How will Renewable Energy Concepts and Nanotechnology affect Engineering Education?

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Abstract *– There is not a day that goes by where we do not hear about Solar Energy, Wind Power, Biodiesel, Ethanol, Biomass, Geothermal and new Nanotechnology devices. All of these have implications for just about every Engineering discipline thus the question arises: Should this information be incorporated into regular Engineering curricula or should it be relegated to seminar topics? If taught in regular courses how much of each topic will be discussed and what will be replaced of the original course material? Will the Chemistry and Physics and Math faculty get on board, or should they be the ones that teach most of these concepts? If the seminar is the chosen avenue, who will present the topics? Can experts in each field be readily found, and if so, how much will it cost to bring in the experts?*
Especially the Renewable Energy Concepts have in certain circles, been highly politicized and therefore it is important that actual data is used and not pie in the sky data. To be fair, conventional energy sources should be considered, which then brings us to fossil fuels and nuclear energy as additional topics.
Faculty in most Engineering areas were not brought up on the above subject matter and in order to be at least proficient in the major areas of renewable energy sources, in fossil fuels , in nuclear energy , much updating is needed. It is fortunate that major University centers run workshops on all of the above subjects during the summer and also during the normal academic year. Engineering curriculums have been inundated in the recent past to incorporate new courses in many areas and where will it leave us, when it comes to protect traditional science, math and engineering subjects. Should we make it possible to create new Energy curriculums based on Engineering Foundations ? There has been a smattering of these curriculums in the US, and it is under consideration in our University. Is this the right way to go? It is worth a spirited discussion.

Index Terms *- Fossil Fuels, Renewable Energy, Nanotechnology, Nuclear Energy*

INTRODUCTION

It is time that the Engineering Community has a very serious dialog about the topics of this paper. It is our obligation as Engineering Educators to try to make sense of the many proposed advantages and disadvantages of these concepts. When we look at all of the political, environmental and self serving pronouncements of leaders of these groups it is very difficult to separate reality from chaff. As the worlds thirst for energy increases all avenues of sources of energies should be looked at but also should be balanced as to viability, environmental effects, cost and effects on future generations. What could be a hot energy topic touted today, could be the disaster of tomorrow. It is a myth that fossil fuels will be replaced in the near future by renewable energy sources. Since at the present time in the US, renewables make up about 7% of all energy used. oil, gas and coal will be with us for a very long time. Our students come to us with energy concept ideas that were picked up through television, the internet, political proclamations, magazines and personal contacts, and how often has one heard comments like why don't we run everything using solar panels? Well, it is not just the student that is confused, but it certainly applies to the general public and most of the University Faculty. How can one keep up with all of the concepts and technologies that are being presented? Some of the energy schemes have been around for centuries, some of the Bio fuel ones for at least 70 years and the basic Biomass scheme is as old as mankind and fire. New exotic schemes seem to spring up just about every week, however this discussion will be limited to some of the more common technologies that are in use today.
In 1958, Nobel Laureate Richard P. Feynman gave his now famous speech " There's plenty of room at the Bottom " , to the American Physical Society at Cal Tech. He was talking about Nanotechnology and his brilliant look into the future has, ever since the invention of the Scanning Tunneling Microscope (STM) in 1981 and the Atomic Force Microscope (AFM) in 1985,

spawned new products and new concepts. It is predicted that within a few years the worldwide market for Nanotechnology based products will be over one trillion dollars. [1]

The topics that were chosen for discussion are topics that at this point have commercial applications and are topics were a manufacturing process was involved. There are of course the processes of generating hydrogen by various means and using it for propulsion of various vehicles. Algae based research is another topic that will possibly have some impact . At this point none of these other topics have widespread commercial applications and will have to wait their turn for future discussion. Water usage for various applications is important and will be addressed in the Bio Diesel and Ethanol discussion as well as in the conclusion. It should be noted , that each one of the topics is discussed in general terms, familiar to most people. A program of Energy Engineering would look at each topic in depth, and with a normal introduction of basic Engineering courses, could be a fascinating new approach .

WIND AND SOLAR POWER

FIGURE 1
WIND MILLS [2]

FIGURE 2
SOLAR ARRAY [2]

Most people now are aware of these technologies and have seen actual installations, similar to the ones shown, in their localities. Many countries, especially in Europe, depend on windmills and solar voltaics for a portion of their power needs. Commercial windmills have over the years matured from an output of approximately 200 Kilowatt to 5 Megawatt and have been installed on land and offshore. In the US the state of Texas leads in wind farm installations and hopes to have 25% of its energy requirements satisfied with wind power by the year 2015. It is of course obvious that the major drawback of wind power is lack of wind. Placements of wind farms requires much research of the yearly average wind velocities and duration. It makes offshore installations more viable because these very rarely have no wind at all. One other concern is the building of numerous transmission lines so the electric power generated can be incorporated into the grid. Standby power has to be supplied by either fossil fuel power plants or nuclear power plants, which would have to come online when wind is absent. This makes the total installation very pricey.

Solar voltaic installations are gaining in popularity because conversion efficiencies have continued to increase over the years, and their low environmental impact and their relative low maintenance are a plus. For large installations, the amount of land required is a problem. To make an installation viable makes location extremely important. The number of sunshine hours per day will determine where to put a commercial project. Usually the closer one is to the equator, the better is the location. Latitude is important. With higher conversion efficiencies though, countries like Germany, which definitely is not in a southern latitude, have managed to make thousands of installations of solar panels on rooftops. Usually government subsidies are needed to accomplish these installations. [2]

A typical problem for students to do, is an Excel [3] spreadsheet problem that compares conversion efficiencies of Photovoltaic cells to landmass needed for installation for cities of 12000 people to 5000000 people. The partial example of this problem is given below

			Input to each city for the given Efficiency values			
Population	Households	Output per City	0.05	0.12	0.13	0.14
12000	4000	40000000	800000000	333333333	307692308	285714286
20000	6667	66666666.67	1.333E+09	555555556	512820513	476190476
50000	16667	166666666.7	3.333E+09	1.389E+09	1.282E+09	1190476190
100000	33333	333333333.3	6.667E+09	2.778E+09	2.564E+09	2380952381
1000000	333333	3333333333	6.667E+10	2.778E+10	2.564E+10	2.381E+10
5000000	1666667	16666666667	3.333E+11	1.389E+11	1.282E+11	1.1905E+11

Avg. use per Household

10000 KW-Hr

Population		No. of Square meters of Solar Panels per city		
12000	365297	152207	140499	130463
20000	456621	253678	234165	217439
50000	1141553	634196	585412	543596
100000	2283105	1268392	1170823	1087193
1000000	22831050	12683917	11708231	10871929
5000000	114155251	63419584	58541154	54359643

Population		No. of Hectares covered by the Solar Panels		
12000	36.5	15.2	14.0	13.0
20000	45.7	25.4	23.4	21.7
50000	114.2	63.4	58.5	54.4
100000	228.3	126.8	117.1	108.7
1000000	2283.1	1268.4	1170.8	1087.2
5000000	11415.5	6342.0	5854.1	5436.0

FIGURE 3
ILLUSTRATION OF LAND MASS NEEDED FOR CITIES OF 12000 TO 5000000 [4] [8]

ETHANOL AND BIODIESEL

FIGURE 4
TYPICAL ETHANOL PLANT IN THE MIDWEST [5]

FIGURE 5
BIODIESEL FRESHMEN PROJECT [8]

The process of creating Ethanol is a chemical reaction which changes glucose in a plant to Ethanol and carbon dioxide through fermentation. Major producers of Ethanol are the US and Brazil. In the US corn is usually the plant base, while in Brazil it is sugarcane. The use of Ethanol has produced much controversy because corn, a food staple is used to propel vehicles which would make corn more expensive for poor countries to buy. The energy content of Ethanol is not as high as gasoline therefore the number of miles traveled per fill up is less. Opponents of Ethanol claim that the energy expended in making it, is greater than the energy obtained from it as a fuel. Ethanol cannot be shipped by pipeline because it absorbs water and therefore must be shipped by truck or rail. Large government subsidies keep the price close to that of gasoline which then makes it competitive. Usually Ethanol is mixed with gasoline and ranges from 10% ethanol to 85% Ethanol. These mixtures are known as E-10 or E-85. Only Brazil runs vehicles with 100% Ethanol. [5]

The June, 2010 issue of the IEEE spectrum devotes numerous pages to trading water for watts. When irrigated, Biofuels present a real problem as far as water consumption is concerned. When driven one kilometer a E-85 vehicle uses 26 liter of water to produce its Ethanol which when compared to using gasoline or diesel fuel, only .33 liter of water is needed to drive one kilometer. [10] [11]

Biodiesel can be obtained from a chemical reaction of a vegetable oil or an animal fat with alcohol (methanol), to produce fatty acid alkyl esters. For the reaction a catalyst like sodium or potassium hydroxide is needed. The final product is Biodiesel and glycerol. [4] Biodiesel is gaining popularity because of its ease of making it, the versatility of its feedstocks, and its excellent lubricating properties as well as its lower exhaust emissions. Feedstocks for Biodiesel can vary depending on its location for processing. In the US usually soybean oil is used, but peanut oil, sunflower oil, animal fats, trap grease, as well as cooking oil from restaurants can be used. In Europe rapeseed is the preferred feedstock. Palm oil or coconut oil can be used in countries where there is an abundance of these plants. Much research is centered on the use of Algae because of its very large yield per acre. The simplest method to produce Biodiesel is is a batch process in a stirred tank reactor. Certain feedstocks that have high free fatty acids will combine with the catalyst and form soap which absolutely has to be removed in a separate process. Numerous other processes have been developed and even a Microwave batch process is in the works. Water has to be removed before the final Biodiesel batch can be used. As is true with Ethanol the use of water when irrigating soybean fields, is very high. It takes 28 liter of water to grow enough soybeans to propel a Biodiesel vehicle over a distance of one kilometer. [10] [11] However there is a distinct difference to Ethanol. Biodiesel can be produced from a large variety of feedstocks that do not need irrigation.

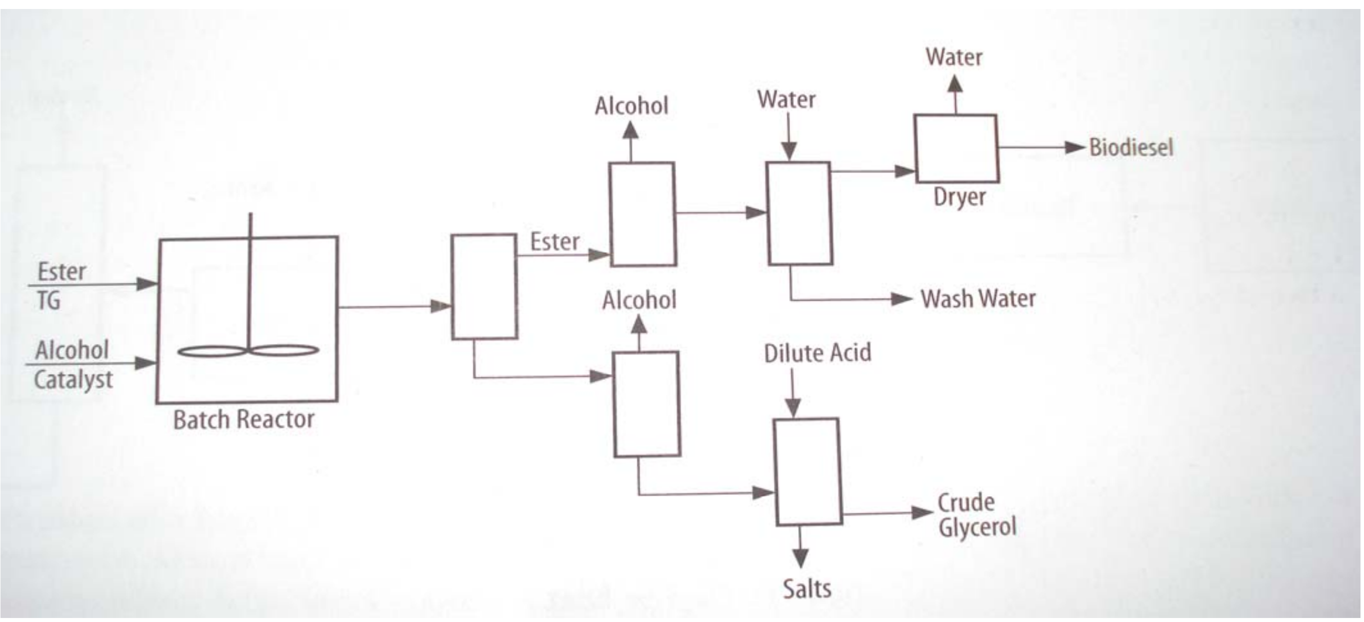
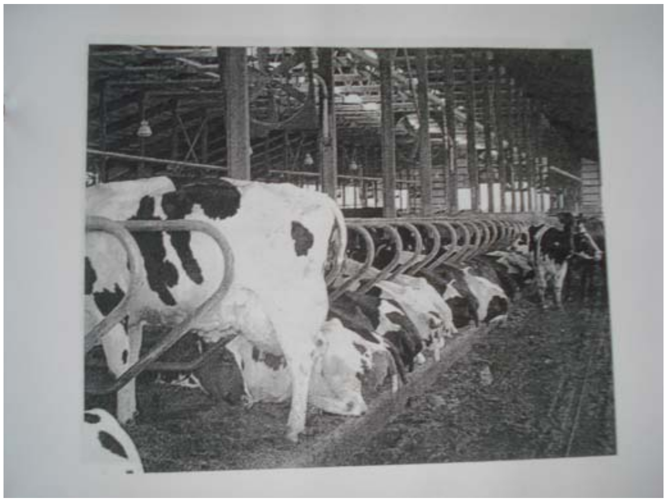


FIGURE 6
BASIC BIODIESEL BATCH PROCESS [6]

BIOMASS



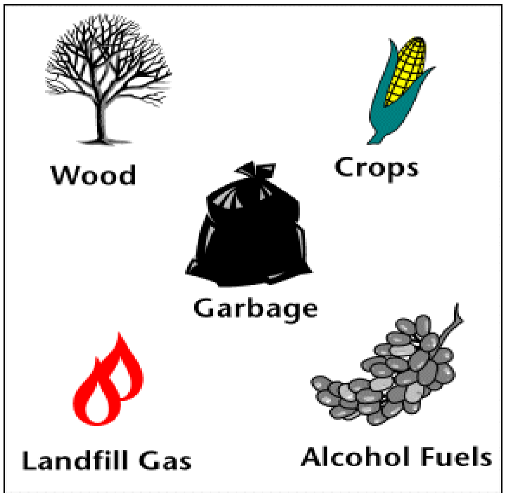


FIGURE 7
MANURE FEEDSTOCK FROM CATTLE NOT GRAZED [7]

FIGURE 8
PARTIAL LISTING OF BIOMASS FEEDSTOCKS [6]

The word Biomass encompasses a large amount of feedstocks that can be used as energy sources. In the northeastern US and in countries like Austria, it is wood that overshadows all others because there is plenty of it. Biomass is stored solar energy and can be used for Combined Heat and Power also referred to as CHP. Separate Heat and Power referred to as SHP is not a fully integrated system. Using CHP essentially gives higher efficiency, because steam from a boiler is used for generation of electricity and for heating purposes and can be referred to as a co-generation facility. CHP systems lend themselves well to supply energy to medium complexes like schools, hospitals, prisons, large apartment complexes and certain industries like greenhouses and nurseries. The wood is run through a large chipper, usually on site and delivered to various customers in the area. The generation of steam in a boiler is used for heating and is used to drive steam turbines to generate electrical power, which can be used on site or delivered to the power grid.
Methane generated from large farm complexes, sewage treatment plants and landfills can also be used for heating, cooling, or to drive a motor generator set for generating electrical power. After treatment to remove many toxic substances, the generated methane could be added to commercial gas lines.

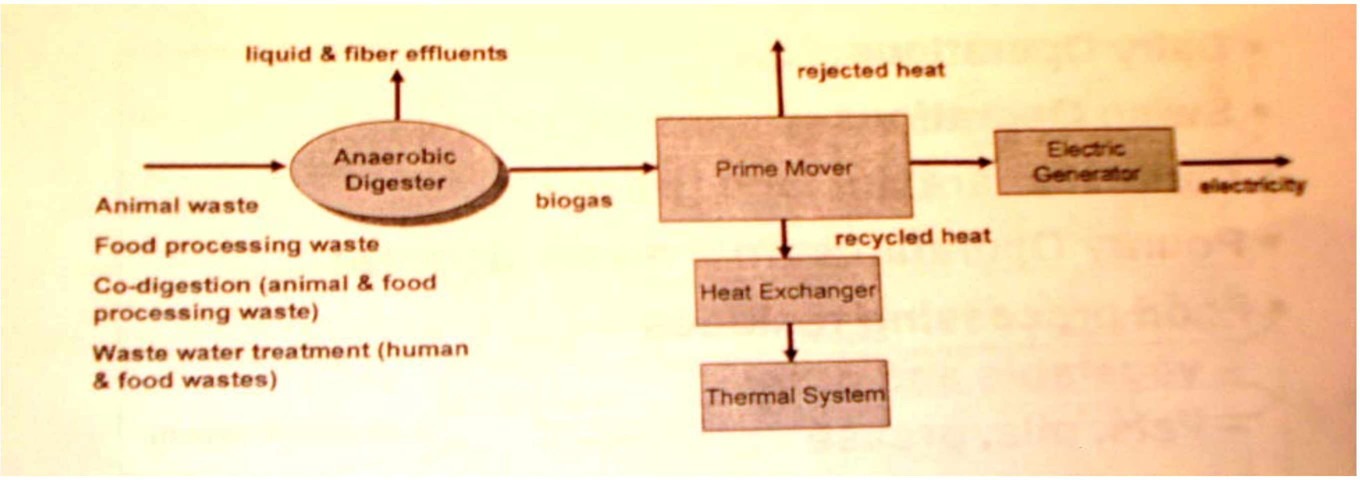
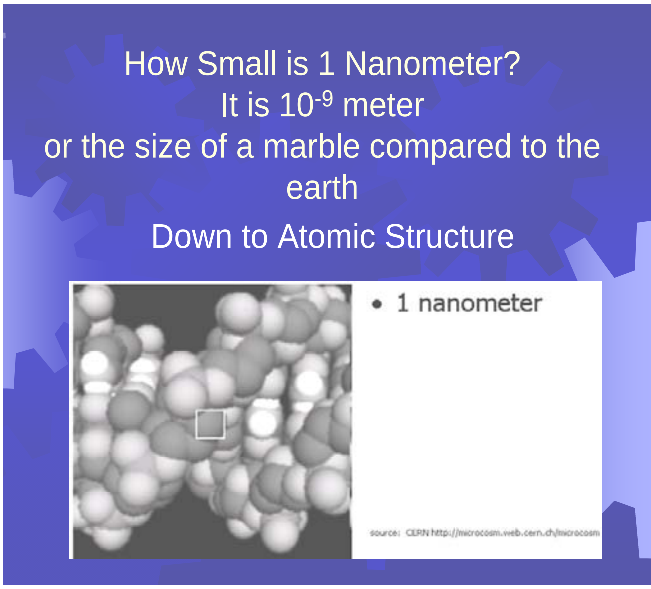


FIGURE 9
BIOGAS CHP APPLICATIONS [7]

NANOTECHNOLOGY



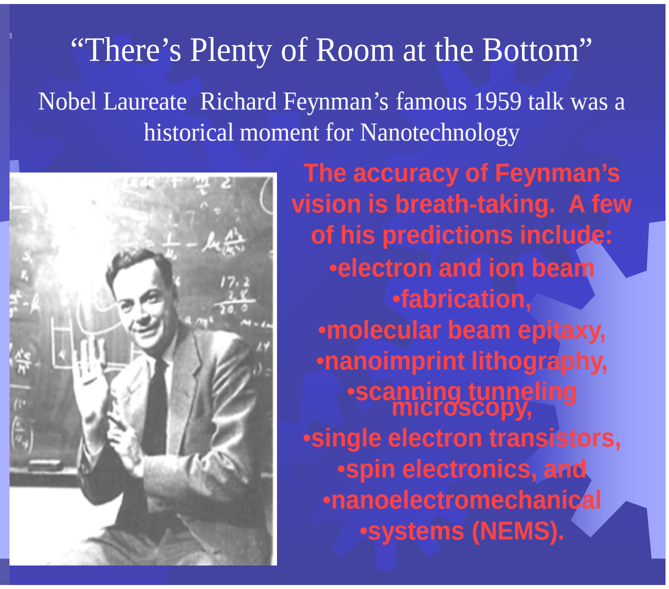


FIGURE 10
DESCRIPTION OF 1 NANOMETER—NOTE SMALL SQUARE [1]

FIGURE 11
RICHARD FEYNMAN AND HIS FAMOUS PREDICTION [1], [9]

In order to discuss Nanotechnology, it is imperative to have a historical understanding of how we got to our present involvement with this technology. It has always been a desire in Engineering to make things smaller, lighter, and more efficient. A good example is the number of transistors that will fit on a chip. We have gone from a few transistors to millions and we are still trying to best that figure. In 1905, who else but Albert Einstein was making measurements at nanoscale to determine the size of sugar molecules. The invention of the electron microscope in 1931 made it possible to look at nanoparticles, but it was Richard P. Feynman (1918-1988) in 1958, whose vision opened the door to present day nanoscale experimentation and research. A flurry of activity in the 1980's and 1990's and early 2000's in the area of physics, chemistry, materials science, and engineering produced devices and materials that would advance nanotechnology to a level recognized by the Federal Government in 2001 with the National Nanotechnology Initiative (NNI). In 2008 the NNI budget was 1.5 billion. Some of the inventions and experiments that propelled Nanotechnology into the forefront were the following: The Scanning Tunneling Microscope (STM) in 1981, The Atomic Force Microscope (AFM) in 1985, The discovery of C 60, (known as buckyballs) in 1985, Discovery of Carbon Nanotubes in 1991, Foundation for nanobiotech laid in 1992 with ATP synthase, Quantum dots in 1993, Nanotransistor in 1997, DNA motor in 2000, Prototype fuel cell from nanotubes in 2001, and even Stain repellent pants in 2002. [1]

Just about every day a news article shows a nanoscale invention or use, like " Nanoparticle coating turns glass into motion detector'," Nanotube ribbons conductive, transparent and flexible", "Development of piezoelectric nanowires" and the list goes on and on. Developments in the medical field will have profound effects on cure rates for all kinds of diseases.

Two processes are involved in the manufacturing of nanodevices. Top down manufacturing or TDM, is essentially the process involved in the making of integrated circuits and is a method that has been used for many years. It can be set up in the laboratory to simulate photolithography and deposition and sputtering . The equipment necessary is fairly standard and includes a vacuum pump, vacuum chamber and some special devices which are also readily available. Bottom up manufacturing, or BUM is the process of spontaneous assembly of raw materials into well organized structures. This is the area that most of the research is based on. [1]

When we can build completely new devices and structures from the assembly of atoms and molecules, when devices and materials can be designed for specific purposes, we have reached a level of sophistication that can be extremely beneficial, but can also be dangerous.. The meaning of self assembly is that atoms can arrange themselves in a fashion that will lead to devices that can be useful and possibly lifesaving. There is however a number of people that worry about the influence of nano materials in the food chain, the biosphere and the area of robotics. Is it possible that nanotechnology could make humans an endangered species? Bill Joy, cofounder and chief scientist at Sun Microsystems certainly thinks so and has great reservations about runaway self assembly. Should we disregard voices like his? No, we should not. When we enter this new world we must make sure that we try to set up safeguards that will prevent dire consequences. [1] [9]

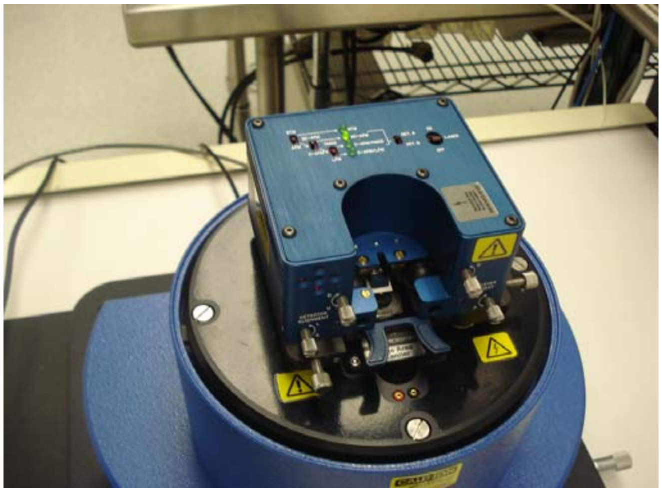


FIGURE 12
THE ATOMIC FORCE MICROCOPE (AFM) [9]

FIGURE 13
THE AUTHOR OPERATING THE AFM [9]

CONCLUSIONS

The topics outlined in this paper are a major portion of the renewable energy spectrum that is in use today. As we go into the first quarter of this century will these priorities change, get more sophisticated or be discarded for technologies that are not possible today? Will we discover more fossil fuel reserves that will make certain renewables so expensive that they will be shelved? It has been found that natural gas reserves in shale formations far exceed previous estimates. Will this impact Biomass use and development? Will Nuclear Fission Energy make a comeback or will the much discussed Nuclear Fusion finally come to fruition?

It is a foregone conclusion that Nanotechnology will play a major part in the development of new energy sources and increasing the efficiencies of present day sources.

Will water scarcity impact the use and development of renewable sources?

One could go on and on with these questions but in many cases there is no answer at the present. It is the future that decides the answer.

Are most Engineering Educators aware of what goes on in energy development and use? The principles of chemical engineering, electrical engineering, mechanical engineering, material science, thermodynamics and engineering economics are all present to a certain degree. Can we incorporate these themes into our present curricula? From this vantage point the answer is a resounding no. We can touch on the vast array of these topics, but we can only do justice to them by establishing new programs. Energy Engineering could be a program, when based on the principles of basic Engineering, that would be an exciting new avenue in Engineering Education. What is your opinion?

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