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Development Chances of Distributed Energy Production on Small Scale

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Abstract

Distributed energy systems, nowadays, are very hot subject all over the world. They considered as a clean and sustainable energy. This kind of energy production will occur far from heat and power plants, in single houses or their small associations. This is not used, yet, in Jordan, put, regulations of power are under consideration and will hopefully appear very soon. A quick survey in the Jordanian markets and research bodies shows that the use of fuel cell compared with other distributed energy systems is very little. For this reason, the main part of this paper has been divorced to the discussion of the potentials of fuel cell systems in Jordan. The Poland experience in this subject has been studied in order to compare with the case of Jordan. The market and technical requirements for small-scale fuel cells in residential applications are investigated. In particular, the peculiar features of the Jordan situation are explored, with its specific energy resources and demands. The attributes and disadvantages are discussed, with a number of technology gaps being identified, and some solutions proposed. It is shown that various technologies could be applied. The obvious premium application of fuel cells in Jordan exists where grid connection is expensive. This study shows obviously many benefits can be gained if the distributed energy systems are applied to the Jordanian markets. These include, but not limited to, the improvements of the peak load, energy economy, and air pollutions. The study shows ,also, that Jordan can be gained a lot from using distributed energy systems.

Keywords: Emission Control; Carbon Dioxide; Fuel Cell Systems; Distributed Energy Production.

Nomenclature *

AFC	Alkaline Fuel Cell	n_{pi}	The amounts in kilo moles of products.
CH_4	Methane.	n_{si}	The amounts in kilo moles of substrates.
CO_2	Carbon Dioxide.	PAFC	Phosphoric Acid Fuel Cell.
DE	Distributed Energy	PEM	Proton Exchange Membrane
DMFC	Direct Methanol Fuel Cell	PV	Photovoltaic
EU	European Union.		
FC	Fuel Cell.	SOFC	Solid Oxide Fuel Cell.
GHG	Greenhouses Gases.		
GWP	Global Warming Potential.	ΔE	Energy Difference.
KOH	Potassium Hydroxide. atmosphere of GHG, in products.	Ψ_{pi}	(divided by 100) times of staying in
IC	Internal Combustion Engines atmosphere of GHG, in substrates.	Ψ_{si}	(divided by 100) times of staying in

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1. Introduction

Distributed energy systems (DE), nowadays, are very hot subject all over the world. They considered as a clean and sustainable energy. Distributed energy systems have already made a significant impact on the energy market and will certainly affect energy scenarios in the near future [1]. Pepermans et. al [2] extract an accurate definition for DE after a long survey. In their view, the best definition of distributed generation that generally applies seems to be 'an electric power generation source that is connected directly to the distribution network or on the customer side of the meter'. They also showed two major factors that contribute to the renewed interest in distributed generation i.e. electricity market liberalization and environmental concerns [2]. These DE systems include but are not limited to photovoltaic (PVS), wind, micro turbine, fuel cells (FC), and internal combustion (IC) engines. Although most of DE systems are not new in technological respect, they are receiving increased attention today because of their ability to provide combined heat and power, peak power, demand reduction, backup power, improved power quality, and ancillary services to the power grid. The visibility of renewable energy sources are increasing significantly due to common concerns about fossil fuel scarcity, increased pollution, weakened national security, and higher production of greenhouse gases related to the conventional power plants [1]. Even with all the benefits renewable energy has to offer, the decision on DE installations are still largely dependent on initial capital cost. Therefore the improvement of the DE economics strongly requires decreased costs for all of its components. Another important aspect to the life-cycle cost of the DE systems is reliability. Numerous researches all over the world deal with DE systems, components, improvement and applications. These works are not the scope of this paper but only few examples were presented in the references list(Italy [3], Poland [4], UK [5], Finland[6], Belgium [7], Spain[8 and 9] Greece[10] Iran[11] USA [1, 12, 13, 14, 15, and 16] China [17] France [18] Taiwan [19], Norway [20], Turkey [21], Algeria [22]. However, this paper is aimed to study the ability of use these ideas in Jordan. Concentration will be given for a comparison between Jordan and Poland [23-25]. Also discussed in this paper are the challenges that must first be overcome to reach the goal of good use of DE in Jordan in future. A quick survey in the Jordanian markets and research bodies shows that the use of FC compared with other DE systems is very little [26-35]. For this reason, the main part of this paper will be the discussion of the potentials of FC systems in Jordan. One must not forget that there are no DE in Jordan as the national electricity is isolated until now. The new law for power is under consideration and legal legislations will come to light very soon. The purpose of this paper is to provide a consolidated resource that describes the most common potentials in Jordan. The objective of this paper is looking for the above issues and study these challenges all around the world and special considerations will be given for Poland and Jordan as case studies. The paper layout will be as follows. The next section, after this introduction, will devoted for a theoretical background that contains ΔE_{GHG} , the chance for new technologies in a frame of distributed energy production and the properties of fuel cells. The next part will be about the properties of fuel cell on small scale. Finally, a summery and conclusions will be given.

2. Theoretical background

In this section, a theoretical background will be given. This will include , in addition to the literature review, the explanation of the main important concepts of the subject that will paved the way to this research.

2.1. *The Carbon dioxide(CO_2) concentration:*

In 2007 the announcement of the European Commission concerning the European strategy in frame of power industry was published. It contains the main priorities of energetic politics of EU even to 2050 [36]. That's the moment when the distributed energy production on small scale has a chance of development and serious treatment. This kind of energy production will occur far from heat and power plants, in single houses or their small associations. From the sixties of the last century an association of both systems (energetic and electric) in one entirety is possible.

The Carbon dioxide (CO_2) concentration in atmosphere changes every moment. It is influenced among other things by year's season, geographical position, the number of factories in a city and so on. The maximum of CO_2 concentration occurs in winter, in the states with a great number of conventional power plants. CO_2causes creating of "warm islands" because its specific gravity is bigger than specific gravity of mixture of oxygen with nitrogen (the air) and therefore CO_2 falls on the ground. So installations for measurement of the CO_2 concentration in atmosphere are installed on clean ecologically areas, a long distance from great cities, for example on the Antarctic. The air samples from ice of Antarctic and Greenland show that CO_2 concentration is twice bigger than in atmosphere from before 15 000 Years. Dakowski et. al [37] indicated that average time of CO_2 stay in atmosphere is 10 years, and main methods of its elimination belong to the group of biochemical methods. Perhaps the consequence of it is more violent growth of flora in the area with increased CO_2 concentration than in the other areas. The air samples of ice of Antarctic and Greenland show that CO_2 concentration is twice bigger than in atmosphere from before 15 000 Years. Counteraction of the climate warming according to means among other things emission decreasing of greenhouses gases (GHG). 80 % part of global emission GHG is according to CO_2 from power industry sector [36]. Therefore the EU ,as many other countries, proposes the using of ecological technology, which in consequence brings decreasing of GHG concentration in atmosphere. The EU project in this frame is ambitious. The EU wants in 2020 to achieve CO_2 emission decreasing in industrialized countries to the level of 30% in comparison with the level in 1990. These countries will have to decrease their own emission to 50% in 2050 in comparison with 1990. For Poland this level will be smaller but not smaller than 20 % to 2020 in comparison with 1990. For Jordan there are no formal statistics that indicate the actual figure but clear trend toward emission reduction can be seen.

2.2. *Challenges to be handled*

For both Poland and Jordan, there are a serious challenges and in all of the related sectors as follows.

Firstly, if the energetic sector is considered, these challenges means that it must propagation of new technologies of energy generation. These developments can be as follows:

- the extensive use of renewable sources,
- the use of biofuels,
- looking for a developed sources, that provide in combustion process with low GHG emission,
- improvement of hydrogen combustion and additionally the process should proceed with total steam condensation,
- the use of extensive power plants, that is conventional power plants storing 100% of CO_2 and H_2O from fuel combustion,
- looking for a safe fusion of light elements that so called thermonuclear power industry of the fourth generation.

Secondly, if the transport sector has been taken into considerations, these challenges means:

- propagation of using biofuels
- design and marketing of automotive vehicle with low petrol or gas consumption
- design of hybrid vehicle using conventional and renewable sources of energy.

Finally, if building industry sector is considered, this means:

- use of new building structures with better insulation properties
- improving insulation properties in existing buildings, houses
- application of energy saving technologies using the conventional and unconventional energy sources
- development of technology of warm accumulation.

In general for all of the above sectors, management of energy is crucial. This means working out and designing methods and management structures for observation activities in energetic sector in all around the world in order to introduction of corrections in Internal energetic strategy. The last point is very important. The World wants to stop the global climate warming by observing and eliminating reasons of GHG emissions. The main blame for disadvantageous climatic changes is ascribed to CO_2 and the globe will combat CO_2 sources with the help of all the available means. Meanwhile we know other, more harmful compounds, which are "treated" softer than CO_2. The world standpoint is not profitable for Poland taking into consideration the national energetic strategy because coal is still the main energetic fossil fuel, because the factor objectively assessing the technological process must be found.

2.3. The Greenhouse Gases energy difference (ΔE_{GHG})

The measure of warming up effect for chemical processes or advisable technologic process for example receiving large amount of warm could be a difference of the specific sums of the products consisting of the GHG amount multiplied by its characteristic features in burning products and substrates (ΔE_{GHG}). At ΔE_{GHG} construction we can use the gas factors GWP(G*lobal Warming Potential*) characterizing the ability of each of the gases to warm accumulation in the earth atmosphere in reference to CO_2 ability. The GWP value of any gas depends on the ability of stopping warm and its stay time in atmosphere. If at gas factor isn't given time that means the mentioned time is 100 years. For example $GWP_{100}(CO_2)=1$ means : the CO_2 influence on atmosphere is definite as 1 at its 100 year stay time in the atmosphere. For methane the analogical GWP value is 23. $GWP_{100}(CH_4)=23$. Therefore the influence of methane is 23 times bigger than for CO_2.

It should be emphasized that GWP_{100} (H_2O) is up to now undetermined. In the official announcements of the EU nothing or very little is said about water vapor in spite of the fact that H_2O is the main GHG and occurs in very large quantities in the earth atmosphere. Additionally it has perhaps a big GWP value. It is estimated that H_2O is responsible for from 36%– 60% to 96%-99% of the warming up effect. Scenarios of early phase of life on the earth assume evaporating of large quantities of water in consequence of sun radiation. It would be a cause of appearance of the earth atmosphere with specific composition and increasing of its temperature to the level which was suitable for life. One can propose to form the index informing about "goodness" of a process for the surrounding. The index could assess objectively a chemical or technological processes. For example as in formula (1) :

$$\Delta E_{GHG} = \left(n_{p1}\, GWP_{p1} + n_{p2}\, GWP_{p2} + ...\right) - \left(n_{s1}\, GWP_{s1} + n_{s2}\, GWP_{s2} + ...\right) \quad (1)$$

where:

n_{pi}, n_{si} are the amounts in kilo moles of products and substrates respectively.

GWP_{pi} GWP_{si} are Global Warming Potential of products and substrates respectively for 100 years stay of gases in the earth atmosphere.

The Formula(1) can be modified with the purpose of inputting the current data important for GHG effect. For example if we want to take into consideration the real stay time in atmosphere of the specific GHG we have to multiply each component by the true time of the gas staying in the atmosphere in years and divide it by 100:

$$\Delta E_{GHG} = \left(n_{p1}\, GWP_{p1}\, \psi_{p1} + n_{p2}\, GWP_{p2}\, \psi_{p2} + ...\right) + \\ - \left(n_{s1}\, GWP_{s1}\, \psi_{s1} + n_{s2}\, GWP_{s2}\, \psi_{s2} + ...\right) \quad (2)$$

Where

ψ_{p_i}, ψ_{s_i} are (divided by 100) times of staying in atmosphere of GHG, in products and substrates respectively. For the burning of the pure carbon it would be using data taken from reference [37] as:

$$\Delta E_{GHG} = n_{p1} * GWP_1 * \frac{7}{100} = 2 * \frac{7}{100} = \frac{14}{100}$$

The matter is very difficult in case of water vapor. For the uncomplicated chemical reaction :

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

It is not easy to obtain the value ΔE_{GHG} . The cause is difficulties in determination of GWP value for water vapor and its real stay time in atmosphere. Up to now we don't have unequivocal opinion in the matter. We don't know how water vapor influences atmosphere of earth. Its quantity changes in air seasonally. Excluding the stoichiometry cases we have problems with estimation whether the increase of the quantity of water vapor is in natural way or is it connected with the used technology. In which layers of atmosphere will it diffuse? Additionally we don't know "which " vapor have the greatest influence on the warming up, how much water vapor is in each atmosphere layer and how to count its summary GWP. In any case we know that water vapor quantity increases fast with temperature increasing. So its investigation from the point of view described above should be priority in short future. After them the classification the influence of the processes on surrounding will be easier.

The ΔE_{GHG} factor can have plus or minus value. The second means that the technological process is easy for the surrounding because it will run with elimination of warming climate effect.

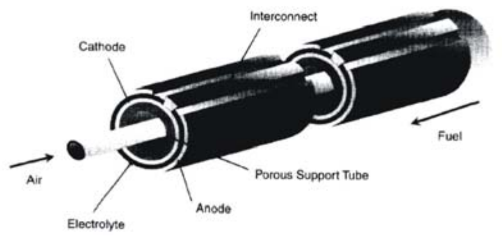
2.4. The Properties of Fuel Cells

The following will be a description of few types of fuel cells that helps with a better understanding of this work [Details of fuel cells can be found in many references in the open literature and examples are given in reference [1,26-28, 38-63].

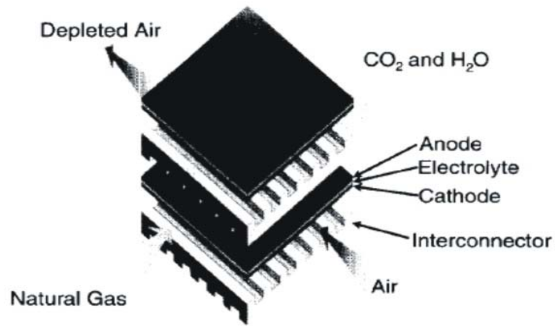
A fuel cell is an electro-chemical device that produces electricity without any intermediate power conversion stage. The most significant advantages of fuel cells are low emission of greenhouse gases and high power density. The energy density of a typical fuel cell is 200 Wh/l, which is nearly ten times of a battery. The efficiency of the fuel cell is also high in the range of 40–60%. If the waste heat generated by the fuel cell is used for cogeneration, the overall efficiency of such a system could be as high as 80% [1]. Fuel cells can be classified into five different categories based on the electrolyte chemistry, including proton exchange membrane fuel cell (PEMFC); solid oxide fuel cell; molten carbonate fuel cell; phosphoric acid fuel cell; and aqueous alkaline fuel cell.

The PEMFCs are rapidly becoming the primary power source in movable power supplies and distributed generation (DG), because of their high energy density, low working temperature, firm and simple structure [1].

One of these cells seems very special and has perhaps " the good future". This is Solid Oxide Fuel Cell (SOFC) with ceramic oxide electrolyte. SOFC have different shapes –flat, tubular [38-40], as shown in figure 1.They have advantages and drawbacks. However the solid electrolyte and work temperature lowering to 500 ^0C - 600 ^0C cause a rise of the prospective application range.



(a) Tubular



(b) Flat

Figure 1. The different shapes of solid oxide fuel cell (SOFC) [38]

In addition, CO_2 emission would have place only in a case of using fuel gases which contain methane. CO_2 is created as a by-product of oxidation and with water vapour is set off through a fuel canal. A cell tightness makes the CO_2 leading out easy. Presently, we don't know exactly how much CH_4 we need for installing 15-25kW electric power, which is indispensable for a middle class building. The research works connected with an efficiency increase and repeated usage of partly oxidized fuel gases are in progress. The SOFC construction for exploitation in single house and the possibility of a supply with different gases , among other biogas from sewage treatment plants of the houses are a additional trump, because biogases can include up to 60% methane. If CH_4 could be separated from the rest, one could use it theoretically in fuel cells, because SOFC now are very sensitive to sulfur compounds.

Alkaline Fuel Cell(AFC) is the oldest type of fuel cells. Its fast development has initiated from the Second World War. The cells are used for power supply on spaceships in 9 Moon missions (Apollo) and cars as shown in figure 2.

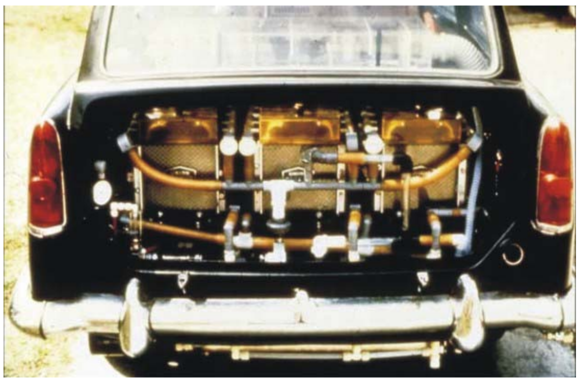


Figure 2. Karla Kordescha's car using fuel cell [41]

AFC electrolyte is KOH whose mass fraction determines the efficiency and work temperature in range 70 ^0C -250 ^0C for power up to 12 kW. If work temperature of fuel cell is over 250 ^0C the mass fraction is about 85%.A susceptibility to CO_2 attack remains all the time, the technical problem to be resolved.CO_2 reacts with KOH and creates indissoluble salts as shown in equation(3).

$$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O \quad (3)$$

The other problem is the displacement of water for the purpose of confinement of KOH concentration on specific level. The great advantage of AFC is relatively safe electrolyte and good tightness. It is connected with metallic construction which can be used for the sake of the low work temperature. Reactions on electrode are described by equation (4,5 and 6).

$$A : 2H_2 + 4OH \rightarrow 4H_2O + 4\bar{e} \quad (4)$$

$$K : O_2 + 2H_2O + 4\bar{e} \rightarrow 4OH \quad (5)$$

$$Total : O_2 + 2H_2 \rightarrow 2H_2O \quad (6)$$

Figure3 shows the AFC system building .

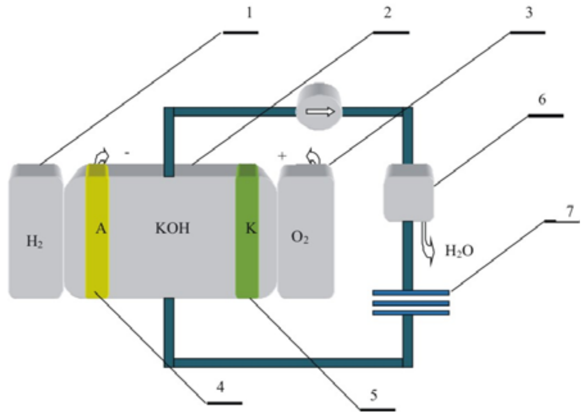


Figure 3. AFC system : 1- hydrogen tank, 2-electrolite, 3-oxygen tank , 4,5-electrode, 6 – water separator , 7- cooler.

Phosphoric Acid Fuel Cell(PAFC) achieves efficiency up to 40%, power up to 1 MW. A work temperature 130^0C - 220^0C. An electrolyte is concentrated H_3PO_4. It is in liquid state in porous silicon carbide. Electrodes are of graphite with platinum additives. Water vapour comes out directly to air and it doesn't thin a electrolyte which is relatively resistant to CO_2. The PAFC advantage is the chance to use hydrogen and natural gas as fuels.

Molten Carbonate Fuel Cell (MCFC) has electrodes from nickel and chromium. A electrolyte contains a molten carbonate of lithium and potassium. The cell is singular because addition of CO_2, for example in biogas, improves the work of cell. The carrying gas used in order to create the flow through the cell and to protect the specific level of CO_3 ions is CO_2. It gives chances to cooperation with conventional power plants on condition of complete separation, storage and dosage of CO_2. This fact is very important both for big power plants and for small systems in buildings. In the second case we can use biogas from biological treatment plant as fuel. A work temperature is high and averages 650^0C. The high temperature permits inner conversion of gases for hydrogen. A reforming of gases takes place in fuel cell directly. An outer installation of conversion like in PAFC isn't necessary. Additionally it excludes expensive catalysts from noble metals because the reaction is self-contained. Therefore costs of production decrease. It is very possible that they can decrease in short time up to 1000 -1500 US$/kW or below.

The membrane is the most important in Proton Exchange Membrane Fuel Cell (PEM, PEMFC). Membranes are chemically inert in both acid and basic environment. A work temperature is low and averages 70^0C -over 200 ^{0}C. Usually it is 120^0C -130^0C. This type of cells becomes resistant to CO. The other method causing increase of CO resistance is growth of work temperature. It influences a better protons ionic conductance without catalysts from platinum. Unfortunately the high temperature is harmful for membrane material. The temperature 200^0C is limiting and connected with thermal strength of membrane material. The development of this cell kind will connect with production of new electrode and catalysts materials , which permits the widening of work temperature range.

The construction of Direct Methanol Fuel Cell (DMFC) evolved from PEMFC .It is resistant to CO poisoning because CO doesn't occur in fuel – methanol. The fuel conversion to hydrogen doesn't occur too. The methanol as liquid is easier to store than gas - hydrogen. However DMFC has disadvantage. Methanol in air oxidizes to carboxylic acid and formaldehyde [42]. Both substances are toxic. They can cause blindness and even death. The big permeability through membrane material causes loss of energy, rated power decreases and its efficiency. The methanol diffusion produces products of methanol burning at both sides of membrane.

2.5. *Properties of fuel cell on small scale*

Technology requirements that must be fulfilled for fuel cell installations on small scale for the purpose of usage in building homes we can divide in some subgroups.

1. Operational safety, including non failure work of installation
2. Long time and low costs of exploitation
3. A possibility of creating hydrogen on place.

Hydrogen is a very lightweight and easy oxidable gas. The oxidation reaction is strongly exothermic. The bottom explosive limit average DGW $[H_2]$= 4% and the upper-GGW $[H_2]$ =74%.

Some effluent and mixing with air is very dangerous. The small molar mass M H_2=2 kg/kmol causes a fast convection upwards. In rooms it cumulates under ceilings. Air grates should be under ceilings. In the best cases hydrogen tanks should stand in some distance from homes. A Leak proofness protection of a tank with the other fuel, methane is easier, because this gas is denser. The molar mass averages M CH_4=16kg/kmol and it is smaller than that of air. Air grates should be under ceilings too. The bottom explosive limit average DGW$[CH_4]$=5% and the upper - GGW$[CH_4]$= 15%. It is for the sake of explosion hazard safer than hydrogen. But after reforming CH_4 we get hydrogen. The place with hydrogen or methane tanks belongs to zone of potential explosion. Therefore non-failure work and specific safety devices are so important. This fact rises production costs.

Methanol as fuel demands a very good ventilation too. It oxidates to toxic compounds both in air and an organism. The leaky tank, cells or fuel pipes will cause health hazard for users of this type of cells.

The most convenient gas as fuel is methane because we know the technology of its storing in pressure vessels. Conversion to hydrogen can proceed in outer installations but it is the best if it will proceed in cells in which the conversion occurs inside, according to equation (7) and (8).

Fuel + water → hydrogen + carbon monoxide (7)

carbon monoxide + water → hydrogen + carbon dioxide(8)

The next method of hydrogen supply for homes is electrolysis of water proceeding in fuel cell in a process opposite to the process of energy production. One should take two possibilities into consideration. The first: on places in home there is one cell , which for some time works as electrolizer . It makes in this time some amount of hydrogen . The gas is stored up in specific tank. During next portion of time the cell produces energy from hydrogen made earlier. We will need only one cell and installation for hydrogen accumulation. The next possibility is connected with two cells. The first works as electrolizer, the second creates energy. The cells must work synchronously and simultaneously. Hydrogen is created in suitable amount , which is safer . The disadvantage are a high costs of investment.

3. The Chance for New Technologies in A Frame of The Distributed Energy Production

The energetic crisis that people feel more painful from year to year is this moment when distributed energy production on small scale has a chance of development and serious treatment. This kind of power industry will occur far from heat and power plants, in single houses or their small associations. Costly power transmission lines will by needless, which is very positive for country economy. Additionally, the self-sufficient houses will lighten the heat and power plants, which from some time relatively frequently switch off the electric current. But for sector of the economy sector , that means:

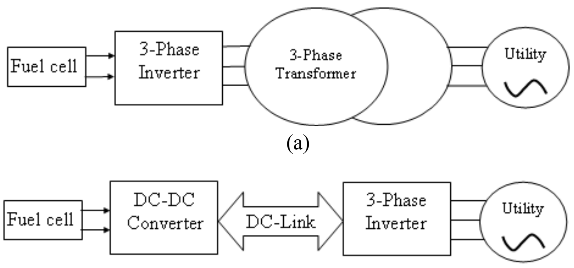
1. "The equality of rights" for the conventional and the distributed energy production, which will jointly operate in a frame of the Common Market of Energy; that requires the specific legislative decision.
2. The system economic invitations for owners of houses (housing associations) – for example the expensive innovation should give back in real time (bank credits, taxes)
3. Information campaigns propagating new technologies in a frame of heat and power production.

The devices of the distributed energy production on small scale are these that can supply heat and power. The first ones are well-known and are constituents of hybrid heating systems. In our climatic zone those are heat pumps, fireplaces with water jacket or heat air divisions, pellet furnaces, solar collectors apart from the conventional furnaces using gas or coal .The electric power produce in this system will be more difficult but we can use solar cells for gate-ways or road lightings, small windmills to 3 kW. Usually both methods of energy supplying work in separate system. There are the heat and electric systems. From the sixties an association of both systems in one entirety is possible. This is enabled by fuel cells. The small sets can produce both electrical and heat energy in one place. Presently there are some cells constructions . They differ from each other with anode , cathode , electrolyte constructions, fuel gases and so on. Some cells have achieved market success and they can be used in building engineering in short time. The very important cells are hydrogen-oxygen cells, in which active substances are those two elements. The chemical reaction on the electrode is described with summary equation (9).

$$H_2 + 1/2O_2 \rightarrow H_2O \text{ + electric energy + heat (side-effect of electricity flow)} \quad (9)$$

In this case CO_2 don't occurs in exhaust gases completely but steam creates in big amount. In the moment we can not obtain ΔE_{GHG} of this process.

Power generated by the fuel cell is DC, hence similar to a PV system, the power conditioning systems, including inverters are required in order to supply normal customer load demand or send electricity into the grid. The simplest form of fuel system power electronics configuration, as shown in Fig. 4(a), consists of a fuel cell followed by the DC–AC converter [1]. A DC–DC converter is usually put between the fuel cell and the inverter, as shown in Fig. 4(b). The DC–DC converter performs two functions, one is the DC isolation for the inverter, and the second is to produce sufficient voltage for the inverter input, so that the required magnitude of the AC voltage can be produced. Power electronics costs { 18-40%, 20% for fuel cell} compared to total capital costs for DE system [1].



(b)

Figure (4) block diagrams of fuel cell systems (a) single inverter and (b) inverter and isolated DC-DC converter [1].

4. Summary and Conclusions

A dispersed energy production has its own group of followers. However bigger and bigger distance between homes and power plants causes the necessity of creation the new electro-energetic system on small scale, on scale of a single home. It is possible due to technical innovations in a frame of energy production , fuel cells among others.

In order to have a chance of adaptation in home's energetic systems fuel cells should be characterized by long-lasting, safe work, resistance to CO, CO_2 poisoning, resistance to other chemical compounds blocking ions flow through cells, safe fuel storage, inexpensive exploitation. The fuel cell having these specific features are DMFC and MCFC presently.

Very important for processes of energy production is obtaining of ΔE_{GHG} value at level near 0. In the main processes occurring in hydrogen-oxygen cells using hydrogen as fuel is created water vapor. In the heat recovery process we can condense H_2O and in the extreme case ΔE_{GHG} =0. In the cells working on methane, methanol can be create CO_2, CO, carboxylic acid and formaldehyde. That's why we have to develop ΔE_{GHG} more deeply. The precondition of the idea is the correct GWP estimation for each gases or chemical compounds and their time of stay in atmosphere. This is especially important in the case of water vapor.

References

[1] S. Chakraborty, B. Kramer, B. Kroposki, "A review of power electronics interfaces for distributed energy systems towards achieving low-cost modular design". Renewable and Sustainable Energy Reviews, Vol. 13, No. 9, 2009, 2323-2335.

[2] G. Pepermans, J. Driesen, D. Haeseldonckx, R. Belmans, W. D'haeseleer, "Distributed generation: definition, benefits and issues". Energy Policy, Vol. 33, No. 6, 2005, 787-798.

[3] C. Bossi, A. Del Corno, M. Scagliotti , C. Valli, "Characterisation of a 3kW PEFC power system coupled with a metal hydride H2 storage". Journal of Power Sources, Vol. 171, No. 1, 2007, 122-129.

[4] J. Paska, M. Sa"ek, T. Surma, "Current status and perspectives of renewable energy sources in Poland". Renewable and Sustainable Energy Reviews, Vol. 13, No. 1, 2009, 142-154.

[5] J. Godefroy, R. Boukhanouf, S. Riffat , "Design, testing and mathematical modelling of a small-scale CHP and cooling system (small CHP-ejector trigeneration)". Applied Thermal Engineering, Vol. 27, No. 1, 2007, 68-77.

[6] K. Alanne, A. Saari, "Distributed energy generation and sustainable development". Renewable and Sustainable Energy Reviews, Vol. 10, No.6, 2006, 539-558.

[7] T. Ackermann, G Andersson, L Söder, "Distributed generation : a definition". Electric Power Systems Research, Vol. 57, No. 3, 2001, 195- 204.

[8] D. Ramirez, L.F. Beites, F. Blazquez, J.C. Ballesteros, "Distributed generation system with PEM fuel cell for electrical power quality improvement". International Journal of Hydrogen Energy, Vol. 33, No. 16, 2008, 4433-4443.

[9]A. Angel, B. Jula "Future development of the electricity systems with distributed generation". Energy, Vol. 34, No. 9, 2009, 377-383.

[10] G.C. Bakos, "Distributed power generation: A case study of small scale PV power plant in Greece". Applied Energy, Vol. 86, No. 9, 2009, 1757-1766.

[11] S. Sanaye, M. R. Ardali, "Estimating the power and number of micro turbines in small-scale combined heat and power systems". Applied Energy, Vol. 86, No. 6, 2009, 895-903.

[12] R.J. Braun, S.A. Klein, D.T. Reindl, "Evaluation of system configurations for solid oxide fuel cell-based micro-combined heat and power generators in residential applications". Journal of Power Sources, Vol. 158, No. 2, 2006, 1290-1305.

[13] S. G. Chalk, F. James. Miller, "Key challenges and recent progress in batteries, fuel cells and hydrogen storage for clean energy systems". Journal of Power Sources, Vol. 159, No. 1, 2006, 73-80.

[14] P. Dondi, D. Bayoumi, Ch. Haederli, D. Julian, M. Suter, "Network integration of distributed power generation,". Journal of Power Sources, Vol. 106, No. 1-2, 2002, 1-9.

[15] D. Rankin, E. Martins, D. C. Walther, "Personal power systems". Progress in Energy and Combustion Science, Vol. 31, No. 5-6, 2005, 422-465.

[16] M.C. Williams, J.P. Strakey, S. Singhal, "U.S. distributed generation fuel cell program". Journal of Power Sources, Vol. 131, No. 1-2 , 2004, 79 - 85.

[17]Y. Ruan, Q. Liu, W. Zhou, R. Firestone, W. Gao, T. Watanabe, "Optimal option of distributed generation technologies for various commercial buildings". Applied Energy, Vol. 86, No. 9, 2009, 1641-1653.

[18] C.E. Hubert, P. Achard, R. Metkemeijer, "Study of a small heat and power PEM fuel cell system generator". Journal of Power Sources, Vol.156, No. 1, 2006, 64 -70.

[19] C. Laia, T. Lin, "Technical assessment of the use of a small-scale wind power system to meet the demand for electricity in a land aquafarm in Taiwan". Renewable Energy, Vol. 31, No. 6, 2006, 877-892.

[20] H. Miland, Øystein. Ulleberg, "Testing of a small-scale stand-alone power system based on solar energy and hydrogen". Solar Energy, Vol. 38, No. 9, 2008, 1815-1822.

[21] W. Lise, "Towards a higher share of distributed generation in Turkey". Energy Policy, Vol. 37, No. 11, 2009, 4320-4328.

[22] M. Mostefaoui, B. Belmadani, A. Babouri and A. Djerdir "Performance System Management: Fuel Cell / Photovoltaic". Global Conference of Renewable Energy and Energy Efficiency of Desert Regions, Amman, Jordan , 2009 .

[23] K. J. Chalvatzis, " Electricity generation development of Eastern Europe: A carbon technology management case study for Poland". Renewable and Sustainable Energy Reviews, Vol. 13, No.6-7, 2009, 1606–1612.

[24] K. Czaplicka, K., Krzysztof Stańczyk, K. Kapusta"Technology foresight for a vision of energy sector development in Poland till 2030. Delphi survey as an element of technology foresighting ". Technological Forecasting & Social Change, Vol. 76, No.3, 2009, 327–338.

[25] M. L. Murray, E. .Seymour, J. Rogut, S.W. Zechowska,"Stakeholder perceptions towards the transition to a hydrogen economy in Poland". International Journal of Hydrogen Energy, Vol. 33, No.1, 2008, 20 – 27.

[26] J. Al Asfar ,M. Hamdan, J. Yamin and Y. Abdullat. "Building and testing of a simple PEM Fuel Cell ". Global Conference of Renewable Energy and Energy Efficiency of Desert Regions, Amman, Jordan , 2009.

[27] J. Al Asfar J, M.Hamdan, and Y.Abdullat ". Theoretical Study of Hydrogen Flow in porous Media of Local Sweileh Sand". Global Conference of Renewable Energy and Energy Efficiency of Desert Regions, Amman, Jordan , 2009.

[28] Z. Abu-Hamatteh, M. Besieso , " Solar Hydrogen and Fuel Cells: A revolutionary and sustainable Source of Energy". Global Conference of Renewable Energy and Energy Efficiency of Desert Regions, Amman, Jordan , 2009 .

[29] E. S. Hrayshat, "Analysis of renewable energy situation in Jordan". Renewable and Sustainable Energy Reviews, Vol.11.No.8, 2007, 1873–1887.

[30] B. A. Akash, M. S. Mohsen, "Current situation of energy consumption in the Jordanian industry". Energy Conversion and Management, Vol. 44, No. 9, 2003, 1501–1510.

[31] J.O. Jaber, M.S. Mohsen, A. Al-Sarkhi, B.A. Akash, "Energy analysis of Jordan's commercial sector". Energy Policy, Vol. 31 No.9, 2003, 887–894.

[32] J.O. Jaber, S.D. Probert, "Purchased-energy consumptions in Jordan's commercial and public-service sector". Applied Energy, Vol. 71, No. 1, 2002, 31–43.

[33] A. Al-Ghandoor, J.O. Jaber, I. Al-Hinti, I.M. Mansour, "Residential past and future energy consumption: Potential savings and environmental impact". Renewable and Sustainable Energy Reviews, Vol. 13, No. 6-7, 2009, 1262–1274.

[34] E. S. Hrayshat, " Viability of solar photovoltaics as an electricity generation source for Jordan". Renewable Energy, Vol. 34, No. 10, 2009, 2133–2140.

[35] E. S. Hrayshat," Wind availability and its potentials for electricity generation in Tafila, Jordan". Renewable and Sustainable Energy Reviews, Vol. 9, No.1, 2005, 111–117.

[36] The announcement of the European Commission concerning the European strategy in frame of power industry. EUR 20245 EN, 2002.

[37] M. Dakowski, A. Wysokinski, " Climate change, greenhouse effect, whether human intervention". www.rurociagi.com.

[38]S. Badwal, K. Foger, K. " Solid Oxide Electrolyte Fuel Cell Review". , Ceramics International, Volume. 22, No. 3, 1996, 257-265.

[39] B.Frederic , Fuel cells , engines and hydrogen an energy approach. 3rd ed. John Wiley &Sons,LTD; 2006.

[40] Wojcik,W, "New directions manufacture and use of energy". Sustainable Systems Eenergy, Lublin Technical University, Technical Report, Poland, 2005.

[41] website , http://www.oeiizk.waw.pl.

[42] Sorsen , B., Hydrogen and Fuel Cells, Emerging technologies and applications,. "Sustainable World" series, Academic Press, 2005.

[43]W. J. Fergus, " Oxide anode materials for solid oxide fuel cells". Solid State Ionics, Vol. 177, No. 17-18, 2006, 1529–1541.

[44] N. Q. Minh, "Review: Solid oxide fuel cell technology—features and applications". Solid State Ionics, Vol. No.1-4, 174, 2004, 271–277

[45] A. Pramuanjaroenkij, S. Kakac, X.Yang. Zhou, "Mathematical analysis of planar solid oxide fuel cells". International Journal Of Hydrogen Energy, Vol. 33, No.10, 2008 , 2547 – 2565.

[46] B.D. Madsen, S. A. Barnett , "Effect of fuel composition on the performance of ceramic-based solid oxide fuel cell anodes". Solid State Ionics, Vol. 176, No. 36-36, 2005, 2545 – 2553.

[47] K. Eguchi, H. Kojo, T. Takeguchi, R. Kikuchi, K. Sasaki, "Fuel flexibility in power generation by solid oxide fuel cells". Solid State Ionics, Vol. 152–153, No.1- 4, 2002, 411 –416.

[48] Ch.Suna, U. Stimming , " Review: Recent anode advances in solid oxide fuel cells". Journal of Power Sources, Vol. 171, No. 2, 2007, 247–260.

[49] Q.Hu, Sh. Wang, T.L. Wen , " Analysis of processes in planar solid oxide fuel cells". Solid State Ionics,Vol. 179, No. 27-32, 2008, 1579–1587.

[50] F. Zink, Y.Lu, L. Schaefer , " A solid oxide fuel cell system for buildings". Energy Conversion and Management, Vol. 48, No. 3, 2007, 809–818.

[51] J. W. Fergus, " Electrolytes for solid oxide fuel cells". Journal of Power Sources, Vol. 162, No. 1, 2006, 30–40.

[52] A. B.Stambouli, E. Traversa, " Solid oxide fuel cells (SOFCs): a review of an environmentally clean and efficient source of energy". Renewable and Sustainable Energy Reviews, Vol. 6, No. 5, 2002, 433–455.

[53] P. Tomczyk , " MCFC versus other fuel cells—Characteristics, technologies and prospects". Journal of Power Sources, Vol.160, No. 2, 2006, 858–862.

[54] F. Bidault, D.J.L. Brett, P.H. Middleton, N. Abson, N.P. Brandon, " A new application for nickel foam in alkaline fuel cells ". International Journal of Hydrogen Eenergy, Vol. 34 , No. 16, 2009, 6799 – 6808.

[55] T. Burchardt, P. Goue´rec, E.Sanchez-Cortezon, Z. Karichev, J. H. Miners, " Alkaline fuel cells: contemporary advancement and limitations". Fuel, Vol. 81, No. 17, 2002, 2151–2155.

[56] B. Y.S. Lin, D. W. Kirk, S. J. Thorpe," Performance of alkaline fuel cells: A possible future energy system". Journal of Power Sources, Vol. 161, No.1, 2006, 474–483.

[57] C. Coutanceau, L. Demarconnay, C. Lamy, J.-M. L´eger, "Development of electrocatalysts for solid alkaline fuel cell (SAFC) ". Journal of Power Sources, Vol. 156, No. 1, 2006, 14–19.

[58] D. Mori, K. Hirose , " Recent challenges of hydrogen storage technologies for fuel cell vehicles". International Journal of Hydrogen Energy, Vol. 34, No. 10, 2009, 4569–4574.

[59] N. Rajalakshmi, S. Pandiyan, K.S. Dhathathreyan, "Design and development of modular fuel cell stacks for various applications". International Journal of Hydrogen Energy, Vol. 33, No. 1, 2008, 449 – 454.

[60] C.E. Hubert, P. Achard, R. Metkemeijer, " Study of a small heat and power PEM fuel cell system generator". Journal of Power Sources, Vol. 156, No.1 , 2006, 64–70.

[61] J.g.Wu, X. Z. Yuan, J. J. Martin, H.Wang, J. Zhang, J. Shen, Sh. hongWu,W.Merid, " A review of PEM fuel cell durability: degradation mechanisms and mitigation strategies". Journal of Power Sources, Vol. 184, No. 1, 2008, 104–119.

[62] Sh. Obara, I. Tanno, " Exergy analysis of a regional-distributed PEM fuel cell system". International Journal of Hydrogen Energy, Vol. 33, No. 9, 2008, 2300–2310.

[63] J. E. Brown, C. N. Hendry, P. Harborne, " An emerging market in fuel cells, Residential combined heat and power in four countries". Energy Policy, Vol. 35, No. 4, 2007, 2173–2186.