted in it saving foreign exchange, as well as creating job opportunities, this is because of appropriate policy framework and its implementation.

Following are some of the key policies and steps taken by the Brazilian government from 1975 to 2000:

1.Encouraged private investments with provision of low-interest loans on Bio-ethanol production units.

2.Guaranteed Purchase (By State Oil Companies)

3.Sales Tax incentives for Bio-ethanol using vehicle

4.Subsidy on Bio-ethanol (To make compatible with Gasoline)

The implemented policy from 1975 to 80s achieved the goal of 20% ethanol mix in the Gasoline, for transportation. During 1980-1989 period majority of cars were converted on the Bio-ethanol. The production of Bio-ethanol increased rapidly to the level of 13-16 billion litres per year in late 90s. The Brazilian Government gradually increased the subsidy as the production of ethanol as well as its market grew by late 90s. Now Bioethanol is 1/3rd of the total fuel consumed by cars and light trucks in Brazil. Brazil's Bio-ethanol fuel-programme provided economic social and environmental benefits. In production of ethanol, Brazil has already saved US$33 billion[9] from the period 1976-1986 and created employment for 700,000 workers in rural areas. This also helped in improvement of the quality of air and reduced emissions. Brazil Bio-ethanol fuel program was successful and has economic social and environmental impact due to its appropriate policy framework and its implementation over the past 28 years as indicated in the following Table 3.

Table-3: **Economic Impact of Bio-ethanol**

Event	Economic Impact
Commercial	350 Private Companies producing Ethanol
	2% Bio-ethanol in gasoline blend – 1980
	13-16 billion litres/year Production of bio-ethanol in 1990
	Selling Price of Anhydrous ETOH=25$ / barrel
	Gasoline Price (in Brazil) (160$/M3)=35 $/barrel
	Subsidy reduced over 25 years through price regulation
	High Energy Fuel (70% of gasoline)
Production	Cost of product decline (because of size of production)
	Estimated Potential / world ethanol production 2 billion t/year
	World ethanol production 21 Million li/year
	Brazil ethanol production 13 billion li/year
	Brazil consumption 12.4 billion li/year
	Average Bio-ethanol production energy ratio (energy
	output/energy input)= 9.2 (Brazil)
	USA – 2nd largest production = 5.5 billion li/year
Other vital statistics	Ethanol 1/3rd of total fuel for transportation
	1976-96: Brazil saved US $33 billion on oil imports
	700,000 employment

It is mentioned that the source of this table is: Howerd Geller, "Energy revolution - policies for a sustainable future" Renewable Energy World, July-August 2003, p.40&42

g. Renewable Energy in Africa

Africa, with about 13% of the world's total population, accounts for about 2% of world economic output and its energy-consumption in 1997 was 11.4 Quadrillion BTU, whereas its production was 26.5 QBTU, in the same year. Energy-demand growth in Africa averaged 2.7 annually from 1980 to 1997, with slightly faster annual average 3.1% from 1990 to 1997. Africa's commercial energy consumption is small for a variety of reasons, some these include; low per-capita incomes, low level of industrialization, ownership and uses of vehicles (around 20 cars per 1000 people) and penetration of electrical appliances, like refrigerators, freezers, air conditioner. Commercial energy-production in Africa has nearly doubled since 1970, and is forecast to increase 68% by 2020[102-105]. Production has remained constant (at around 7%), as a share of the world total[7]. Some details are as below:

i. Energy Consumption:

-African commercial-energy-production is distributed very unevenly throughout the continent. Around 99% of Africa's coal output, for instance, is in southern Africa (mainly South Africa). Natural-gas production, on the other hand, is overwhelmingly concentrated in North Africa (mainly Algeria and Egypt). Crude-oil production is concentrated in North Africa (Algeria, Egypt and Libya), West Africa (Nigeria), Central Africa (Gabon), and southern Africa (Angola). East Africa produces almost no oil, gas or coal.

-As of 1997, Africa consumed around 26,300 Btu of commercial energy per 1997 dollar of GDP, and 14.9 million Btu per person. This compares with world averages of about 13,600 Btu per 1997 dollar of GDP and 65 million Btu per person, respectively.

-In 1997, Africa accounted for 3% of total world commercial energy- consumption. In that year, Africa accounted for 3.8% of world coal- consumption, 3.4% of oil, 2.4% of natural gas, and 2.4% of hydroelectricity.

-Compared to the rest of the world, Africa has very low levels of electricity-consumption per person. This is due mainly to poorly developed power-distribution grids and to heavy use of biomass in theresidential sector.

-Energy consumption patterns vary greatly between southern Africa and the rest of Africa. Most significantly, southern Africa depends heavily (68%) on coal, while the rest of Africa is dominated (60%) by oil[131-135].

ii. Energy Production:

-Africa produces significant amounts of commercial energy – about the same amount as South America. Energy-production varies greatly by subregion within Africa. Most importantly, oil and gas make up 23% of southern African energy-production, compared to 97% in the rest ofAfrica[106-110].

-Only South Africa has nuclear power-production. Overall, nuclear- power accounts for 1% of African energy-demand.

-Natural gas makes up a little less than one-sixth of Africa's commercial energy-output. Almost all (96%) of this is concentrated in only 5 countries (Algeria, Egypt, Libya, Nigeria, and Tunisia).

-Hydroelectricity/others account for 3% of Africa's total energy- production, spread out widely throughout the continent.

-Nearly two-thirds of Africa's commercial energy-output is oil. Oil production (including crude oil and natural gas liquids) is heavily concentrated, with 5 countries (Algeria, Angola, Egypt, Libya, and Nigeria) accounting for 88% of the continent's total oil output[111-115].

h. Major African Environmental Challenge : Use of Biomass Energy

-Africa is the world's largest consumer of biomass-energy calculated as a percentage of overall energy-consumption (fire-wood, agricultural residues, animal wastes and charcoal).

-Biomass accounts for as much as two-third of total African final energy-consumption. In comparison, biomas accounts for about 3% of final energy-consumption in OECD countries.

-Africa consumed an estimated 205 million tons of oil-equivalent (Mt oe) of biomass and 136 Mt oe of conventional energy in 1995, according to the International Energy Agency[121-130].

-Most of Africa's biomass energy-use is in sub-Saharan Africa. Biomass accounts for 5% of North African, 15% of South African, and 86% of sub-Saharan (minus South Africa) consumption.

-Wood, along with charcoal, is the most commonly used form and it is the most detrimental to the environment.

-South Africa is unique in sub-Saharan Africa as biomass accounts for only 15% of its energy-consumption. There is a range of energy options available in South Africa : biomass, kerosene, coal, liquefied petroleum gas (LPG), and solar power.This range of choices reflects the country's high level of economic development, relative to other African countries[116-120].

III. Results and Discussion

-Deforestation is now one of the most pressing environmental problems faced by most African nations, and one of the primary causes of deforestation is utilization of wood as fuel.

-Women and children suffer disproportionately from negative health- effect, due to the smoke generated with the use of fuel wood for cooking (smoke is a carcinogen and causes respiratory problems). About 75% of wood harvested in sub-Saharan Africa is used for household cooking.

-Production of traditional fuels is often insufficient to satisfy the rising demand. Fuel available to the poorest communities is expected to decline, which will intensify environmental degradation in those communities.

-End-use efficiency for most traditional fuels is low. A high concentration of fuels is needed to produce a low level of energy, and a significant share is wasted.

-Several African nations have made considerable advances in the use of photovoltaic (PV) power.

-In Kenya, a series of rural electrification and other programs has resulted in the installation of more than 20,000 small-scale PV- systems since 1986. These PV systems now play a significant role in decentralized and sustainable electrification.

-The direct conversion of solar into electrical energy with solar (PV) cells does not at this stage seem to be an economic proposition. The recently developed Amorphous Silicon-Technology holds considerable promise, but further developmental work in this direction is imperative, especially for the use in small units for communications, lighting and water-pumping.

IV. Conclusions

Over one billion people live in underdeveloped economic conditions around the world, between latitudes 35^{o} N and 35^{o}S. In general, greatest amount of solar energy is found in two broad bands around the earth between latitudes 15o and 35o north and south of the equator, and three approaches to the utilization of this solar energy are:

(a)use of low grade heat, (b) direct conversion to electric energy and (c) Photosynthetic and biological conversion processes. The technology of low- grade heat devices only has so far been developed to such an extent that they have immediate application. However, the urgent RD&D needs are:

i) a realistic assessment through field trials on a continuous basis, of the impact of these devices under our social and economic conditions; the need for research and development to improve these should be kept under review; (The priorities of application are : hot water (e.g. for process heat), providing drinking & irrigation water, crop drying and cold storage of agricultural products, and space heating);

ii) Available data on commercially manufactured solar water-heaters of small, medium and large capacities, as well as solar distillation, should be widely disseminated with a view to select appropriate types and their local production;

iii) Techno-economic studies should be undertaken to improve the efficiency of solar water-heaters by:(a) use of reflectors, (b) modified collector-design, and(c) architectural integration.

Acknowledgement

The authors are grateful to the PKL electricity research group named Dr. M A Latif, Dr. Md. Sajjad Hossain, Dr. Md. Fakrul Islam, Dr. Bapy Guha, Md. Mehdi Hassan, Md. Shamsul Alam and Dr. Jesmin Sultana for their valuable suggestions and whole hearted cooperation during research work.

References

[1] Akter T, Bhuiyan MH, Khan KA, Khan MH (2017) Impact of photo electrode thickness and annealing temperature on natural dye sensitized solar cell. Published in the Journal of Elsevier. Ms. Ref. No.: SETA-D-16-00324R2

[2] Guha B, Islam F, Khan KA (2018) Studies on redox equilibrium and electrode potentials. IJARIIE 4(4):1092–1102

[3] Hamid MR (2013) Characterization of a battery cell fueled by Bryophyllum pinnatum sap. Int J Sci Eng Res 4(3):1–4

[4] Hamid MR, Yusuf A, Wadud AMA, Rahaman MM (2016) Design and performance test of a prototype of a 12 volt dc battery fueled by Bryophyllum pinnatum Sap and improvement of its characteristics. Int J Electron Electr Eng 4(5):1–5

[5] Haque MM, Ullah AKMA, Khan MNL, Kibria AKMFF, Khan KA (2018) Phyto-synthesis of MnO2 Nanoparticles for generating electricity. In: the International conference on physics-2018, venue-Department of Physics, University of Dhaka, Dhaka1000, Bangladesh, Organizer-Bangladesh Physical Society (BPS), 08–10 March

[6] Hasan M, Khan KA (2016) Bryophyllum pinnatum leaf fueled cell: an alternate way of supplying electricity at the off-grid areas in Bangladesh. In: Proceedings of 4th international conference on the developments in renewable energy technology [ICDRET 2016], P. 01, 2016. https://doi.org/10.1109/ICDRET.2016. 7421522

[7] Hasan M, Khan KA (2018) Dynamic model of Bryophyllum pinnatum leaf fuelled BPL cell: a possible alternate source of electricity at the off-grid region in Bangladesh. Microsyst Technol. https://doi.org/10.1007/s00542-018-4149-y

[8] Hasan M, Khan KA (2018) Identification of BPL cell parameters to optimize the output performance for the off-grid electricity production. International conference on Physics-2018, Venue-Department of Physics, University of Dhaka, Dhaka1000, Bangladesh, Organizer-Bangladesh Physical Society (BPS), 08–10 March

[9] Hasan M, Haque S, Khan KA (2016) An experimental study on the coulombic efficiency of Bryophyllum pinnatum leaf generated BPL Cell. IJARIIE 2(1):1–9

[10] Hasan MM, Khan MKA, Khan MNR, Islam MZ (2016) Sustainable electricity generation at the coastal areas and the islands of Bangladesh using biomass resources. City Univ J 02(01):09–13

[11] Hasan M, Hassan L, Haque S, Rahman M, Khan KA (2017) A study to analyze the self-discharge characteristics of Bryophyllum pinnatum leaf fueled BPL test cell. IJRET 6(12):6–12

[12] Hasan M, Khan KA, Mamun MA (2017) An estimation of the extractable electrical energy from Bryophyllum pinnatum leaf. AIJRSTEM 01(19):100–106
[13] Hasan L, Hasan M, Khan KA, Islam SMA (2018) SEM analysis of electrodes and measurement of ionic pressure by AAS data to identify and compare the characteristics between different biofuel based electrochemical cell. In: the International conference on physics-2018, Venue-Department of Physics, University of Dhaka, Dhaka-1000, Bangladesh, Organizer-Bangladesh Physical Society (BPS), 08–10 March
[14] Hassan MM, Arif M, Khan KA (2018) Modification of germination and growth patterns of Basella alba seed by low pressure plasma. J Mod Phys. Paper ID: 7503531, 97–104
[15] Hossain MA, Khan MKA, Quayum ME (2017) Performance development of bio-voltaic cell from arum leaf extract electrolytes using Zn/cu electrodes and investigation of their electrochemical performance. Int J Adv Sci Eng Technol 5(4)
[16] Islam F, Guha B, Khan KA (2018) Studies on pH of the PKL extract during electricity generation for day and night time collected Pathor Kuchi leaf. IJARIIE 4(4):1102–1113
[17] Khan MKA (1998) Copper oxide coating for use in linear solar Fresnel reflecting concentrating collector. In: Journal of Elsevier renew energy, an international journal, WREN (World Renewable Energy Network), UK, RE: 12.97/859
[18] Khan KA (1999) Technical note ''Copper oxide coatings for use in a linear solar Fresnel reflecting concentrating collector''. J Renew Energy 17(4):603–608
[19] Khan KA (2008) Inventors, electricity generation form Pathor Kuchi Leaf (PKL), Publication date 2008/12/31, Patent number BD 1004907
[20] Khan MKA (2008) Studies on electricity generation from stone chips plant (Bryophyllum pinnatum). Int J Eng Tech 5(4):393–397
[21] Khan KA (2009) Electricity generation form Pathor Kuchi Leaf (Bryophyllum pinnatum). Int J Sustain Agric Technol 5(4):146–152
[22] Khan MKA (2018) An experimental observation of a PKL electrochemical cell from the power production view point. In: Presented as an invited speaker and abstract published in the conference on weather forecasting & advances in physics, 11–12 May 2018, Department of Physics, Khulna University of Engineering and Technology (KUET), Khulna, Bangladesh, pp 75–90
[23] Khan KA, Alam MM (2010) Performance of PKL (Pathor Kuchi Leaf) electricity and its uses in Bangladesh. Int J Soc Dev Inf Syst 1(1):15–20
[24] Khan KA, Arafat ME (2010) Development of portable PKL (Pathor Kuchi Leaf) Lantern. Int J SOC Dev Inf Syst 1(1):15–20
[25] Khan KA, Bosu R (2010) Performance study on PKL electricity for using DC fan. Int J SOC Dev Inf Syst 1(1):27–30
[26] Khan KA, Hossain MI (2010) PKL electricity for switching on the television and radio. Int J Soc Dev Inf Syst 1(1):31–36
[27] Khan KA, Paul S (2013) A analytical study on electrochemistry for PKL (Pathor Kuchi Leaf) electricity generation system. In: Publication date 2013/5/21, conference-energytech, 2013 IEEE, publisher, IEEE, pp 1–6
[28] Khan KA, Hossain A (2018) Off-grid 1 KW PKL power technology: design, fabrication, installation and operation, In: Proceedings of CCSN-2018, 27–28 October, 2018 at Kolkata, India
[29] Khan MKA, Obaydullah AKM (2018) Construction and commercial use of PKL cell. IJARIIE 4(2):3563–3570
[30] Khan KA, Rasel SR (2018) Prospects of renewable energy with respect to energy reserve in Bangladesh. IJARII 4(5):280–289
[31] Khan KA, Rasel SR (2018) Studies on wave and tidal power extraction devices. Int J Adv Res Innov Ideas Educ 4(6):61–70
[32] Khan KA, Yesmin F (2019) PKL electricity—a step forward in clean energy. Int J Adv Res Innov Ideas Educ 5(1):316–325
[33] Khan KA, Paul S, Adibullah M, Alam MF, Sifat SM, Yousufe MR (2013) Performance analysis of BPL/PKL electricity module. Int J Sci Eng Res 4(3):1–4
[34] Khan KA, Paul S, Zobayer A, Hossain SS (2013) A Study on solar photovoltaic conversion. Int J Sci Eng Res 4(3):1–6
[35] Khan KA, Bakshi MH, Mahmud AA (2014) Bryophyllum pinnatum leaf (BPL) is an eternal source of renewable electrical energy for future world. Am J Phys Chem 3(5):77–83. https://doi.org/10. 11648/j.ajpc.20140305.15
[36] Khan KA, Alam MS, Mamun MA, Saime MA, Kamal MM (2016) Studies on electrochemistry for Pathor Kuchi leaf power system. J Agric Environ 12(1):37–42
[37] Khan KA, Rahman A, Rahman MS, Tahsin A, Jubyer KM, Paul S (2016) Performance analysis of electrical parameters of PKL electricity (an experimental analysis on discharge rates, capacity and discharge time, pulse performance and cycle life and deep discharge of PathorKuchi Leaf (PKL) electricity cell). In: Innovative smart grid technologies-Asia (ISGT-Asia), 2016 IEEE, pp 540–544
[38] Khan MKA, Paul S, Rahman MS, Kundu RK, Hasan MM, Moniruzzaman M, Al Mamun M (2016) A study of performance analysis of PKL electricity generation parameters: (an experimental analysis on voltage regulation, capacity and energy efficiency of pathor kuchi leaf (PKL) electricity cell). In: Power India international conference (PIICON), 2016 IEEE 7th, pp 1–6
[39] Khan MKA, Rahman MS, Das T, Ahmed MN, Saha KN, Paul S (2017) Investigation on parameters performance of Zn/Cu electrodes of PKL, AVL, tomato and lemon juice based electrochemical cells: a comparative study. In: Electrical information

and communication technology (EICT), 2017 3rd international conference on. IEEE, 2017. IEEE, Khulna, Bangladesh, Bangladesh, pp 1–6. https://doi.org/10.1109/EICT. 2017.8275150

[40] Khan KA, Ali MH, Mamun MA, Haque MM, Ullah AKMA, Khan MNI, Hassan L, Obaydullah AKM, Wadud MA (2018) Bioelectrical characteristics of Zn/Cu-PKL cell and production of nanoparticles (NPs) for practical utilization. In: 5th international conference on 'microelectronics, circuits and systems', Micro 2018, 19th and 20th May, 2018, In Association with: International Association of Science, Technology and Management, pp 59–66. http://www.actsoft.org

[41] Khan KA, Ali MH, Mamun MA, Ibrahim M, Obaidullah AKM, Hossain MA, Shahjahan M (2018) PKL electricity in mobile technology at the off-grid region. In: Published in the proceedings of CCSN-2018, 27–28 October, Kolkata, India, p 57

[42] Khan KA, Ahmed SM, Akhter MM, Alam R, Hossen M (2018) Wave and tidal power generation. Int J Adv Res Innov Ideas Educ 4(6):71–82

[43] Khan KA, Bhuyan MS, Mamun MA, Ibrahim M, Hassan L, Wadud MA (2018) Organic electricity from Zn/Cu-PKL electrochemical cell. Adv Intell Syst Comput. https://doi.org/10.1007/978981-13-1540-4

[44] Khan KA, Bhuyan MS, Mamun MA, Ibrahim M, Hassan L, Wadud MA (2018) Organic electricity from Zn/Cu-PKL electrochemical cell. In: Published in the Souvenir of first international conference of contemporary advances in innovative & information technology (ICCAIAIT) 2018, organized by KEI, In collaboration with Computer Society of India (CSI), DivisionIV (Communication). The proceedings consented to be published in AISC Series of Springer

[45] Khan KA, Hassan L, Obaydullah AKM, Islam SA, Mamun MA, Akter T, Hasan M, Alam M, Ibrahim M, Rahman MM, Shahjahan M (2018) Bioelectricity: a new approach to provide the electrical power from vegetative and fruits at off-grid region. J Microsyst Technol 24(3):2. https://doi.org/10.1007/s00542018-3808-3

[46] Khan KA, Hasan M, Islam MA, Alim MA, Asma U, Hassan L, Ali MH (2018) A study on conventional energy sources for power production. Int J Adv Res Innov Ideas Educ 4(4):214–228

[47] Khan KA, Hossain MS, Kamal MM, Rahman MA, Miah I (2018) Pathor Kuchi leaf: importance in power production. IJARIIE 4(5)

[48] Khan KA, Hossain MA, Obaydullah AKM, Wadud MA (2018) PKL electrochemical cell and the Peukert's law. IJARIIE 4(2):4219–4227

[49] Khan KA, Mamun MA, Ibrahim M, Hasan M, Ohiduzzaman M, Obaidullah AKM, Wadud MA, Shajahan M (2018) PKL electrochemical cell for off-grid areas: physics, chemistry and technology. In: Proceedings of CCSN-2018, 27–28 October, 2018 at Kolkata, India

[50] Khan KA, Manir SMM, Islam MS, Jahan S, Hassan L, Ali MH (2018) Studies on nonconventional energy sources for electricity generation. Int J Adv Res Innov Ideas Educ 4(4):229–244

[51] Khan KA, Miah MS, Ali MI, Sharma SK, Quader A (2018) Studies on wave and tidal power converters for power production. Int J Adv Res Innov Ideas Educ 4(6):94–105

[52] Khan MKA, Obaydullah AKM, Wadud MA, Hossain MA (2018) Bi-product from bioelectricity. IJARIIE 4(2):3136–3142

[53] Khan KA, Rahman ML, Islam MS, Latif MA, Khan MAH, Saime MA, Ali MH (2018) Renewable energy scenario in Bangladesh. IJARII 4(5):270–279

[54] Khan KA, Rahman MA, Islam MN, Akter M, Islam MS (2018) Wave climate study for ocean power extraction. Int J Adv Res Innov Ideas Educ 4(6):83–93

[55] Khan KA, Wadud MA, Hossain MA, Obaydullah AKM (2018) Electrical performance of PKL (Pathor Kuchi Leaf) power. IJARIIE 4(2):3470–3478

[56] Khan KA, Wadud MA, Obaydullah AKM, Mamun MA (2018) PKL (Bryophyllum pinnatum) electricity for practical utilization. IJARIIE 4(1):957–966

[57] Paul S, Khan KA, Islam KA, Islam B, Reza MA (2012) Modeling of a biomass energy based (BPL) generating power plant and its features in comparison with other generating plants.IPCBEE.https://doi.org/10.7763/IPCBEE.2012.V44.3

[58] Ruhane TA, Islam MT, Rahaman MS, Bhuiyan MMH, Islam JMM, Newaz MK, Khan KA, Khan MA (2017) Photo current enhancement of natural dye sensitized solar cell by optimizing dye extraction and its loading period. Optik 149:174–183

[59] Sultana J, Khan KA, Ahmed MU (2011) Electricity generation from Pathor Kuchi Leaf (PKL) (Bryophyllum pinnatum). J Asian Soc Bangl Sci 37(4):167–179

[60] Khan KA, Yesmin F(2019) Cultivation of Electricity from Living PKL Tree's Leaf In: J Of Advance Research and Innovative Ideas In Education 5(1): 462-472

[61] Khan KA, Rasel S R and Ohiduzzaman M (2018) Homemade PKL Electricity Generation for Use in DC Fan at Remote Areas. 1st International Conference on 'Energy Systems, Drives and Automations', ESDA2018: 90-99.

[62] Khan KA, Yesmin F(2019) Solar Water Pump for Vegetable field under the Climatic Condition in Bangladesh. In: J of Advance Research And Innovative Ideas In Education 5(1): 631-641

[63]Khan KA, Rasel S R(2019) Solar Photovoltaic Electricity for Irrigation under Bangladeshi Climate. In:J of Advance Research And Innovative Ideas In Education 5(2): 28-36

[64] Khan KA, Rasel S R(2019) The Present Scenario of Nanoparticles in the World. In: J of Advance Research And Innovative Ideas In Education 5(2): 462-471

[65] Khan K.A., Yesmin F, Wadud M A and Obaydullah A K M(2019) Performance of PKL Electricity for Use in Television Int: C on Recent Trends in Electronics & Computer Scienc-2019, Venue: NIT Silchar, Assam, India, Conference date: 18th and 19th of March, 2019. Organizer: Department of Electronics and Engineering, NIT Silchar, Assam, India.P: 69
[66] Mamun MA, Ibrahim M , Shahjahan M. and Khan KA(2019) Electrochemistry of the PKL Electricity, Int: C on Recent Trends in Electronics & Computer Scienc-2019, Venue: NIT Silchar, Assam, India, Conference date: 18th and 19th of March, 2019. Organizer: Department of Electronics and Engineering, NIT Silchar, Assam, India.P: 71
[67] Khan KA, Hossain MA, Kabir MA, Rahman MA and Lipe P(2019) A Study on Performance of Ideal and Non-ideal Solar Cells under the Climatic Situation of Bangladesh, Int: J of Advance Research And Innovative Ideas In Education 5(2): 975-984
[68] Hassan SJ, Khan KA(200 7)Determination of Optimum Tilt angles of Photovoltaic panels in Dhaka, Bangladesh."Int: J. Eng. Trach 4(3): 139-142, December 2007. Webiste : www. Gsience. Net
[69] Hassan SJ, Khan KA (2007) Design, Fabrication and performance study of Bucket type solar candle machine, Int: J. Eng. Trach 4 (3), December 2007. Webiste : www. Gsience. Net,
[70] Khan MA Hamid, Khan DMKA (2005) Title=? Nuclear science and Applications. Vol. 14, No. 11 June 2005
[71] Khan DMKA(2002) Prospect of Solar Energy for Food Supply in Bangladesh, Bangladesh J of Scientific and Industrial Research BJSIR, 37:(1-4)
[72] Sen BK, Khan KA, Khan MAH, Awal MA(2001) Studies on Optical & thermal properties of black copper solar selective coating on copper substance, Jahang. Phys. Studs. 9:() pp:
[73] Ahsan MN, Sen BK, Khan KA & Khan MA Hamid (1999) Performance of a Low Cost Built-in-storage Solar Water Heater, Nuclear Science and Applications 8(1-2)
[74] Khan AJ, Khan KA, Mahmood ZH & Hossain M (1991) Performance of an Intermittently Tracked Linear Solar Fresnel Reflecting Concentrator, The Dhaka University studies, part B (science) 39(2)
[75] Khan KA, Khan AJ & Rabbani KS(1998) Design & performance studies of a Linear Fresnel Reflecting Solar Concentrator-Receiver System, Bangladesh J.Sci. Res. 16 (2): 143-146,
[76]Khan MKA (2008) Studies on Electricity Generation from Stone Chips Plant (Bryophyllum pinnatum), Int: J. Eng. Tech 5(4): 393-397
[77] Islam S, Khan KA, Islam AKS ,Ali MJ(2000) Design, Fabrication & performance study of a Paraboloidal Solar Medical Sterilizer, Bangladesh J.Sci. Res. 18(2): 211-216,
[78] Khan MKA (1998) Solar Selective Coating for use in Solar Concentrating Collector, Bangladesh J. Sci. Res. 16(2): 249-252
[79] Khan MKA(1999) The performance of a Fresnel Reflecting Concentrating Collector with Auxiliary Heating, Bangladesh J. Sci. Ind. Res. 34(2)
[80] Khan MKA(1998) Production of Candles by Solar System in Bangladesh, Nuclear Science & Applications 7(1,2)
[81] Khan MKA (1997) Field Testing of a Fresnel Reflecting Solar Concentrator, Nuclear Science & Applications 6(1,2)
[82] Khan MKA, Khan AJ & Rabbani KS(1998) Solar Thermal Steam Production & Distillation Device by Fresnel Reflecting Concentrator – Receiver System, Bangladesh J. Sci. Res.16(2): 221-228
[83] Islam MS and Khan MKA (2008) Performance Studies on Single Crystal Solar PV Modules for Practical Utilisation in Bangladesh, International J.Eng. Tech 5(3):348-352
[84] Khan MKA (2008) Studies on Fill Factor(FF) of Single Crystal Solar PV Modules For Use In Bangladesh, International J.Eng. Tech 5(3):328-334
[85] Khan MKA(2008) Performance Studies of Monocrystallinne PV module considering the shadow effect, International J.Eng. Tech 5(3): 342-347
[86] Islam MS and Khan MKA(2008) Study the Deterioration of a Monocrystal Solar silicon PV module Under Bangladesh Climate, International J.Eng. Tech 5(2):26 3-268
[87]Sheikh Jafrul Hassan and Md. Kamrul Alam Khan, Design,Fabrication And Performance Study of a Single phase Inverter for use in Solar PV system, International J.Eng. Tech 5(1):212-216, March, 2008
[88] Khan DMKA (2009) Soap Production Using Solar Power, International J. Eng. Tech 6(1):414-419 Website :www.gscience.net
[89] Khan DMKA(2009) Wave and Tidal Power Generation: An Overview, Int:J.Eng. Tech 6(1):420-423 Website :www.gscience.net
[91]Dr. Md. Kamrul Alam Khan(2009) Materials Used in Electricity Generation by Solar Thermal System, Int: J. Eng. Tech 6(1):515-520 Website :www.gscience.net
[92] Khan DMKA(2009) Comparative Study on Single Crystal and Polycrystalline solar pv modules for use in Bangladesh climate, Int:J. Eng. Tech 6(1):527-529 Website :www.gscience.net
[93] Khan DMKA(2009) Solar Thermal Studies Of Open Sun Drying (OSD) of various Crops Under Bangladesh Climatic Condition, Int. J. Sustain. Agril. Tech. 5(7): 85-94
[94] Khan DMKA(2009) An Investigation on Various Solar Cells Under the Climatic Condition of Bangladesh, Int: J. Eng. Tech. 6(3): 547-551
[95] Khan DMKA, Islam MS(2010) Studies on Performance of Solar Photovoltaic System Under the Climate Condition of Bangladesh, Int. J. SOC. Dev. Inf. Syst. 1(1): 37-43

[96] Khan DMKA(2009) Application of Solar Thermal Technology for Various Developing Countries, International J. Eng. Tech. 6(6)
[97] Saifuddin SM & Khan DMKA(2010), Performance Study of Hybrid SPV, ST and BPL/PKL electricity Generation and storage for Practical Utilization in Bangladesh, International J. Eng. Tech : ISSN 1812 – 7711, 7(2)
[98] Saifuddin SM & Khan DMKA (2010
) Survey of Hybrid Solar Photovoltaic (SPV) and Solar Thermal (ST) Collectors in Bangladesh, Int: J. Eng. Tech : 7(3) ISSN 1812 – 7711
[99] Saifuddin SM & Khan DMKA(2010) Performance Study of Solar Photovoltaic and Solar Thermal Hybrid System Utilized in India, International J. Soc. Dev. Inf. Syst. 1 (4) : 10 – 16
[100] Sultana Jesmin, Khan KA and Ahmed MU(2010) Present situation of Solar Photovoltaic System in different countries, ASA University Review, 4(2), ISSN:1997-6925
[101] Rahman AA and Khan DMKA(2010) The Present situation of the Wave energy in some different countries of the world, IJCIT, ISSN 2078 5828(print),ISSN2218-5224(online),2(1),Manuscript code:110754
[102]Hasnat A,Ahmed P,Rahman M and Khan K A(2010) Numerical Analysis for Thermal Design of a Paraboloidal Solar Concentrating Collector, International Journal of Natural Sciences(2011),1(3) 68-74
[103] Khan DMKA & Rubel AH (2011) Simulated Energy Scenarios of the Power Sector in Bangladesh, ASA University Review, 592, Page: 101-110, ISSN:1997-6925
[104] Sultana J, Khan MKA and Ahmed MU(2011) Electricity Generation from Pathor Kuchi Leaf(Bryophyllum Pinnatum), J.Asiat.Soc.Bangladesh.Sci.,37(2):167-179
[105]Rashid MA, Mamun RA, Sultana J,Hasnat A, Rahman M and Khan KA(2012) Evaluating the Solar Radiation System under the Climatic Condition of Bangladesh and Computing the Angstrom Coefficients, International Journal of Natural Sciences 2(1):38- 42. Received: November 2011, Accepted: March 28
[106] Sultana J, Khan KA and Mesbah Uddin Ahmed MU (2012) The Present Situation of Solar Thermal Energy in the World, ASA University Review, 4(2) ,ISSN:1997-6925
[107] Khan KA,Shatter MA, Paul S, Zishan SR, Yousufe MR(2012) A Study on Tidal Power Conversion for Use in Bangladesh, International Journal of Scientific Engineering Research, 3(12),
ISSN 2229-5518
[108] Bhuiyan MSA, Khan KA and Jabed MA(2012) A Computerized study on the metrological parameter conversions for rural agribusiness development, Journal of Innovation & Development Strategy (JIDS)(J. Innov. Dev. Strategy)J. Innov. Dev. Strategy 6(2):94-98
[109] Khan DMKA, Paul S, Zobayer A, Hossain SS(2013) A Study on Solar Photovoltaic Conversion, International journal of Scientific and Engineering Research ,Volume-4,Issue-3,March-2013,ISSN2229-5518 (Impact Factor: 1.4)

[110] Khan DMKA, Paul S, Zobayer A, Hossain SS (2013) A Study on Solar Thermal Conversion, International journal of Scientific and Engineering Research , 4(3),ISSN2229-5518 (Impact Factor: 1.4)
[111] Bhuiyan MSA and Khan KA(2013) Software Development Studies on the Metrological Conversions for Local Agri-Business Units of Area and Volume Weight Measures, Journal of Innovation & Development Strategy (JIDS), Canada, 7(1). ISSN 1997-2571
[112] Ahsan MN, Kumar S, Khan MKA, Khanam MN, Khatun R, Akter S, Aheikh MAR, Islam MM, Islam MS, Saha S and Alam MM(2013) Study of Spatial Resolution of a Positron Emission Tomography(PET) System, Jagannath University Journal of Science, 2(1), ISSN 2224 – 1698.
[113]Paul S, Khan KA and Kundu RK(2013) Design, Fabrication and Performance Analysis of Solar Inverter, Published in the Proceedings of IEEE, ENERGYTECH, USA, [Participated and Presented in the "EnergyTech2013Conference sponsored by the Institute of Electrical and Electronic Engineers(IEEE) at Case Western Reserve University in Cleveland, Ohio, USA, 21 may-23 May ,2013, USA.]
[114]Paul S, Khan KA and Kundu RK(2013), Performance Studies of Mono-Crystal Silicon Solar Photovoltaic module with booster reflector under Bangladeshi Climatic condition, Published in the Proceedings of IEEE, ENERGYTECH, USA.[Participated and Presented in the "EnergyTech2013Conference sponsored by the Institute of Electrical and Electronic Engineers(IEEE) at Case Western Reserve University in Cleveland, Ohio, USA, 21 may-23 May ,2013, USA.]
[115]Rahman AA and Khan KA(2013) Feasibility Studies on WEC (Wave Energy Converter) for use in Coastal Belt at Cox's Bazar of Bangladesh under the Climate Condition of the Bay of Bengal, International Journal of Engineering and Innovative Technology,3660 East Bay Drive, Apartment no.116 Largo, Florida US,33771 (IMPACT FACTOR:1.895) (ISO 9001:2008 Certified)
[116] Khan KA, Latif A, Alam S, Sultana J and Ali H(2014) A Study on Internal Resistance of the Pathor Kuchi Leaf (PKL) Cell, Published in the journal of Agriculture and Environment,10(1): 24-28.
[117] Ahasan MN, Quadir DA, Khan KA and Haque MS(2014) Simulation of a thunderstorm event over Bangladesh using wrf-arw model, Journal of Mechanical Engineering,44(2) ,Transaction of the Mechanical Engineering Division, The Institute of Engineers, Bangladesh.
[118] Uddin MK, Khan MKA,Sobhan MA, Ahmed F and Nabi MN(2015) On the Implications of Dynamic Wireless Spectrum Management Canons Issues in Uncertainty Use of Cognitive Radio, Published in the journal of the Bangladesh Electronics Society Journal (BESJ), 15(1-2),17-24

[119] Uddin MK, Khan MKA, Ahmed F and Nabi MN(2016) A Concept of Potential Radio Spectrum Administration Seeking Easy Access Spectrum (EAS) Paradigm Figured on Signal to Interference Noise Ratio (SINR) and Interference Thresholds, Published in the journal of the Bangladesh Journal of Scientific and Industrial Research, 2015 (in Review)
[120] Uddin MK, Khan MKA, Sobhan MA, Ahmed F and Nabi MN(2015) Dispensation of Commons Radio Spectrum Management Framework Issues in Implementation: Challenges and Opportunities, Published in the J. of Electronic Engineering
[121] Uddin MK, Khan MKA, Sobhan MA, Farruk Ahmed, and Nabi MN(2015) Dispensation of Commons Radio Spectrum Management Using Conceptual Benefit and Cost Analysis Framework Issues in Bangladesh, Published in the journal of the Chittagong University Journal of Science
[122]Shamsuzzaman M, Sikder S, Siddiqua T, Rahman MS, Bhuiyan MMH, Khan KA, and Paul S(2015) Standardization of Gamma Radiation Field for Characterizing Radiation Detecting Instrument at SSDL facilities in Bangladesh, Published in the journal of the Bangladesh Journal of Physics (BJP),18(65-72) ISSN No.:1816-1081, BPS
[123] Kabir MU, Sobhan MA, Khan MKA, Khan MAR(2015) Broad Network Wide Statistics of TCP Indicator Measurements to Reassume the Status of the Wireless 3G Network Monitoring, Published in the journal of the Journal of the University of Information Technology and Sciences (UITS) Journal. 4(2) ISSN: 2226-3128
[124] Sruti RN, Islam MM, Rana MM, Bhuiyan MMH, Khan KA, Newaz MK and Ahmed MS(2015) Measurement of Percentage Depth of a Linear Accelerator for 6 MV and 10 MV Photon Energies, Published in the journal of Nuclear Science and Applications, AEC, Dhaka, Bangladesh, 24(1 & 2): 29-32

[125] Uddin MK, Sobhan MMA, Ahmed F, Khan MKA and Nabi MN(2015) A potential Electrical and Electronic Debris Management Model and Ecological Impact and Awareness Issues in Bangladesh, Journal of the National University Journal of Science. 2(1) ISSN: 1994-7763
[126]Hasan MM, Khan DMKA, Rahman MN and Islam MZ(2015), Sustainable Electricity Generation at the coastal areas and the Islands of Bangladesh Using Biomass Resource Published in the City University Journal, 2(1): 09-13
[127] Kabir MU, Ahmed PDF, Sobhan DMA And Khan MKA(2016) Dispensation of Commons Radio Spectrum Management Framework Issues in Implementation: Challenges and Opportunities, Published in the journal of the Bangladesh Electronic Society (BES), (ISSN: 1816-1510) 16 (1-2)
[128] Khan KA, Alam MS, Mamun MA, Saime MA & Kamal MM(2016) Studies on electrochemistry for Pathor Kuchi Leaf Power System, Published in the Journal of Bangladesh J. Agric. And Envirin. 12(1): 37-42
[129]Akter T, Bhuiyan MH, Khan KA and Khan M H(2016) Impact of photo electrode thickness and annealing temperature on natural dye sensitized solar cell, Published in the journal. of Elsevier. Ms. Ref. No.: SETA-D-16-00324R2
[130] Khan MKA (2017) Performance of electricity generation from Bryophyllum Leaf for Practical Utilization, Abstract published and Presented in the APS April meeting, January 28-31, Session T1(Page No.: 201), Washington DC, USA.Bulletin of the American Physical Society, 62(1)
[131] Ruhane TA, Islam (MT), Rahaman MS, Bhuiyan MMH, Islam JMM, Newaz MK, Khan MK, Khan MA(2017) Photo current enhancement of natural dye sensitized solar cell by optimizing dye extraction and its loading period, Published in the journal of Elsevier : Optik - International Journal for Light and Electron Optics, Available online 6 September 2017, In Press, Accepted Manuscript-Note to users
[132] Ohiduzzaman M, Khan KA , Yesmin F and Salek MA (2019) Studies on Fabrication and Performance of Solar Modules for practical utilization in Bangladeshi Climate. IJARIIE 5(2): 2626-2637
[133] K.A.Khan and Salman Rahman Rasel (2019)A study on electronic and ionic conductor for a PKL electrochemical cell, IJARIIE, 5(2):3100-3110
[134] **Khan KA** and Rasel SR (2019) Development of a new theory for PKL electricity using Zn/Cu electrodes: per pair per volt, IJARIIE, 5(3):1243-1253
[135] Ohiduzzaman M, Khatun R, Reza, **Khan K A**, Akter S, Uddin MF, Ahasan MM (2019) Study of Exposure Rates from various Nuclear Medicine Scan at INMAS, Dhaka. IJARIIE, 5(3): 208-218