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Fuel cell co-generation: the future of co-generation

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Abstract

This paper presents the position of co-generation in a number of countries in the European Union and in more detail the situation in The Netherlands where, at this moment, about more than 30% of the electricity production is based on co-generation. The principal obstacles for the future development of co-generation has been presented. Based on the development of co-generation, which is the most economic and the most efficient way of producing electricity with the advantages for energy conservation and the environment, the fuel cell can play an important role in the change to a more decentralized power production. A future development with a household fuel cell, as an ultimate consequence for decentralized power production, has been presented as a challenge for the actors in the energy market. Based on the Dutch experience, the requirements and critical success factors for fuel cells in a household application have been discussed.

Keywords: Fuel cells; Co-generation

1. Introduction

And there was light.

When Edison started electricity production he believed in an integrated approach to the production and the distribution of electricity. Of course the production of electricity was based on direct current. The bulb was lit by direct current. Direct current is more efficient than interrupting the electricity production 50 times per second. Growing demand for electricity has introduced alternative current. With the invention of the transformer the technology became available to fulfill the objectives of a massively increasing demand. The integrated vision of Edison of producing electricity where it is needed has been contradicted by the invention of the transformer and introduced the 'holy' network of the electricity industry.

This is a topic of more or less than 100 years ago and the question is once again: centralized or decentralized power production?

Today, technical changes are pushing towards a much more decentralized approach of the supplying of electricity. The question is: alternating or direct current? A large number of technological developments pushes one to the application direct current. New technologies enables us to think over the revolutionary way to reorganize the energy society.

Twenty years ago people in the information industry believed that the future of communication would be based on big computers. What has actually happened is that nowadays everybody has at his disposal a small personal computer with a larger capacity than the big brother computer of twenty years ago with communication facilities with other counterparts. The production of electricity in the future will be developed in a similar way: small units operating together and supplying electricity locally, only the surplus production being transmitted. We are returning to the vision of Edison: integrated production and use of electricity, and the use of the transformer for the surplus production only.

2. Development of co-generation

Co-generation, which is a decentralized power production at the same time as heat production, where there is a demand, is a successfull story. It is the most environmental-friendly and the most economic way of producing electricity. In a number of European countries a fast development of co-generation is taking place.

Of course, co-generation has not been developed without difficulties (see the paper *The Barriers of Co-generation*), published by Cogen Europe). It seems that almost all barriers are of political and economic nature:

(i) political constraints, conservatism of existing structures, discussion on how to handle existing power stations in the future (a situation for which Eurelectric has raised the issue of stranded costs);

(ii) difficulties in the understanding of energy prices in the electricity sector, especially for the extensive electricity users;

(iii) discussions on costs to be avoided and transparancy of pricing, and

(iv) resistance in the electricity sector to develop co-generation schemes.

The environmental concern of Society has been the key parameter for the development of co-generation. When you are obtaining a 20–40% energy saving, you have a point in your favour. The shortage of fuel in the 1960s created an enormous motive in the transport services towards a more efficient equipment. In the motor car industry, the engine efficiency was increased by 30%. Gas turbines doubled their efficiency in an R&D period of ten years. Extremely useful for decentralized power production with the same efficiency of central power production with steam turbines, the latter equipment made co-generation as an effective and efficient form of electricity production on the scene, making use of the availability of gas in a number of industrialized countries, which contributes to a cost-effective infrastructure in the field of co-generation.

Higher fuel prices also stimulated a new evaluation of the combustion process. Burning of gas gives temperatures of 1400 to 2000 °C (for most applications a range between 70 and 500 °C is only needed). Hot gases from gas turbines and gas engines can be used very effectively in decentralized electricity production which is based on the local demand for heat and where the heat is required. Therefore, co-generation based on the the demand for heat will lead to the optimal use of natural gas and to a cost-effective use of energy.

3. Economic conditions for co-generation

Let us turn to the macro-economics of co-generation, see Figs. 1 and 2. What do we learn from these two figures?

1. The macro-demand for electricity can be: a base load which is mainly an industrial plant (a demand for 7000 h/year), and a middle load (as an average a demand for 4000 h/year). In the past the only fully reliable source of energy supply was based on large power stations. But it is not a precondition. It is a result of a choice in another time and other circomstances.
2. In most industrial countries, there is sufficient heat demand for the base load of electricity to be supplied by co-generation. Certainly for the coming twenty years there are sufficient possibilities to mobilize the industrial heat demand for baseload electricity production. It is a waste of energy and money to build conventional power plants. The other type of heat demand is mainly demand for low heating or cooling for space heating, small industries, hospitals, swimming pools, etc. This requires a production of roughly 4000 h/year. In this today's market decentralized production of electricity is already the most economic solution. In this market the fuel cells will be launched on a commercial base for the first time.
3. In all cases on a macro-economic basis, not based on actual prices, the investment in co-generation is the cheapest way of the production of electricity when you take into account the advantages of heat production, on an avoided cost basis, in the production of electricity.

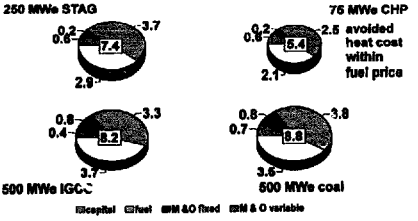

Fig. 1. Cost of the production of electricity (cents/kWh), based on 7000 operating hours, US capital and operating costs and Dutch fuel prices.

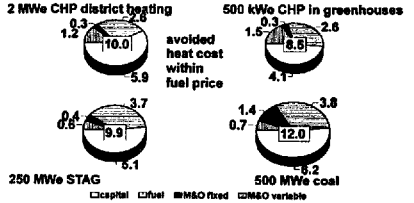

Fig. 2. Cost of the production of electricity (cents/kWh), based on 4000 operating hours. Utility: US capital and operating costs; CHP: Dutch capital and operating costs, and Dutch fuel prices.

3.1. Conclusions

1. Gas is the best fuel supply for the most economic power production.
2. Decentralized power production will be compulsary.
3. The construction of central power stations for new capacity is no longer required.
4. Existing power stations will be evaluated against modern technologies and the question will be raised if, on economic conditions, it will be a better solution to implant new power stations close to existing plants.

4. Development of the political climate

The production electricity was largely based on strong governmental influence that delegated the responsability to monopolistic structures, where security of supply, increasing electricity demand and infrastructure required for producing electricity was dependent on the existent structure of network, going from a local to a regional structure.

Nowadays, in a number of countries, liberalization of the energy market is going hand in hand with more decentralized electricity production. Hundred years ago, the electricity market was privatized. Today, we are again in the beginning of the privatization of the electricity market. Independent power

suppliers, free access to the network and transparency of costs are tools in the evaluation process of the most efficient and most economic way of power production. In the future, changes in the electricity industry will contribute to more decentralized power production. The new profile of the old-fashioned electricity industry, where the priority for the core business was producing electricity, will change to trading electricity as a commodity: buying and selling electricity. The profile of the electricity production companies will change also. They will produce electricity in a much more competitive environment, be asked to fulfill the demand of different qualities of electricity, and be faced to other competitors on the market of electricity production.

5. Development of the energy infrastructure

The costs that will be passed to the consumer are an essential part, being, at the average, at least 50% of the overall price. Also, the transport costs for heat, gas and electricity are very high and represent investments with a long-term commitment.

Electricity is a marvellous product, its flexibility constituting its most important characteristic. It can be transported into two directions. This means that, where existing networks are based on a one-way flow from the central production plant to the customer, larger capacities of existing networks can be used when the core business is transporting the surplus of the production of and/or demand for electricity, the difference between being local production and demand.

Electricity has one very unpleasant characteristic: it is difficult to store. Another infrastructure, existing at the household level, in a number of countries, is the supply of gas. An optimal use of the gas and electricity infrastructure based on the local demand can be made. It introduces easier facilities of storing energy in case of a local production of heat. This will create an ideal infrastructure for the best use of energy.

In the future we should face the effects of long-term commitments, already made, for a better environment. That means commitments for decreasing the use of energy and giving preference to a most efficient production. A large number of options for this political issue have already been implied: self-contained production units; production of chemicals without emission into the atmosphere, and by making an effective use of gas in a general gas-supply network. Oil residues and recycled plastics will be incinerated, coal will be gasified, etc. A hydrogen-gas distribution instead of that of natural gas might give a better solution. This step will fulfill the environmental-friendly requirements and will also contribute to more a decentralized and more efficient electricity production.

The equipment will be multifunctional; integrated in the production of electricity are gas turbine, gas engines, fuel cells; there will be a strong tendency to incorporate renewable units. There wil be requirements for electricity based on photovoltaic cells and solar cells to fullfill the requirements of the demand for heat and these will be brought into the integrated energy circle.

6. Future prospects

Summarizing, for all these elements mentioned, one can anticipate the use of the already existing electricity and gas networks with the possibility of using hydrogen. There will be a fuel cell in each house, connected to an internal household direct current system.

Voilà: Edison is back!

Nowadays, the application of halogen lighting needs direct current. Your TL lighting also needs direct current, as well as the audio. The whole communication industry is based on direct current; the computer needs direct current, the photovoltaic cell produces direct current. The fuel cell is more economic when it produces direct current. The existing network in the house can be used (plug and socket for alternating works also on direct current). A dimmer which is an electronic device works easily on direct current instead of a switch.

The implication of these prospects for fuel cells is not a question of technological development but organizing of political dicision.

The challenge for the fuel cell industry is to anticipate and to plan these developments.