Environmentally Friendly and Sustainable Source of Energy from Photovoltaics and Fuel Cells

A. Boudghene Stambouli , N. Larbi and E. Traversa*

University of Sciences and Technology of Oran.
Department of Electronics, BP 1505, EL M'Naouer. Oran (31000). Algeria
*University of Roma "Tor Vergata", Department of Chemical Science and Technology
mailto:aboudghenes@yahoo.com

ABSTRACT
Several definitions of sustainable development have been put forth, including the following common one: development that meets the needs of the present without compromising the ability of future generations to meet their own needs. A recent World Energy Council (WEC) study found that without any change in our current practice, the world energy demand in 2020 would be 50 to 80% higher than 1990 levels. According to a recent U.S. Department of Energy (DoE) report, annual energy demand will increase from a current capacity of 363 million kilowatts to 750 million kilowatts by 2020. The world's energy consumption today is estimated to 22 billion kWh per year, 53 billion kWh by 2020. Such ever increasing demand could place significant strain on the current energy infrastructure and potentially damage world environmental health by CO, CO_2, SO_2, NO_X effluent gas emissions and global warming. Achieving solutions to environmental problems that we face today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions since the intimate relationship between renewable energy and sustainable development. More rational use of energy is an important bridge to help transition from today's fossil fuel dominated world to a world powered by non-polluting fuels and advanced technologies such as photovoltaic (PV) and fuel cells (FC). This paper discusses the potential for such integrated systems in the stationary and portable power market in response to the critical need for a cleaner energy technology. Anticipated patterns of future energy use and consequent environmental impacts (acid precipitation, ozone depletion and the greenhouse effect or global warming) are comprehensively discussed in this paper. Throughout the paper several issues relating to renewable energies, environment and sustainable development are examined from both current and future perspectives.

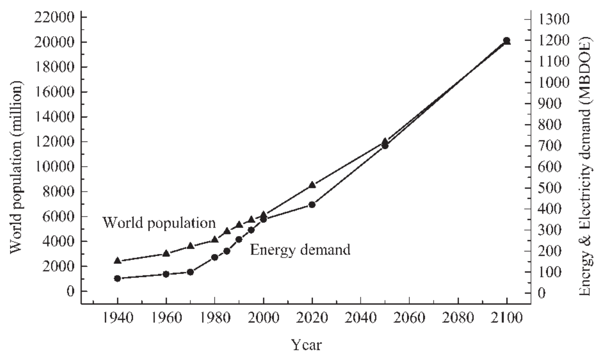
KEYWORDS: Environment, Energy, Photovoltaics, Fuel Cells

INTRODUCTION
Energy security, Economic growth and Environmental protection are the national energy policy drivers of any country of the world. As world populations grow, many faster than the average 2%, the need for more and more energy is exacerbated (Fig. 1). Enhanced lifestyle and energy demand rise together and the wealthy industrialized economies, which contain 25% of the world's population, consume 75% of the world's energy supply. The world's energy consumption today is estimated to 22 billion kWh per year. About 6.6 billion metric tons carbon equivalent of greenhouse gas emission are released in the atmosphere to meet this energy demand (USDoE, 2001). Approximately 80% is due to carbon emissions from the combustion of energy fuels. At the current rate of usage, taking into consideration population increases and higher consumption of energy by developing countries, oil resources, natural

Correspondent author: A. Boudghene Stambouli, email: aboudghenes@yahoo.com

gas and uranium will be depleted within a few decades. As for coal, it may take two centuries or so.

Technological progress has dramatically changed the world in a variety of ways. It has, however, also led to developments - e.g. environmental problems - which threaten man and nature. Build-up of carbon dioxide and other greenhouse gases is leading to global warming with unpredictable but potentially catastrophic consequences. When fossil fuels burn, they emit toxic pollutants that damage the environment and people's health with over 700,000 deaths resulting each year, according to the World Bank review of 2000.



(MBDOE=Millions of Barrels per Day of Oil Equivalent)

Figure 1. Actual and estimated world population and energy demand

At the current rate of usage, taking into consideration population increases and higher consumption of energy by developing countries, oil resources, natural gas and uranium will be depleted within a few decades, as shown in Fig. 2. As for coal, it may take two centuries or so. One must therefore endeavor to take precautions today for a viable world for coming generations.

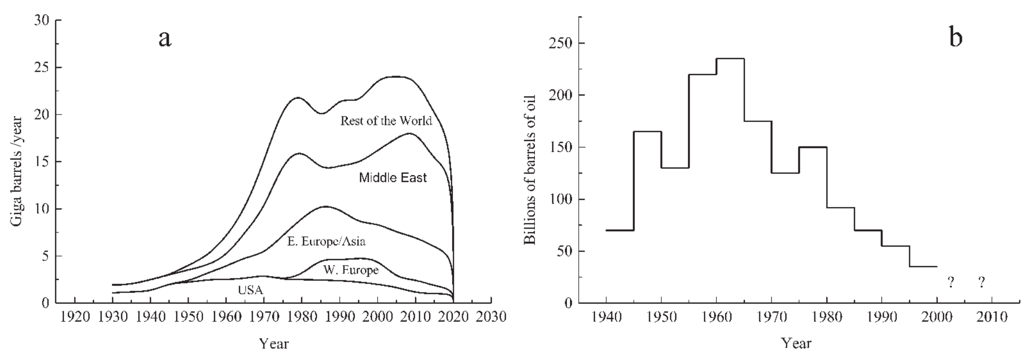


Figure 2. a. World oil production in the next 10-20 years.
b. Volume of oil discovered worldwide.

Research into future alternatives has been and still being conducted aiming to solve the complex problems of this recent time - e.g. rising energy requirements of a rapidly and constantly growing world population and global environmental pollution. Therefore, options for a long-term and environmentally friendly energy supply have to be developed leading to the use of renewable sources (water, sun, wind, biomass, geothermal, hydrogen) and fuel cells. Renewables could shield a nation from the negative effect in the energy supply, price and related environment concerns. Hydrogen for fuel cells and the sun for photovoltaic have been considered for many years as a likely and eventual substitute for oil, gas, coal and uranium. They are the most abundant elements in the universe. The use of solar energy or photovoltaics for the everyday electricity needs has distinct advantages: avoid consuming resources and degrading the environment through polluting emissions, oil spills, and toxic by-products. A one-kilowatt PV system producing 150 kWh each month prevents 75 kg of fossil fuel from being mined, 150 kg of CO_2 from entering the atmosphere, and keeps 473 liter of water from being consumed. Electricity from fuel cells can be used in the same way as grid power: to run appliances and light bulbs, and even to power cars since each gallon of gasoline produced and used in an internal combustion engine releases roughly 12 kg of CO_2, a greenhouse gas that contributes to global warming.

ENVIRONMENTAL PROBLEMS

Technological progress has dramatically changed the world in a variety of ways. It has, however, also led to developments of environmental problems, which threaten man and nature. During the past two decades the risk and reality of environmental degradation have become more apparent. Growing evidence of environmental problems is due to a combination of several factors since the environmental impact of human activities has grown dramatically because of the sheer increase of world population, consumption, industrial activity, etc. Throughout the 1970s most environmental analysis and legal control instruments concentrated on conventional effluent gas pollutants such as SO_2, NO_X, CO_2, particulates, and CO. Recently environmental concern has extended to the control of micro- or hazardous air pollutants, which are usually toxic chemical substances and harmful in small doses, as well as to that of globally significant pollutants such as CO_2. Aside from advances in environmental science, developments in industrial processes and structures have led to new environmental problems. For example, in the energy sector, major shifts to the road transport of industrial goods and to individual travel by cars has led to an increase in road traffic and hence a shift in attention paid to the effects and sources of NO_x and volatile organic compound (VOC) emissions. Environmental problems span a continuously growing range of pollutants, hazards and ecosystem degradation over wider areas. The main areas of environmental problems are: major environmental accidents, water pollution, maritime pollution, land use and sitting impact, radiation and radioactivity, solid waste disposal, hazardous air pollutants, ambient air quality, acid rain, stratospheric ozone depletion, and global warming (greenhouse effect, global climate change).

Problems with energy supply and use are related not only to global warming that is taking place, due to effluent gas emission mainly CO_2, but also to such environmental concerns as air pollution, acid precipitation, ozone depletion, forest destruction, and emission of radioactive substances. These issues must be taken into consideration simultaneously if humanity is to achieve a bright energy future with minimal environmental impacts. Much evidence exists, which suggests that the future will be negatively impacted if humans keep degrading the environment (Table 1).

Table 1. Global emissions of the top fourteen nations by total CO_2 volume (billions of tonnes)

Rank	Nation	CO_2	Rank	Nation	CO_2	Rank	Nation	CO_2
1	U.S.A	1.36	6	India	0.19	11	Mexico	0.09
2	Russia	0.98	7	U.K.	0.16	12	Poland	0.08
3	China	0.69	8	Canada	0.11	13	S. Africa	0.08
4	Japan	0.30	9	Italy	0.11	14	S. Korea	0.07

During the past century, global surface temperatures have increased at a rate near 0.6 °C/century (US National Oceanic and Atmospheric Administration, 2001) and the average temperature of the Atlantic, Pacific and Indian Oceans (covering 72% of the earth surface) has risen by 0.06 °C since 1995. Global temperatures in 2001 were 0.52 °C above the long-term 1880-2000 average (*the 1880-2000 annually averaged combined land and ocean temperature is 13.9 °C)*. Also, according to the U.S. Department of Energy (DoE), world emissions of carbon are expected to increase by 54 % above 1990 levels by 2015 making the earth likely to warm 1.7-4.9 °C over the period 1990-2100, as shown in Fig. 3 (US National Centre for Atmospheric Research, 2001). This is just one of many energy use environmental impacts. Such observation and others (A. Boudghene S., 2000) demonstrate that interest will likely increase regarding energy related environment concerns and that energy is one of the main factors that must be considered in discussions of sustainable development.

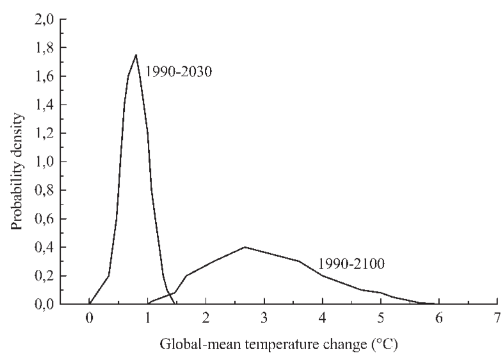


Figure 3. Global-mean temperature change over the period of 1990-2100 and 1990-2030

PHOTOVOLTAICS

The sun is a very important source of energy and no path into the future can ignore the sun. This type of energy is diffused in the space and reaches the earth in the form of solar light (47%), ultraviolet rays (7%) and infrared rays or heat (46%). The solar light and infrared rays are the only elements that provide useful energy for thermal and photovoltaic conversion. Efficiency improvement, cost reduction and high reliability have contributed to the expansion of solar-depending systems globally. Solar energy is cost-effective in terms of fuel (because no fuel is required) and its price would not be affected by the supply and demand of fuels. Solar energy is also pollution free. In addition, as solar energy does not use fuel, it also eliminates the problems that arise during the recovery, transportation and storage of fuels.

In April 2001, a record has been surpassed for electricity produced by solar cells made from cadmium telluride, a development that could help meet expanding demand for solar systems. Cadmium telluride represents one of the most promising technologies for the so-called thin film solar cells that yield higher wattage per square meter, at a lower price per watt of capacity. The measurement of 16.4% efficiency bested the previous threshold of 15.8% efficiency for cells based upon the same material, a record that has stood since 1992 (Gary Schmitz, 2001). Increasing efficiency and lowering costs are being made by developing new materials and processes (organic materials and bicolour solar cells technology) to improve adhesion, light collection, electronic properties and help reduce the cost of solar electric systems by some ten-fold. The measurement of 22% efficiency has been reached by using GaAs/Si bicolour technology (Joseph Galdo, 2001). Earlier this year many laboratories throughout the world embarked on a program to reduce PV price by another 50% by the end of the decade.

In 2000, the photovoltaic industry increased production by 39% worldwide, 42% in 2002. In recent months the rising cost of fuel and the increasing demand for a cleaner energy technology have spurred an even greater surge in installation of solar electric systems for homes and businesses, with the solar industry expanding to meet this rising demand (see Fig. 4 and Table 2).

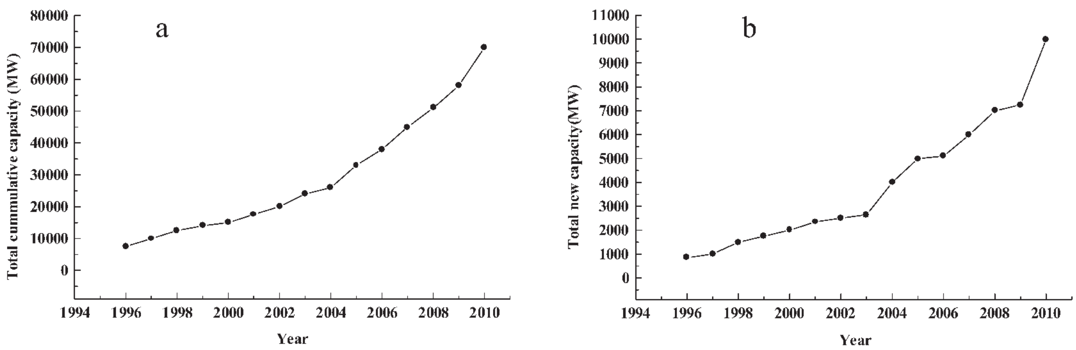


Figure 4. a. Total global cumulative capacity power photovoltaic production (1996-2010).
b. New capacity power photovoltaic production in MW (1996-2010)

Table 2. World photovoltaic cell / module shipment in MW (8WEC, 2002)

Country	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
USA	22.4	25.6	34.7	38.8	53.0	64.5	85.0	100.2	151.58	222.84
Japan	16.7	16.5	16.4	21.2	35.0	44.1	64.2	84.15	94.17	100.50
Europe	16.5	21.7	20.1	18.8	29.3	35.4	54.2	71.27	101.20	131.39
Rest of the world	4.4	5.6	6.35	9.75	9.40	12.5	25.1	35.40	48.48	51.02

Aiming to protect the environment worldwide, mid-term and long-term goals in the application of PV modules, until the year 2030, is shown in Table 3 with a willing power storage density of 5 kWh/m^2 (WEC, 2002).

Table 3. Photovoltaic mid-term and long-term programme goals worldwide

Factor	1995-2000	2005-2010	2010-2030
Module efficiency (%)	15-20	20	20-25
Electricity price $/kW	0.2-0.5	0.2	0.2-0.05
System lifetime (years)	20-25	25-30	25-30
Installed capacity (MW)	2200	50000	50000-200000

Nowadays, solar energy represents 4.5% of all prime energy use which will jump to 10% in the near future, by the year 2020, it could reach a minimum 25% of the world energy supply, depending on the considered scenarios of the World Energy Council (WEC) and 45% by 2060 as predicted by Shell international petroleum company (power production exceeding 1250 exajoules, 1 exajoule = 10^{18} joules; it's also roughly equivalent to the energy from 170 billion barrels of oil) (Shell, 1998). If sufficient research and development effort occurs before this horizon the share of the solar might reach more for the long-term perspective.

Arab countries are endowed with large reserves of energy sources, mainly hydrocarbons and solar energy. Practical applications of solar energy, however, are still limited due to the high costs and the need for advances in technology. It is now important in educating the public as well as introducing special energy legislation to increase the usage of this clean form of energy whether in private or public sectors and show the importance of energy efficiency and conservation. Solar energy is the most abundant natural resource in Algeria. It becomes imperative for Algeria to exploit this important energy resource. Overall, Algeria hopes to increase the share of solar in the country's electricity mix to 5% by 2010.

FUEL CELLS

A fuel cell is an energy conversion device that converts the chemical energy of a fuel gas directly to electrical energy and heat without the need for direct combustion as an intermediate step, giving much higher conversion efficiencies than conventional thermo-mechanical methods. The operating principles of fuel cells are similar to those of batteries, i.e., electrochemical combination of reactants to generate electricity, a combination made of a gaseous fuel (hydrogen) and an oxidant gas (oxygen from the air) through electrodes and via an ion conducting electrolyte. However, unlike a battery, a fuel cell does not run down or require recharging. Fuel cell operates as long as both fuel and oxidant are supplied to the electrodes and the influence it exerts on the surrounding environment is negligible. Fuel cells promise to be extremely useful in large, high-power applications such as full-scale industrial stations and large-scale electricity-generating stations.

DESIGN AND OPERATION OF FUEL CELLS

A fuel cell consists of two electrodes sandwiched around an electrolyte. Hydrogen fuel is fed into the anode of the fuel cell and oxygen, from the air, enters the cell through the cathode. The hydrogen, under the action of the catalyst, splits into protons (hydrogen ions) and electrons, which take different paths towards the cathode. The proton passes through the electrolyte and the electron create a separate current that can be used before reaching the cathode, to be reunited with the hydrogen and oxygen to form a pure water molecule and heat as shown in Fig. 5.

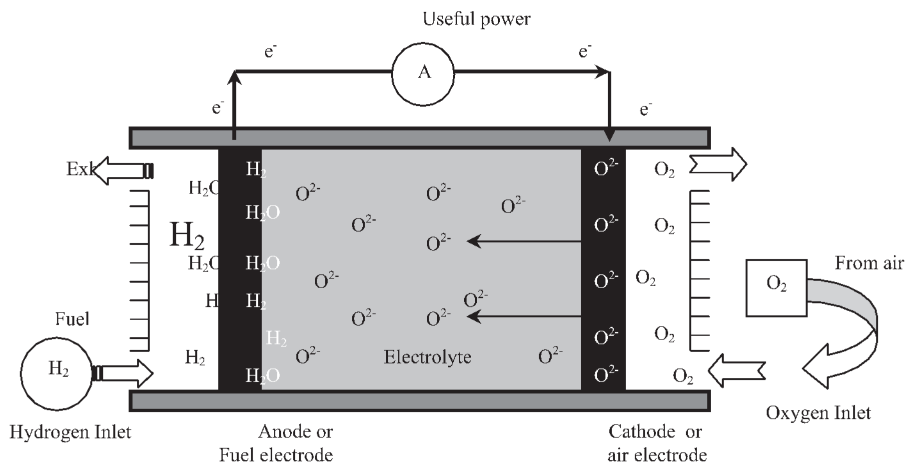


Figure 5. Concept diagram of a fuel cell based on oxygen-ion conductors

TYPES OF FUEL CELLS

Fuel cells are generally classified by the chemical characteristics of the electrolyte used as the ionic conductor in the cell, as summarized in Table 4.

The first five types are characterized by their low to medium temperature (50-210 ºC) of operation, their relatively low electrical generation efficiencies (40-50% when operated on readily available fuels such as methanol and hydrocarbons, 50% when using pure hydrogen fuel). The latter three types are characterized by their high temperature of operation (600 and 900 º C), their ability to utilize methane directly in the fuel cell and thus their high inherent generation efficiency (45-60% for common fuels such as natural gas, 90% with heat recovery) (Int. Fuel Cells, 2000).

COMPONENTS OF FUEL CELLS

A fuel cell is mainly composed of two electrodes, the anode and the cathode, the catalyst, and an electrolyte. The fuel is also important as the principal parameter but independent of the other as it is most of the time converted into hydrogen. The main function of the electrode is to bring about reaction between the reactant (fuel or oxygen) and the electrolyte without itself being consumed or corroded. It must also bring into contact the three phases i.e. the gaseous fuel, the liquid or solid electrolyte, and the electrode itself. The anode, used as the negative post of the fuel cell, disperses the hydrogen gas equally over the whole surface of the catalyst and conducts the electrons, that are freed from hydrogen molecule, to be used as useful power in an external circuit. The cathode, the positive post of the fuel cell, distributes the oxygen fed to it onto the surface of the catalyst and conducts the electrons back from the external circuit where they can recombine with hydrogen ions, passed across the electrolyte, and oxygen to form water. The catalyst is a special material that is used in order to facilitate the reaction of oxygen and hydrogen. This can be a platinum coating as in Proton Exchange Membranes or nickel and oxide for Solid Oxide fuel cells. The nature of the electrolyte, liquid or solid, determines the operating temperature of the fuel cell. It is used to prevent the two electrodes, by blocking the electrons, to come into electronic contact. It also allows the flow of charged ions from one electrode to the other. It can either be an oxygen ion conductor or a hydrogen ion (proton) conductor, the major difference between the two types is the side in the fuel cell in which the water is produced : the oxidant side in proton-conductor fuel cells and the fuel side in oxygen-ion-conductor ones. To produce significant amounts of power, practical fuel cell elements are assembled into a stack, analogous to a multi-layered sandwich (Fig. 6).

Table 4. Technical characteristics of different fuel cells

Types of FC	Electrolyte	Operating T	Fuel	Oxidant	Efficiency
(AFC)	Potassium hydroxide (KOH)	50-200 °C	Pure hydrogen or hydrazine	O_2/Air	50-55%
(DMFC)	Polymer	60-200 °C	Liquid methanol	O_2/Air	40-55%
(PAFC)	Phosphoric acid	160-210 °C	Hydrogen from hydrocarbons and alcohol	O_2/Air	40-50%
(SAFC)	Sulphuric acid	80-90 °C	Alcohol or impure hydrogen	O_2/Air	40-50%
(PEMFC)	Polymer, proton exchange membrane	50-80 °C	Less pure hydrogen from hydrocarbons or methanol	O_2/Air	40-50%
(MCFC)	Molten salt such as nitrate, sulphate, carbonates...	630-650 °C	Hydrogen, carbon monoxide, natural gas, propane, marine diesel	CO_2/O_2/Air	50-60%
(SOFC)	Ceramic as stabilised zirconia and doped perovskite	600-900 °C	Natural gas or propane	O_2/Air	45-60%
(PCFC)	Thin membrane of barium cerium oxide	600-700 °C	Hydrocarbons	O_2/Air	45-60%

(AFC)=Alkaline, (DMFC)= Direct Methanol, (PAFC)= Phosphoric Acid, (SAFC)= Sulphuric Acid, (PEMFC)= Proton-Exchange Membrane, (MCFC)= Molten Carbonate, (SOFC)= Solid Oxide, (PCFC)= Protonic Ceramic

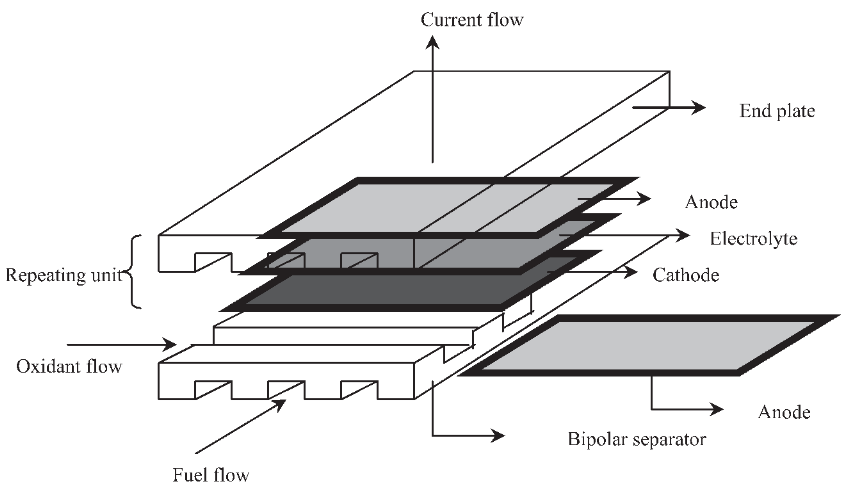


Figure 6. Typical planar flat-plate fuel cell stack configuration

The stack is the main component of the power section in a fuel cell power plant in which cell assemblies, each including an anode, electrolyte, and cathode, are stacked with interconnecting plates between them that connect the anode of one cell to the cathode of the next cell in the stack. The cells are connected in electrical series to build a desired output voltage and can be configured in series, parallel, series-parallel or as single units, depending upon the type of applications. The number of fuel cells in a stack determines the total voltage, and the surface of each cell gives the total current.

PHOTOVOLTAICS/FUEL CELLS

There is, however, one disadvantage to solar energy: the sun does not always shine and we need a way to store solar energy for times when the sun is not shining. In the long term, the concept of solar energy also includes the question of energy storage. After all, electricity must still be available even if the sun isn't shining. Hydrogen, the most attractive storage medium, provides a safe, efficient, clean way to do this. Here is how the solar hydrogen cycle works: electricity from photovoltaic panels can be used to run an electrolyser, a device which splits water (H_2O) into its elemental parts, hydrogen (H_2) and oxygen (O_2). The oxygen is released into the air and the hydrogen is pumped into storage tanks, where it can be kept on site or transported to sun-poor regions. At night, when solar energy is not available, the hydrogen is recombined with oxygen from the air (20% availability) in a fuel cell, an electrochemical power plant that directly converts the chemical energy in hydrogen into electric current without major pollution. The only by-product of this process is pure water. Solar/fuel cells will allow the use of power from the sun twenty-four hours a day, and will provide an abundant, clean, efficient, locally produced source of energy as shown in Fig. 7.

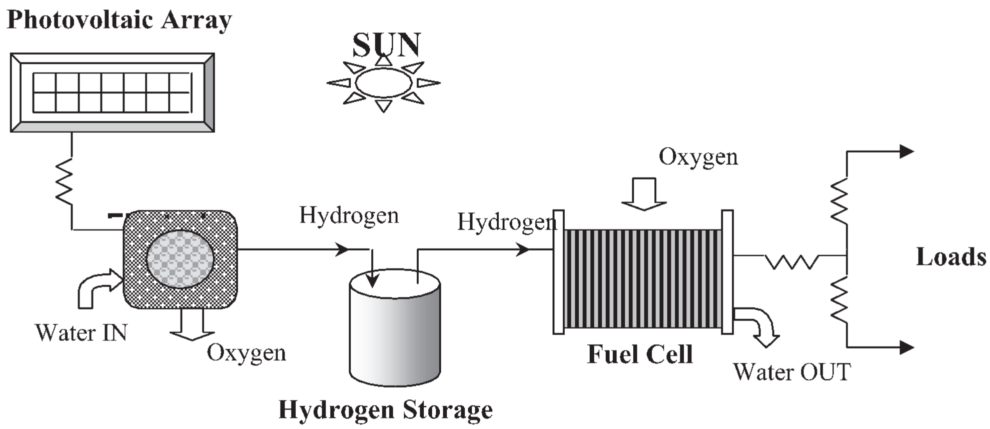


Figure 7. Photovoltaic/Fuel Cells, the process

The solar-hydrogen energy system for Algeria would could extend the availability of fossil fuels resources, reduce pollution, and establish a permanent energy system. In the future Algeria could become an exporter of hydrogen to Europe. Algeria and the International Energy Agency agreed on technological cooperation in developing solar power to provide a clean permanent energy system, and would enable Algeria to maintain and improve its overall GNP, as well as improving its quality life.

APPLICATIONS OF PHOTOVOLTAICS/FUEL CELLS

Photovoltaics/fuel cells could be used in many applications. Each proposed use raises its own issues and challenges. The most needed uses are:

- High power reliability: computer facilities, call centres, communication facilities, data processing centres and high technology manufacturing facilities
- Emission minimization or elimination: urban areas, industrial facilities, airports, zones with strict emissions standards
- Limited access to utility grid: rural or remote areas, maximum grid capacity
- Biological waste gases are available: waste treatment plants, fuel cells can convert waste gases to electricity and heat with minimal environment intrusion. The emission of fuel cell running on hydrogen derived from a renewable source will be noting but water vapor.

PHOTOVOLTAICS/FUEL CELLS, THE ENVIRONMENTAL IMPACT

Issues of efficiency and ecology converge at this time to renew interest in Photovoltaic/fuel cells as systems for electricity generation. In recent times, they attract serious attention in the utility industries, particularly in co-generation of heat and power. The environmental impact of Photovoltaics/fuel cells use depends upon the source of hydrogen-rich fuel used. If pure hydrogen is used, fuel cells have virtually no emissions except water and heat. As mentioned earlier, hydrogen is rarely used due to problems with storage and transportation, but in the future many people have predicted the growth of a solar hydrogen economy. In this scenario, fuel cells generating stations would have no real emissions of greenhouse or acid gases, or any other pollutants.

It is predominantly during the fuel processing stage that atmospheric emissions are released by a fuel cell power plant. However, high efficiency of fuel cells results in less fuel being consumed to produce a given amount of electricity, which corresponds to lower emission of carbon dioxide CO_2, the main 'greenhouse gas' responsible for global warming. When hydrogen from natural gas is used as a fuel, fuel cells have no net emissions of CO_2 because any carbon released is taken from the atmosphere by photosynthetic plants. A reduction of carbon dioxide emissions by more than 2 million kg per year can be obtained. Moreover, emissions from photovoltaic/fuel cell systems will be very low with near-zero levels of NO_X, SO_X and particulates, therefore eliminates 20000 kg of acid rain and smog-causing pollutants from the environment. In any case fuel cells generally provide the lowest emissions of any non-renewable power generation method such as traditional thermal power plants, as shown in Table 5 (Hydrogen and Fuel Cell Letter, 2001).

Table 4. Technical characteristics of different fuel cells

Air emissions*	**SO_X**	**NO_X**	**CO**	**Particles**	**Organic compounds**	**CO_2**
Fossil fuelled plant	12740	18850	12797	228	213	1840020
Fuel cell system	0	0	32	0	0	846300

*kgs of emissions per 1650 MWh from one year full operation x

This is very important regarding energy related environment concerns. When combined with a heat engine that uses any waste heat, fuel cells are the most clean and efficient devices available for this purpose.

PHOTOVOLTAICS/FUEL CELLS BENEFITS

Photovoltaic/fuel cells systems have many advantages: they can be modular, they can be distributed to eliminate the need for transmission lines, they operate quietly and are vibration free. Fuel cells could provide higher system efficiency and higher power density. At low enough costs, they could compete with combined cycle gas turbines for distributed applications. The benefits also include:

- Energy security: reduce oil consumption and increase the amount of the country's available electricity supply.
- Reliability: achieves operating times in excess of 90% and power available 99.99% of the time.
- Low operating and maintenance cost: the efficiency of the Photovoltaics/fuel cells system will reduce drastically the energy bill (mass production) and have lower maintenance costs than their alternatives.
- Constant power production: generates power continuously unlike backup generators, diesel engines or Uninterrupted Power Supply (UPS).

CONCLUSION

Energy from fossil fuels is reaching its limits; future alternatives must therefore be conducted to develop options for a long term and environmentally friendly energy supply for a constantly growing world population. Solar energy and fuel cells provide highly efficient, pollution-free power generation. Their performance has been confirmed by successful operation power generation systems throughout the world. Electrical-generation efficiencies of 20% and 70% respectively are possible nowadays along with a heat recovery possibility. In the near future, thermal, photovoltaic and fuel cells based power systems will be ideal distributed power-generation systems: reliable, clean, quiet, environmentally friendly, and fuel conserving.

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منابع طاقة مستدامة و محافظة على البيئة: الطاقة الشمسية و خلايا الوقود

بودغن سطمبولي، ن. العربي، إ. ترافرسا*

جامعة العلوم والتكنولوجيا بوهران، معهد الإلكترونيك، ع ب 1505 ، المنور، وهران ،(31000). الجزائر
* جامعة روما" تورفرقاتا". معهد علم الكيمياء والتكنولوجيا

ملخص

قد قدمت عدة تعريفات للتنمية المستدامة بما فيها: التنمية التي تواكب متطلبات العصر الحالي، دون الإساءة إلى قدرة تحقيق المتطلبات الذاتية للأجيال القادمة. دراسات حديثة للمجلس الدولي للطاقة (WEC) استيقنت أنه إذا لم يكن أي تغيير للتطبيقات الحالية، الاستهلاك العالمي للطاقة في 2020 سيفوق مستوى 1990 بنسبة تتراوح من 50 إلى 80%. وفقا لتقرير حديث للمعهد الأمريكي للطاقة (DoE)، الاستهلاك السنوية للطاقة سيزيد من سعته الحالية التي تقدر بـ 363 كيلو واط إلى 750 كيلو واط في 2020. يقدر اليوم الاستهلاك العالمي للطاقة بـ 22 بليون كيلو واط ساعة، وسيصل إلى 53 كيلو واط ساعي في 2020. هذه الزيادة في الاستهلاك قد تؤثر بطريقة ملموسة في البنية التحتية للطاقة وبإمكانها إلحاق ضرر بصحة البيئة في العالم عن طريق إصدار الغازات الملوثة التالية: CO, CO_2, SO_2, NO_X وارتفاع عام لدرجة حرارة سطح الأرض .و من أجل الوصول إلى حلول لمشاكل البيئة التي نواجهها اليوم يتطلب منا بذل مجهودات ذات نظرة بعيدة المدى لتحقيق تنمية مستدامة. في هذا الإطار ونظرا للعلاقة الجوهرية الكامنة بين الطاقات المتجددة و التنمية المستدامة، تبدو الطاقات المتجددة من بين الحلول الفعالة والمؤثرة. الاستعمال العقلاني للطاقة يعتبر جسراً هاماً لمساعدة الانتقال من هيمنة الوقود المستخرج من تحت الأرض على العالم إلى عالم مغذى بوقود غير ملوث وتكنولوجيات متقدمة كالطاقة الشمسية (PV) وخلايا الوقود (FC). هذا المقال يناقش إمكانية استعمال هذه الأنظمة المندمجة، في سوق الطاقة للاستعمالات الثابتة والمحمولة، من أجل تلبية الاحتياجات الحرجة لتكنولوجيا طاقوية أنظف. وسيكون كذلك محل نقاش شامل للنماذج المسبقة لاستعمالات الطاقة في المستقبل و نتائج تأثيراتها على البيئة (الأمطار الحمضية، ثقب الأزون، و الارتفاع الحراري على سطح الأرض). برئا حالية ومستقبلية ستفحص كذلك، من خلال هذا المقال، عدة مسائل متعلقة بالطاقات المتجددة، البيئة والتنمية المستدامة.