Energy Policy Act of 2005 and Its Impact on Renewable Energy Applications in USA

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***Abstract*--The US Energy Policy Act of 2005 will impact the applications and R & D efforts for every type of renewable energy source. A part of the bill has the stated purpose of achieving energy self-sufficiency by the year 2025 within the US, Canada, and Mexico. This bill also has provisions for anyone wishing to connect to the existing power grid at the distribution level and sell power to a utility or other entity including incentives for generation of electricity from certain types of sources. This paper will provide a comprehensive review and describe the impact this bill has on several types of renewable energy presently being considered for practical applications, its effect on the electricity market, national electrical grid, and perhaps the future of how electricity will be delivered in the US.**

***Index Terms*—Energy Policy Act, Renewable Energy**

I. Introduction

IN 2003 there were a total of 15,756 generators in the United States with a combined nameplate capacity of 1.031×10^6 MW [14]. Figure 1 depicts the breakdown. Figure 3 shows the corresponding numbers for the amount of energy produced by these resources. In 2003 all the electrical generation in the US produced a combined total energy of 3.88×10^{12} kWh [3].

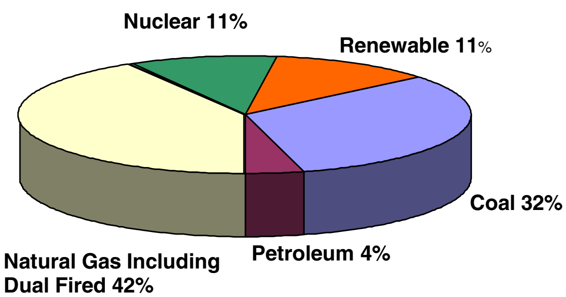

Fig. 1: Installed Generation Capacity (% MW) by Fuel

The 11% of total installed capacity and 10% of energy generated using renewable sources (including hydro) can be further broken down by fuel type, as depicted in Figures 2 and 4. Interesting to note that, 86% of the generation capacity is hydropower producing 75% of all renewable energy.

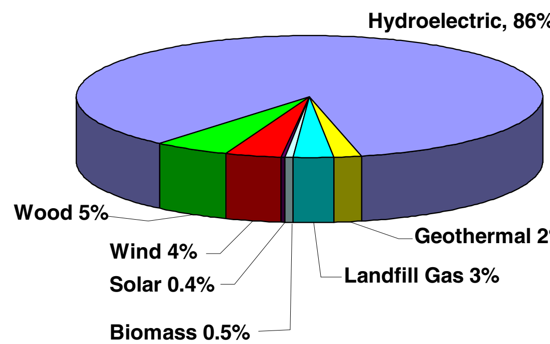

Fig. 2: Installed Renewable Generation Capacity (% Renewable MW) by Fuel

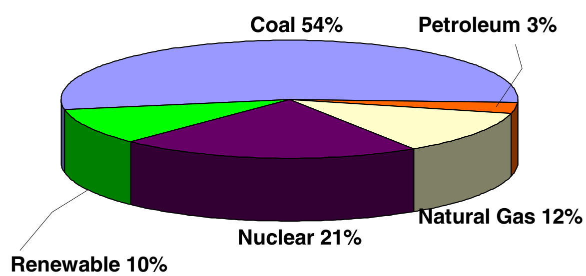

Fig. 3: Energy Production (% kWh) by Fuel Type

It is interesting to note that while nuclear installed (MW) capacity is only 11% of total generation capacity it produced 21% of the nation's energy and coal is only 32% of the installed capacity but produced 54% of the nation's energy. Coal and nuclear sources alone made up 75% of the total energy consumed in the US.

The generation capacity and corresponding energy production requires an understanding of "capacity factor." The annual capacity factor can be defined as the actual energy produced by a power plant in a given year divided by the maximum energy it could produce if its generators operated 24 hours a day for 365 days a year (100% of the time).

Capacity factors can vary from one fuel to another for several reasons. Nuclear and coal plants, as an example, are used for base loading since they cannot be turned "on" and "off" quickly. These units are also typically much larger in size (ranges between 400-1200MVA). These types of plants would

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typically have higher capacity factors since they have relatively low-cost fuel available nearly 100% of the time and are run as much as possible. Figure 5 shows the combined annual capacity factors for all generators in the US by fuel type. Nuclear plants have the highest capacity factor of 83% followed closely by wood, geothermal and coal.

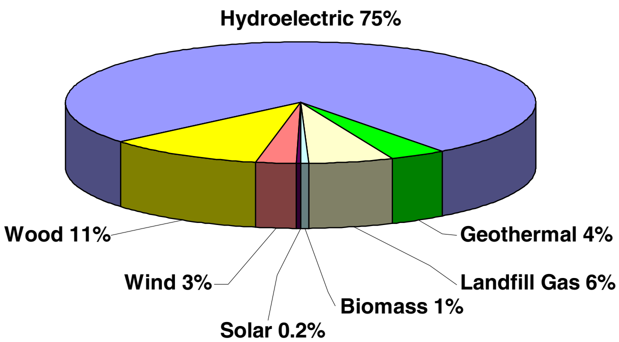

Fig. 4 Energy Production (% Renewable kWh) of Renewable Source

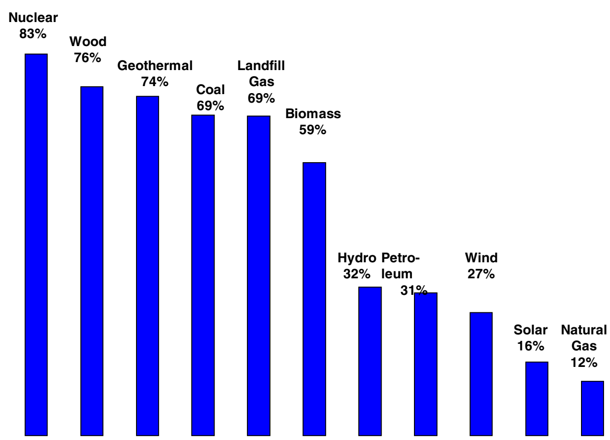

Figure 5: Annual Capacity Factors by Fuel

The relatively more expensive fuels are used only in plants utilized for peaking units. Natural gas and petroleum fall into this category. These types of plants deliver energy when needed for shorter periods of time or under emergency conditions and can be started quickly (within minutes). However the fuel is more expensive compared to coal or nuclear fuel. These plants are, in general, relatively smaller (5-100MW range) in size. They run only when peaking power is required for a shorter period of time and the high cost of fuel can be justified. That is why natural gas and petroleum plants have relatively low capacity factors.

Other types of power plants have their capacity factors limited by the availability of fuel or energy source. Hydroelectric, photovoltaic (PV), and wind power plants fall into this category. Hydroelectric plants, for example, can produce power at any time of the day or night as long as fuel (potential and kinetic energy) in the form of water behind a dam (or other head) is available. Solar plants are limited to the daylight hours, and wind plants, especially those located inland, often have unpredictable fuel (wind) supplies. This reduces their capacity factors and it is understandable why solar and wind has the lowest capacity factors among the renewable sources.

Engineers often talk about "availability factors" of power plants and these should not be confused with "capacity factors." Availability factors describe the percentage of time a power plant is available to run. For example, a wind power plant or hydroelectric plant may have an availability of nearly 100% but cannot run due to lack of wind or due to the amount of water stored resulting in a low capacity factor.

Installed cost estimates for different types of generation vary greatly depending upon the sources consulted. A recent estimate is shown in Figure 6. [4] [5]

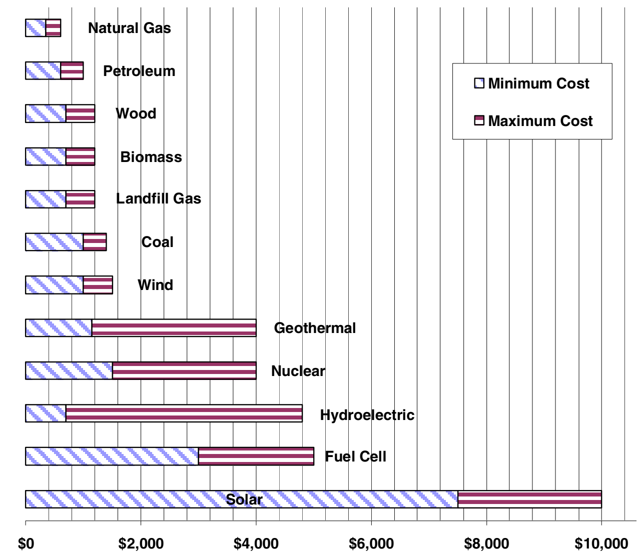

Fig. 6: Generation Installed Cost $/KW

The Energy Policy Act of 2005 directly authorizes $6.41 billion for various types of renewable energy and also for fuel cell/hydrogen electricity production. In addition it authorizes $2.2 billion for renewable energy projects or research. The appendix breaks down these authorizations. This paper will provide a comprehensive review of the bill's potential impact on renewable technologies and explore perhaps how electricity will be delivered in the U.S into the future.

II. PHOTOVOLTAIC AND SOLAR

The energy bill has stated the purpose of "procurement and installation of photovoltaic (PV) solar electric systems for electric production in new and existing public buildings." The Department of Energy [6] claimed in 2004 that this commitment had already been met by the installation of "solar energy systems" mostly in the form of hot water heating on 20,000 Federal buildings. Only 309 of these 20,000 installations are PV. It is not clear how many additional PV systems, if any, the government would be required to install, and this part of the bill seems contradictory. The bill states the purpose of acquiring 150MW peak installed capacity during this period. The funding level proposed is not sufficient to acquire the

150MW as stated. The bill authorizes \$50 million for each year from 2006-2010. This would be a total of \$12,500 per building. To install 150 MW of PV with the amount of money authorized would require an installed cost of \$1.67/W. PV systems are unlikely to decrease in cost to this point over the time span covered by the bill.

The bill also directs research, development, demonstration, and commercial application for solar energy systems. These projects may include PV, solar hot water, solar space heating, or concentrating solar power. Lighting systems that integrate sunlight and electrical lighting in complement to each other in common lighting fixtures for the purpose of improving energy efficiency are also included. Projects which would lower manufacturing costs of high quality solar systems or produce products that can be easily integrated into buildings are included in this part of the bill.

The bill requires that the Department of Energy carry out a program of "research, development, demonstration, and commercial application for solar energy". This includes solar heating as well as solar electric systems. \$140 million is authorizes for 2007, \$200 million for 2008, and \$250 million for 2009. Of these amounts \$40 million in 2007 and \$50 million in 2008 and 2009 each is earmarked for "installing innovative technologies" in State or local government buildings. The Federal Government would pay 40% of any solar energy project for a State or local government building if the State or local government would agree to bear the rest of the cost.

The Energy Bill also contains tax incentives for residential installations of PV systems. A tax incentive of 30% of the cost of a PV system up to a total of \$2,000/taxable year is provided for. Taking maximum advantage of this provision would allow for a homeowner to spend up to \$6,666.67 on a PV system each year \$2,000 of which would be returned as a tax credit. At \$9.41/watt installed this would allow a homeowner to install approximately a 700W system. For an average solar site with a capacity factor of 15% this would produce approximately 2.5kWh/day or 900 kWh/year. To pay back in 25 years with an interest rate of 6% would require an average residential energy rate of 25.0¢/kWh for an excellent solar site or 40.0 ¢/kWh for an average solar site. As a straight comparison the average price for residential electricity in the U.S. during 2004-2005 was 9.74¢/kWh, ranging from a high (for the contiguous 48 states) of 15.56 ¢/kWh in New York State to a low of 6.21 ¢/kWh for Kentucky [9]. Hawaii has the highest rate in the U.S. at 20.27 ¢/kWh [9].

The federal tax incentive alone will not be sufficient to make small grid-connected solar installations cost effective for a homeowner. However, several states have instituted their own incentive programs to encourage homeowners to install residential renewable energy systems [8]. An additional state funded subsidy of approximately \$3,500, or approximately \$5.00/kW (for the proposed 700 W system), would be sufficient to make an average solar site break even in 25 years and an additional subsidy of \$2,700 or \$3.85/watt would be necessary to make an excellent solar site cost effective for the homeowner (assuming no additional maintenance would be needed during the system's life).

As a point of reference, the average demand in a typical residential home in the U.S. is between 1.5-4 kW (primarily depending on the size, locations in the country, season and appliances utilized). The peak demand may vary between 4-12 kW. The total energy usage is between 12,000-18,000 kWh/year. [13]

III. GEOTHERMAL

The geothermal provisions of the bill mainly concern the leasing of public lands with geothermal potential. It amends the Geothermal Steam Act of 1970 [10] and provides for a schedule of rates and royalties charged for land leases dependant upon the geothermal potential. It allows a royalty of 1-2.5% during the first 10 years and 2-5% each year afterward to be collected on the gross proceeds from the sale of electricity produced under federal leases. The bill allows the Secretary of Energy to provide the geothermal electric producer credits to offset royalties charged under for the production of electricity. The Secretary of Agriculture is also directed to process in timely manor applications for geothermal leasing of Forest Systems land and leases will be competitively granted.

The bill also provides for the funding of demonstration projects using several types of renewable energy using improved technologies and utilizing wind, solar, ocean energy, biomass, and geothermal fuel sources. Under this provision \$279 million in 2007, \$292 million in 2008, and \$328 million in 2009 would be available to fund projects using any of these sources. The bill does not state how much funding would be applied to any single type of fuel, but, all or part of this funding could be used for research and demonstration projects in geothermal energy. The portion of this funding must focus on improved detection of geothermal resources, decreased drilling costs, decreased maintenance costs using improved materials, potential for other revenue such as mineral production, increased understanding of reservoir management, or demonstrate the delivery of electricity to rural and remote locations.

IV. HYDROELECTRIC

The bill includes incentive payments for adding hydroelectric facilities at an existing dam or conduit. An incentive payment of 1.8 ¢/kWh up to a total of \$750,000 per facility per year may be paid for electricity produced by such a facility. The bill authorizes \$10 million/year for the years 2006-2015 to make these payments. At 1.8 ¢/kWh and a total authorizations of \$100 million this would increase the hydroelectric production in the U.S. by 555×10^6 kWh/year if this money was paid out at a rate of 1.8 ¢/kWh to the same facilities each year. If different facilities were chosen each year 555×10^6 kWh of production would be added each year for a total of 5.55×10^9 kWh/year of new production after the ten year period.

The combined installed capacity of all hydroelectric generation plants in the U.S. was 96,352 MW in 2003 [2]. These plants produced a total of 271.5×10^9 kWh during that year

[3]. This is a capacity factor of 32% for all hydroelectric generation in the U.S. To produce $555x10^6$ kWh of production electric energy in one year at a capacity factor of 32% would require the addition of approximately 200 MW of generation. To produce $5.55x10^9$ kWh/year would require the installation of approximately 2,000 MW of generation. If fully implemented, this provision of the bill will increase the installed hydroelectric capacity and the corresponding electricity generation by the facilities by between 0.2% and 2%, respectively.

The hydroelectric plant can receive 1.8 ¢/kWh up to $750,000 per year. To receive the maximum amount of funding the plant would need to produce approximately $42x10^6$ kWh/year. For an average hydroelectric plant with a capacity factor of 32% this would require the installation of a typical 15 MW generator. The average size of a hydroelectric generator installed in the U.S. is 23.24MW [2]. Assuming the plant owner could depend on receiving this subsidy in each of the ten years allowed by the bill, the present worth of $750,000 paid out over 9 years plus the initial payment of $750,000 at 6% interest would be approximately $5.85 million. This would give the plant owner a subsidy of $390/kW installed and this may be a considerable incentive to install a hydroelectric plant at an existing dam considering that the life of such a plant will far exceed the 10 years covered by the bill and may be 50 years or more. Watersheds of sufficient capacity to support this generation capacity would have to be identified and if the money authorized were paid out in the way described here, a total of 13x15MW plants of this type could be added.

The energy bill also authorizes an additional $10 million for each year from 2006-2015 to make incentive payments to owners or operators of existing facilities which would increase the efficiency of these facilities by 3% or more. A maximum of $750,000 may be paid to any single facility.

In 2003 there were 4,145 hydroelectric generators installed in the US[2]. Over the 10 yrs. included in this bill would give a total of $24,125 to each (equally). Of course, the money will not be divided equally among all hydro plants and would be put to best use by the older (50^+ yrs.) hydroelectric plants. If the full amount of $750,000 were paid to 133 different plants this would affect about 3.2% of all the hydroelectric plants in the U.S. If each of them increased output by 3%, this would be a gain of $262x10^6$ kWh/year or about 0.1% of all hydroelectric production in the United States. The provision of the bill that added new hydroelectric plants at existing dams would add a minimum of $555x10^6$ kWh/year of production while this provision to improve efficiency at existing plants will add only $262x10^6$ kWh/year (about 50%) while expending the same amount of money. To achieve the same increase in energy per dollar this provision of the bill would have to increase the output of 280 hydroelectric plants (or 6.7% of all plants in the U.S.) by 3% at a cost of less than $358,000 each.

V. FUEL CELLS AND HYDROGEN PRODUCTION

Hydrogen can be used as a heat transport medium for transportation or converted into electricity for stationary power applications. [16] It does not occur naturally in its pure state and must be produced using some other form of energy to power the extraction. Hydrogen can be produced from natural gas or other fossil fuels, but for the hydrogen economy to succeed long-term hydrogen must be produced using carbon neutral energy sources like renewables (wind, solar, or biomass). The bill focuses to the development of hydrogen infrastructure and the supply of vehicle and electric power for critical consumer and commercial applications. The bill calls for programs that address a diverse range of hydrogen production including: fossil fuels, which may include carbon capture and sequestration, hydrogen-carrier fuels (including ethanol and methanol), renewable energy resources, including biomass; and nuclear energy. The bill also calls for the establishment of an interagency task force for Hydrogen and industry based Hydrogen Technical and Fuel Cell Advisory Committee.

The bill authorizes the following amounts for hydrogen production, storage, distribution and dispensing, transport, education and coordination, and technology transfer activities: $160 million for 2006, $200 million for 2007, $220 million for 2008, $230 million for 2009, $250 million for fiscal year 2010; and such sums as are necessary for each of fiscal years 2011-2020. This is the largest authorization in the bill for a single type of renewable or distributed generation.

The bill authorizes funds for a limited number of demonstration projects in the hydrogen area. These projects address distributed generation using renewable sources and incorporate renewable hydrogen production, off-grid electricity production, and fleet applications in industrial or commercial service.

The bill authorizes the appropriation of “sums as are necessary” for the years 2006-2020 to establish 5 projects to demonstrate the production of hydrogen at existing solar and wind facilities. One of these projects must be located at a National Laboratory or institution of higher education. This would include developing and constructing concentrated solar power devices and cogeneration facilities that may be used for the production of both electricity and hydrogen. The bill also calls for the support of existing facilities and programs of study related to methods of using concentrated solar power or PV devices for onsite production of hydrogen. These projects may evaluate the economics of small-scale electrolysis for hydrogen production and study the potential of modular PV devices for the development of a hydrogen infrastructure. The appropriated funds would also be used to study the security implications and other benefits of a hydrogen infrastructure. The Secretary of Energy is instructed to support programs at institutes of higher education which concentrate on the development of solar and wind technologies for the production of hydrogen.

The bill addresses the development of safe, durable, affordable, and efficient fuel cells for portable, stationary, and transportation applications. The goal is to encourage the development of economical and environmentally sound hydrogen fuel cells for light duty vehicular or stationary applications.

The bill supports various fuel cell related technology development. Money is authorized for developing fuel-flexible fuel cell power systems, improving manufacturing processes, developing high-temperature membranes, and cost-effective fuel processing for natural gas. Also included are the improvement of reliability, low-temperature operation, and cold start capability.

The bill authorizes the following amounts for the fuel cell activities: M$150 for 2006, $160 million for 2007, $170 million for 2008, $180 million for 2009 and M$200 for 2010.

The bill also contains provisions for tax credits for the residential installation of fuel cells. A tax credit of 30% per year up to $500 per ½ kW is allowed. Unlike the credit for residential PV, this tax credit is not limited to the size. Installed cost for fuel cells is approx. $3,000-$5,000/kW [4]. This tax credit would offset 1/5 to 1/3 of the cost of a fuel cell installation no matter how large the fuel cell may be while the maximum tax credit that can be taken for a PV installation is $2,000.

Fuel cells have the disadvantage compared with PV and wind that some type of fuel must be provided. Hydrogen cannot be considered a transport medium for renewable resource unless it is manufactured using a renewable energy source such as wind, PV, biomass, or hydroelectric. There is presently no infrastructure in place capable of delivering hydrogen to homeowners for use in residential fuel cells. The hydrogen contained in natural gas can be used as the transport medium for a fuel cell. Without the creation of a new fuel delivery infrastructure, this may be the only source of fuel available for residential fuel cells for many years.

The average price of residential natural gas for the 2004-2005 heating season was estimated as $1.02/100,000 Btu. [11]. 100,000 Btu is equal to 29.28 kWh. A home using an average of 1.5kW would require an input of approximately 10,000 Btu per hour assuming the fuel cell had a natural gas to electricity conversion efficiency of 50%. The fuel only cost of electricity produced would be 10.2 ¢/kWh.

The waste heat from a fuel cell can be used for residential water or space heating. In co-generation applications fuel cells have achieved an overall efficiency of 70%. This would somewhat offset the cost of fuel for a homeowner if all the waste heat from the fuel cell could be used during the year. However, with modern natural gas furnaces achieving efficiencies of 90% it is questionable whether using waste heat from a fuel cell for heating is the most economical use of natural gas.

Installed cost of a 1.5kW fuel cell is approximately $6,000 [4]. The bill would give a tax credit of $1,500 for this size. The expected lifetime of a fuel cell at this time is relatively short and the maintenance costs are high. It is unknown how much improvement in maintenance and life will be achieved by technological advances. However, with an average residential electrical rate of 9.74¢/kWh the fuel only cost makes the present use of fuel cells in a residential application uneconomical even if some waste heat is reclaimed. And if future natural gas price increases mirror the increases in residential electrical rates, the residential use of fuel cells using natural gas is unlikely to become economical for most users even if rebates were offered to completely offset the cost of installation.

VI. BIOMASS

The bill gives special attention to biomass plants in communities with population less than 50,000. Communities with populations of 10,000-50,000 are home to about 10% of the nation's inhabitants [12]. This Bill authorizes $50 million for the years 2006-2016 which may be made to any person in a community of less than 50,000 people who operates a facility that uses biomass to produce electricity, heat, or transportation fuel. These grants may be used to offset the cost of purchasing biomass and each grant may be $20/ton of biomass.

Grants may also be given to offset the cost of projects to develop or research methods to improve the use of biomass. These grants are capped at a maximum of $500,000 each.

The bill authorizes $213 million in 2007, $251 million in 2008 and $274 million in 2009 for bio-energy demonstration projects and bio-refineries. A maximum of $100 million may be spent on any single project. However, part of the criteria for considering how this money is distributed is the ability of the project to demonstrate using biomass technologies for the production of electrical energy.

VII. WIND

The bill provides for the funding of research, development, demonstration, and commercial application for wind energy projects using improved technologies. The bill does not specifically list the amount authorized for wind. This is included as part of the funding for renewable energy research development, and deployment. The wind projects funded by this bill will focus on low speed wind energy, offshore wind energy, construction of a facility capable of research and testing wind turbines, or wind-powered distributed generation.

Interestingly, loan guarantees are included in the bill for a project that will combine coal gasification, combined cycle technology and wind generation. This facility must be located in the Upper Great Plains and have an output of at least 200 MW. The project must also include the production of hydrogen and the ability to sequester carbon dioxide emissions.

VIII. MICROTURBINE

A qualified micro-turbine is defined in the bill as a micro-turbine with a nameplate rating of less than 2MW and has an electricity-only efficiency of not less than 26%. It must convert fuel into electricity and thermal energy (combined heat and power or CHP). The business installation of a qualified micro-turbine facility would entitle the owner to a maximum of \$200/kW tax credit, until December 31, 2007.

IX. FEDERAL PURCHASE OF RENEWABLE ENERGY

The bill provides that a certain percentage of the electrical energy consumed by the Federal Government must be obtained from renewable sources, 3% of the electricity in 2007-2009, 5% from 2010-2012, and 7.5% from 2013 onward must be from renewable sources. If the energy is produced on-site, on Federal lands, or on native Indian land, it is to be doubled.

The Federal Government in the year 2002 used 1.4% of all energy used in the United States [6]. 18% of this energy or 5.53×10^{10} kWh is in the form of electricity. The average price paid for the portion of the electricity used in "standard buildings" was 6.247¢/kWh and somewhat less in other types of facilities. This provision of the bill would require the Federal Government to purchase 1.659×10^9 kWh per year in 2007-2009, 2.765×10^9 kWh per year between 2010-2012, and 3.871×10^9 kWh per year thereafter from renewable sources. The effect of this provision will greatly depend upon how it is implemented. If the electricity purchased is generated by existing hydroelectric plants located on Federal land, and is purchased for use in federal facilities, then this provision will have little effect since this represents only about 1% of the total hydroelectric power generated in the US. However, if 100% of this additional electricity is to come from other (non-hydro) renewable sources such as solar or wind then the amount needed after 2012 represents an amount of energy equivalent to 30% of all the electricity produced in the U.S. in 2004 by wind and solar sources [3]. How meaningful this provision of the bill will depend on its implementation and interpretation.

X. CONCLUSION

The Energy Policy Act of 2005 authorizes a grand total of \$6.41 billion for various types of renewable energy applications and also for fuel cell/hydrogen electricity production. The Appendix enumerates these authorizations and Figure 7 shows (not include the tax-incentives and un-capped authorizations) how these authorization are allocated among renewable energy fuel types. Most authorizations are made between 2006-2010. Funding after 2010 is not spelled out and is listed as "as needed". Over half the funds authorized to renewable sources are dedicated to fuel cell and hydrogen production, showing the level of commitment to the "hydrogen economy."

Tax credits are given for small (under 1kW) residential PV installations and fuel cell installations of any size and are being favored over other renewable sources such as wind. Residential fuel cells are favored over PV above 1kW output.

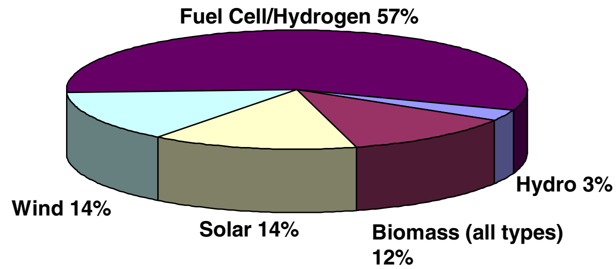

Fig. 7: Renewable Energy Appropriations by Fuel

While the research in fuel cell and hydrogen technologies has made some progress, the money authorized for these projects is unlikely to result in substantial additional energy production in the short term. The funding authorized for wind energy is mainly for experimental and demonstration projects or for hydrogen production. Solar (and PV) energy, from a purely economic standpoint, should also result in only small percentage gains in energy generation. The money authorized for biomass is mainly for experimental type projects or dedicated to small communities and it is unclear how effective these funds will be in increasing energy production. The smallest amounts directly authorized is for hydroelectric generation, and these funds have the potential of increasing hydroelectric (which already generates most of the electricity from renewable sources) production by up to 2% (the largest amount) in the short term. The funding authorized in the bill for renewable energy will not increase energy production in the U.S. by any significant amount. The benefits of the research funding and fuel cell and hydrogen production funding will come through future technological advances.

The bill includes tax credits for residential PV projects and fuel cell installations. These are insufficient by themselves to give homeowners much economic incentive. With additional state incentives some of these projects in states with high electrical rates may become economical.

While not discussed in this paper, the bill also includes provisions to improve energy efficiency in public buildings. It includes authorizations for rebates and education designed to increase energy efficiency and conservation in both publicly and privately owned buildings.

Also not discussed in this paper are changes made to the Public Utility Act of 1978 (PURPA) which require utilities to consider allowing each customer to interconnect a distributed resource. The utility is also required to consider offering net time-based metering (smart metering) to each residential customer with a distributed resource [14]. These changes greatly favor the installation of renewable energy resources at the residential and commercial level.

XI. APPENDIX

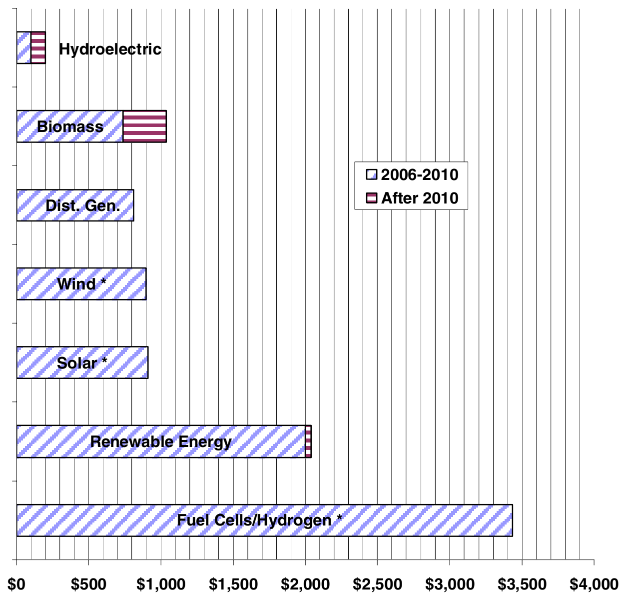

Fig. 8 Summary (Partial) of Authorizations in Millions of Dollars[14]
*Funds "As Needed" are to be appropriated after 2010

Note: There is some overlap between categories. Some funds appropriated for wind, solar and renewable energy are also dedicated to hydrogen production.

XII. REFERENCES

[1] "Energy Policy Act of 2005," Washington, DC, 2005.

[2] Table 2.2 "Existing Capacity by Energy Source, 2003", Energy Information Administration of the Department of Energy. www.eia.doe.gov

[3] Table 8.2c "Electricity Net Generation: Electric Power by Sector Plant Type 1989-2004", Energy Information Administration of the Department of Energy. www.eia.doe.gov

[4] W. McNamara, "Comparison Shopping: Distributed vs. Central Station Generation," *Power Engineering Magazine*, August 2005.

[5] J. Makanski, "Windy Expectations and Frustrations," *Power Engineering Magazine*, September 2005.

[6] "Annual Report to Congress on Federal Government Energy Management and Conservation Programs Fiscal Year 2002," U.S Department of Energy, September 29, 2004.

[7] S. Anders et. al., "Potential for Renewable Energy in the San Diego Region," Tech. Report, August 2005.

[8] Amendment 37, "Colorado Renewable Energy Initiative," November 2004.

[9] Table 5.6.A "Average Retail Price of Electricity to the Ultimate Customers by End-Use Sector, State by State, June 2004-June 2005", Energy Information Administration of the Department of Energy. www.eia.doe.gov

[10] http://www4.law.cornell.edu/uscode/html/uscode30/usc_sup_01_30_10_23.html, Geothermal Steam Act of 1970,

[11] http://www4.law.cornell.edu/uscode/html/uscode30/usc_sup_01_30_10_23.html, Geothermal Steam Act of 1970, http://www.eia.doe.gov/neic/brochure/oil_gas/natgas04/Chapter1.htm

[12] J. Henderson and S. Weiler, "Defining Rural America", The Main Street Economist, Kansas City, KS, July 2004.

[13] J. Higbee, et al., "Residential Electric Power Systems: Implications for Distributed Generation," in *Proc. North American Power Symposium (NAPS)*, Ames, IA, pp. 475-480. Oct. 2005.

[14] K. Malmedal, B. Kroposki and P. K. Sen, "The Energy Policy Act of 2005 and its Impact on Distributed Generation," in *Proc. 2006 IEEE Rural Electric Power Conf.*, IEEE Catalog No. 06CH37745, pp. C2-1:C2-8,

[15] "Fuel Cells and Hydrogen: The Path Forward, A Comprehensive Strategy for Federal Investment In Fuel Cell Technology and Fuel Infrastructure," Breakthrough Technologies Institute, Washington, DC, January 2003.

[16] B. Kroposki, et al., "Electrolysis: Opportunities for Electric Power Utilities in a Hydrogen Economy," in *Proc.* *2006 North American Power Symposium (NAPS)*, Carbondale, IL, pp. 697-706, Sept. 2006.

[17] B. Kroposki, et al., "Benefits of Power Electronic Interfaces for Distributed Energy Systems," *2006 IEEE Power Engineering Society Annual Meeting*, Canada, June 2006.

XIII. BIOGRAPHIES

Keith Malmedal (Member) received his BSEET degree from the Metropolitan State College of Denver in 1995, a MSEE degree (Power) and a MSCE degree (Structures) from the University of Colorado at Denver in 1998 and 2002, respectively. He has over fifteen years experience in designing electric power systems and is presently a principal engineer and project manager at NEI Electric Power Engineering, Arvada, Colorado, specializing in all aspects of power system design. Mr. Malmedal is a registered professional engineer in 14 states. Currently Keith is pursuing his Ph.D degree at Colorado School of Mines, Golden, CO.

Benjamin Kroposki (Sr. Member) received his BSEE and MSEE at Virginia Tech in 1990 and 1992, respectively. Currently he is a senior engineer at the National Renewable Energy Laboratory (NREL) and leader of the Distributed Power Systems Integration Team. His expertise includes the design and testing of distributed power systems. Mr. Kroposki also participates in the development of distributed power standards and codes for the IEEE, the International Electrotechnical Commission (IEC), and the National Electrical Code (NEC). He is a registered professional engineer in Colorado. Ben is pursuing his Ph.D degree at Colorado School of Mines, Golden, CO.

Pankaj K. (PK) Sen (Sr. Member) received his BSEE degree (with honors) from Jadavpur University, Calcutta, India, and the M.Eng. and Ph.D. degrees in electrical engineering from the Technical University of Nova Scotia (Dalhousie University), Halifax, NS, Canada. He is currently Professor of Engineering and the Site Director of the Power Systems Engineering Research Center at Colorado School of Mines in Golden, Colorado. His research interests include application problems in electric machines, power systems, renewable energy and power engineering education. Dr. Sen is a registered professional engineer in the State of Colorado.