JOURNAL OF ENGINEERING annals OF FACULTY OF ENGINEERING HUNEDOARA
Tome V (year 2007), Fascicole 1, (ISSN 1584 – 2665)

PREDICTIONS ON PV TECHNOLOGY DEVELOPMENT IN THE LIGHT OF KYOTO PROTOCOL

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ABSTRACT
This paper presents the impact of Kyoto Protocol on the development of renewable sources of energy, in order to diminish the greenhouse effect. The reducing CO_2 emission is comparatively analyzed, for different renewable sources and from different points of view, as: technology, size, cost and performance characteristics, generating capability and generation, environmental impact.
Prediction, in an international context, and possibilities of development of both on and off grid photovoltaic systems are discussed.
KEYWORDS:
Technology development, Kyoto protocol, non-conventional energy source

1. INTRODUCTION

PV systems utilization tends to become an important application in domain of non conventional energy source, from the point of view of Kyoto Protocol, as well as from the decentralized energy.

The outcome of the Kyoto Protocol was a meeting in which the developed nations agreed to limit their greenhouse gas emissions, relative to the levels emitted in 1990.

The Committee on Science of the U.S. House of Representatives asked the Energy Information Administration (EIA) to analyze the energy use and prices and the economy in the 2008-2012 time frames". It has been hypothesized that the continued accumulation of greenhouse gases could lead to an increase in the average temperature of the Earth's surface and cause a variety of changes in the global climate, sea level, agricultural patterns, and ecosystems that could be, on net, detrimental[1].

By another hand, in June 2002, the WADE (World Alliance for Decentralized Energy) was launched by a group of major companies and national industry associations to accelerate the development of decentralized energy (DE) system worldwide, which technologies consist of: high efficiency cogeneration/CHP; on-site renewable energy systems; energy-recycling systems. [2].

Dispersed renewable energy use in the residential sector includes wood, solar thermal, geothermal energy, photovoltaic cells. PV technology seems to be also a solution for dispersed renewable energy (ex. a photovoltaic array, disconnected from the electric power grid).

From the environmental impact point of view the photovoltaic technologies presents important advantages, even comparative with other renewables, as: 0% clean technology, reduces fossil fuel consumption, quiet. [3].

2. PV – ON AND OFF GRID TECHNOLOGIES

The global installed capacity of PV was nearing 2 GWp at the end of 2002. This could increase to an estimated 207 GW by 2002, with PV providing up to a billion people with power, and the industry employing 2 million, [4]. The most sales are going into the grid-connected sectors in Japan, Germany and United States.

Solar photovoltaics - PV- was once a marginal and exotic technology, used mainly for outer space applications or in very remote areas. In the last decade of 20th century, however, it became a key technology for generating distributed power in the built environment, and it has the prospects of cost break-even with cost near the level of those for conventional grid power for residential consumers within two decades, i.e. around 2020. Natural disaster, blackout, terrorist strike- photovoltaics can provide the necessary power. If the industry and PV-market analyst were to consider "security" as an independent market segment it would focus attention on developing PV security applications and products and on marketing them as such[5].

While plants producing 20-25 MW of PV per year have been the industry norm in recent years , manufacturers such as Sharp, Sanyo and Kyocera are now all planning in terms of 200MW. Japan was responsible for almost 50% of global PV production during 2002.[6].

In table 1 is presented the world PV market by application area, 1990-2002(MW).
The off-grid commercial and industrial applications represent the second largest sector of the PV market. Telecommunication applications range from all modes of communication, including fiber-optics, satellite links and cable links to small data link stations via phone, TV, and secure communications throughout the country.

Table 1 – World PV market by application area, 1990-2002 [MW]

Application	1990	1996	1998	2000	2002
Consumer products	16	22	30	40	60
US off-grid residential	3	8	10	15	25
World off-grid rural	6	15	24	38	60
Communications and signal	14	23	31	40	60
PV-diesel commercial	7	12	20	30	45
Grid connected residential/commercial	1	7	36	120	270
Centralized (> 100 kWh)	1	2	2	5	5
Total [MW/year]	48	89	153	288	525

Remote PV power systems serve as sensor power sources and also provide power for data communication in wide range of applications, including weather and storm warning, monitors of seismic activity, radiation or pollution, security phones on highways. Since the utilization of PV for terrestrial purposes started, one of the largest PV market segments has been communication. One of the most visible communication applications is the roadside emergency telephone. Others are less visible, but, PV is already the solution of choice for radio and television repeaters and off-grid telecom sites, including microwave repeaters and cellular base stations [6].

Most applications in the off-grid consumer sector are in remote habitats. They include PV for remote residences, boats, motor homes, travel trailers, farms. The systems provide electricity for all types of loads used in modern habitats. Most system are less than 1 kW in size, have several days of battery storage, and normally use DC loads. Some larger systems use stand-alone inverters to power AC loads, and may have a diesel generator as back-up.

A PV serves a diverse array of applications. These include photovoltaic – diesel hybrid power stations that can serve remote sites or act as transportable systems for emergency power.

Off-grid photovoltaic systems are economical, although when the high cost of grid connection is taken into account, even in a highly urbanized town centre location.

Photovoltaic provide small-scale electricity generation, often in remote locations, using semiconductors to transform sunlight directly into electricity, which may be used for a variety of functions, such as water pumps or remote lighting systems.

In U.S. domestic shipments in the PV market (including both dispersed and grid-connected systems) have grown significantly since 1980s, but they also were affected by the repeal of the tax credit. Capital costs for renewable technologies were increased to reflect impacts of expected short-term supply bottlenecks that could result if capacity increase rapidly above existing levels. Biomass, solar, and wind capacity could increase 25 percent annually without incurring higher capital costs. Costs were assumed to increase by one-half percent for every 1 percent increase of capacity in excess of 25 percent.

Electricity supply companies must fulfill certain requirements for power quality at the delivery point, such as voltage limits, voltage fluctuations, interruptions and harmonics The supply voltage at the delivery point must be ± 10% of the nominal voltage for European LV networks according to European Standard EN 50160 [7]. For example, a study of PV penetration made in Denmark tries to satisfy all requirements. PV reduces the peak power demand from the network, as long as high penetration coincides with peak demand situation. The marginal costs per kWh that PV imposes on the power system are likely to be substantially lower than for bulk power.

3. COMPARATIVE DISCUSSION ON PV AN THE OTHERS RENEWABLE

Kyoto Protocol established emissions targets for each of the participating developed countries relative to their 1990 emissions levels. The targets range from an 8-percent reduction for the European Union (or its individual member states) to a 10-percent increase allowed for Iceland, and 7 percent for United States till 2008-2012. In table 2 are presented the cost and performance characteristics of the generating technologies. Across the carbon reduction cases, the projections show a consistent shift away from coal to natural gas and renewable for electricity generation.

In the analysis made by EIA (Energy Information Administration)[1], a few scenarios have been studied: the Kyoto Protocol agreement(which means 1990-year of reference), and some others in which the CO_2 emissions levels are disposed above or below the reference(+24%, +14%, -3%, -7%). In table 3 are presented the predictions for electricity generation and generation capacity from renewable for the years 2005, 2010 and 2020. for -7 percent below case.

For the same case, which is also the aim of Kyoto Protocol for the U.S., in table 4 is presented the renewable energy consumption by sector and source.

Table 2. Cost and Performance Characteristics of Renewable Generating Technologies

Technology	Size [MW]	Lead Time [years]	Overnight capital Cost (1995 $ / kWh)	Fixed O&M (1996 $ / kWh)	Heat rate (Btu / kWh)	Carbon Emissions (Pds/ MWh)
Biomass	100	4	1476	43.0	8224	0
Geothermal	50	4	2025	95.7	-	0
Municipal Solid Waste	30	1	5289	0.0	16000	0
Solar Thermal	100	3	1910	46.0	-	0
Solar Photovoltaic	5	2	3185	9.7	-	0
Wind	50	3	965	25.6	-	0

In every carbon reduction case PV are projected to gain significant market penetration because of high costs. With payback periods of more than 20 years, the success of technologies seems largely dependent on reducing production costs and increasing efficiency (which will result in further cost reductions for the consumer). Federal financial assistance would also play a role in their success.

Table 3. Renewable Energy generating Capability and Generation, for U.S.(-7%) scenario

Electric generators (excluding cogenerators) Net Summer Capability [10^3 MW]	1990-Level	2005	2010	2020
Conventional Hydropower	79.74	80.70	81.84	81.92
Geothermal	3.32	3.74	4.75	7.81
Municipal Solid Waste	3.66	3.66	3.95	4.44
Wood and other Biomass	2.25	2.18	5.32	43.99
Solar Thermal	0.38	0.38	0.44	0.54
Solar Photovoltaic	0.08	0.08	0.39	0.91
Wind	5.35	6.27	18.17	51.37
Total	94.78	97.00	114.85	190.97
Generation [10^6 kWh]	1990-Level	2005	2010	2020
Conventional Hydropower	312.54	317.03	321.93	322.35
Geothermal	20.02	23.01	30.37	53.35
Municipal Solid Waste	24.53	24.53	26.49	29.88
Wood and other Biomass	20.20	19.51	36.40	305.05
Solar Thermal	0.96	0.96	1.15	1.47
Solar Photovoltaic	0.20	0.20	1.01	2.30
Wind	13.40	15.80	48.87	142.77
Total	391.84	401.04	466.22	857.17

Table 4. Renewable Energy Consumption by Sector and Source, for U.S. (-7%) scenario

Sector and Source	1990 Level	2005	2010	2020
Electric Generators	4.52	4.68	5.53	9.72
Conventional Hydroelectric	3.21	3.26	3.31	3.31
Geothermal	0.59	0.68	0.95	1.71
Municipal Solid Waste	0.39	0.39	0.42	0.48
Biomass	0.18	0.17	0.32	2.72
Solar Thermal	0.01	0.01	0.01	0.00
Solar Photovoltaic	0.00	0.00	0.01	0.02
Wind	0.14	0.16	0.50	1.47
Total Marketed Renewable Energy	7.35	7.51	8.87	13.47
Non-Marketed Renewable Energy Selected Consumption	1990 Level	2005	2010	2020
Residential	0.02	0.02	0.03	0.06
Solar Hot Water Heating	0.01	0.01	0.01	0.01
Geothermal Heat Pumps	0.01	0.01	0.02	0.05
Commercial	0.03	0.03	0.03	0.04
Solar Thermal	0.03	0.03	0.03	0.04

Currently electricity from PV is approximately 1.4 to 5.8 times the price to consumers of electricity from utility grids. Average prices in 1998 were 461 mills for PV systems. To increase the market penetration rates of the alternative technologies their costs would have to be more competitive.

PV is examined on the basis of its potential for the further market penetration in 2010 for the 1990-3%, assuming cost reductions 30-50%, and performance improvements 70 percent. Payback periods are calculated for the regions where these technologies are most likely to penetrate.

The effects of various private and government-assisted financing plans, such as rolling the cost of the alternative technology into mortgage plan, tax credits, and depreciation, are summarized in the chart below.

The first bar shows the projected payback periods in 2010 for the 1990-3% case with current technology performance and costs. The other projection incorporate performance improvements for PV of 70 percent. The second bar shows the effects of the assumed performance improvement.

The third includes a 30-percent production cost reduction, the fourth includes a 50-percent cost reduction, the fifth includes the incorporation of capital costs into a mortgage plan, and the sixth includes a tax credit for PV and depreciation adjustment for business. It is important to note that the substantial cost reduction and improvements in efficiency (70 percent for PV) are arbitrary assumptions and are not calculated projections for future costs and efficiencies.

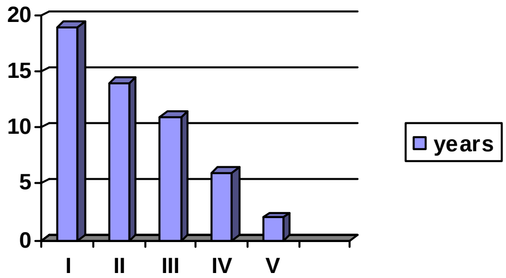

Figure 1.Projected payback periods for PV purchases under different Assumpption, in 2010, (1990-3% scenario):I-performance improvement (pi), II-pi and 30% cost reduction, III-pi and 50% cost reduction, IV- pi, 50% cot reduction and mortgage incorporation, V-pi, 50%cost reduction, mortgage incorporation and tax credits.

Under the most favorable assumptions shown in the graph, payback periods could be reduced to less than 2 years for PV. Although penetration levels are hard to predict from payback periods, it can generally be assumed for the commercial and residential sectors that paybacks within 3 or 4 years would be needed for significant penetration.

The energy production efficiency of PV modules has also improved, to approximately 12 percent today from 9 percent in 1980. Reaching the goal of 70 percent improvement in performance, would require an efficiency level of 20 percent in 2010. Since 1980, the rate of improvement in performance for PV has been less than 2 percent annually, whereas a 4.3 percent annual rate would be needed to achieve a 70-percent improvement by 2010. That improvement would also have to be accompanied by cost improvements to achieve a 3 – to 4-year payback period.

4. CONCLUSIONS

If solar photovoltaic (PV) technology is to become a significant source of power production it needs to negotiate two major obstacles.

One is the manufacturing costs of PV systems (although these have decreased dramatically over the past decades, expectations of a breakthrough in the development of low-cost solar cells are high, and work in modularization and standardization of components in PV systems is an important step in cost reduction).

The second obstacle to grid-connected PV is presented by the limitations of the power distribution networks. Instantaneous power production from PV often exceeds the instantaneous power consumption in residential areas with a high concentration of PV systems. Electricity supply companies must fulfill certain requirements for power quality at the delivery point, such as voltage limits, voltage fluctuations, interruptions and harmonics.

Although generally too expensive to implement as a stand-alone technology on conventional payback criteria without grant support or subsidy, renewable energy is included in a concept were dilution economics and the advantages of private wire technology can be applied – by integrated renewable energy with sustainable green technologies.

Off-grid photovoltaic are more economical both in capital and running cost terms than conventional, grid connected pay-and-display machines. The off-grid photovoltaic system was cheaper both in capital and running cost terms when the high cost of grid connection is taken into account, even in a highly urbanized town centre location. [8]

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