

SELF-GENERATION HOUSING: A NEW CHALLENGE/ OPPORTUNITY

J.M. Bell, Strategic Projects, Natural Resources Canada, Toronto, Canada.

ABSTRACT:

Increasing concern about the impact of human activities on the global climate and the impact of deregulation of the electricity generation business on price and reliability is driving world interest toward distributed generation. Placing small generating units in residences (self-generation housing) creates the possibility of using the waste heat of generation in the residence (combined heat and power). This is very efficient and results in lower environmental emissions. Electrical reliability and price are under the control of the equipment owner (the householder). Rapid advances in small self-generation systems are presently being made with technologies such as fuel cells, Stirling engines and micro turbines. There will be challenges and opportunities for the heat pump industry. Potential opportunities for heat pumps to integrate with residential self-generation systems involve the use of thermally driven heat pumps driven by the thermal output of the self-generation system to provide space heating and cooling.

1. INTRODUCTION

Increasing concern about the impact of human activities on the global climate and the impact of deregulation of the electricity generation business on price and reliability is driving world interest toward distributed generation. Distributed generation is electrical generation situated at the location of the end user rather than in a central generation plant. A self-generation house is a single-family residence that incorporates a distributed generation device within the building to generate electricity while simultaneously producing heat for space conditioning and domestic water heating. This is very efficient and results in lower environmental emissions than central electricity generation with separate residential heating systems. A typical residential self-generation system would be the size of a furnace. Residential self-generation systems based on modified automobile engines have been conceptualized for years without success because of poor reliability and because market conditions were not right. But recent changes in worldwide trends are creating conditions that make such systems more attractive. These trends concern climate change, the deregulation of the electricity market and the development of new technology.

2. CLIMATE CHANGE

Concerns about changes to the global climate have resulted in the international Kyoto Agreement wherein many countries have agreed to substantially lower atmospheric emissions. Meeting the Kyoto requirements will not be easy and governments are actively supporting the development of cleaner energy systems. There will be increased regulation of emissions and emphasis on increased energy efficiency resulting in higher prices for electricity and increased attractiveness of emerging high efficiency technologies.

3. ELECTRICITY DEREGULATION

The deregulation of the electricity market means that there will be a competitive marketplace for electricity with many suppliers. Electricity prices will be driven by market competition. In locations where the market has been deregulated already, the price of electricity has been volatile and to a great extent, prices have risen. In addition, reliability has been poor. For example, there have been rotating blackouts in California.

Deregulation will allow individuals to generate their own electricity and even export the excess to the electricity grid. In a period where electricity price and reliability may be uncertain, residential self-generation may be very attractive as costs are known (and fixed) and supply is certain. Self-generation also provides protection against weather caused distribution failure and against terrorist attacks on central facilities.

Some traditional electricity suppliers are actively involved in the development of the residential self-generation market with the intention of becoming the supplier of such systems. It is even possible to envision a virtual electric generation utility that supplies the grid by exercising control over the surplus electricity of thousands of residential self-generation systems.

4. WORLD ATTENTION

Because of climate change and deregulation, self-generation is receiving world attention with a high level of R&D and investment focussed on developing new technologies suitable for residential scale use. The residential market is difficult as the systems must be extremely economical and reliable as well as easy to install and maintain using local tradesmen.

Residential self-generation represents such a huge market that even a small penetration is extremely attractive to investors. The pace of development activity is high with announcements being made on a daily basis.

By using the waste heat produced by the electric generation process, for example in space and domestic water heating, residential self-generation systems have high system efficiency. (When a system is used to produce both electricity and heat it is known as a combined heat and power (CHP) system). The high efficiency results in low specific emissions and produces environmental benefits compared to central electrical generation with separate residential space heating.

5. RESIDENTIAL SELF-GENERATION TECHNOLOGIES

The main new technologies for the residential DG market are the fuel cell and the Stirling engine with the most effort worldwide being placed on fuel cell development. The micro turbine is the prime technology of interest for commercial and larger systems.

5.1 FUEL CELLS

Fuel cells are the prime focus for the residential self-generation market because they are quiet, clean, efficient and have few moving parts. The fuel cell is an electrochemical device that converts the hydrogen extracted from fuel and oxygen from the air to generate DC electricity directly without combustion. As a by-product, it also produces heat. The fuel cell requires two auxiliary systems: one to extract hydrogen from a fuel such as natural gas (the fuel converter) and one to convert the DC electrical output to AC (the inverter). Compact residential systems (about the size of a refrigerator or furnace) are under development for installation in houses as a furnace replacement. The present status is that the core technology is being refined to increase its life and to reduce its cost, both of which are presently unsatisfactory. The developers are optimistic and there is much excitement and investment world wide in fuel cells.

There are a number of different fuel cell types with two of prime applicability to the residential market known as the proton exchange membrane (PEM) fuel cell and the solid oxide fuel cell (SOFC). Residential fuel cell size is still being evaluated but is expected to be in the range of 1 to 10kW electric and 2 to 20 kW thermal. At this point in time, most manufacturers of residential systems are considering that natural gas will be the fuel. Some residential fuel cell manufacturers of PEM systems are Ballard/ Ebara, H-Power, Hydrogenics, Idatech, Plug Power and of SOFC systems are Fuel Cell Technologies, Global Thermoelectric, Sulzer-Hexis. R&D efforts are concentrated on developing the core technology to increase operating life and to reduce cost. Further development of the fuel processor is especially key for the PEM systems which require high purity hydrogen. In addition, advanced fuel processors that would allow a wider range of fuels including gasoline and diesel fuel would be attractive to some markets.

Prototype residential fuel cell systems are being field tested by utilities such as Gas De France, Bonneville Power Authority, ECO (US rural co-operative), Osaka Gas, EnBW (Germany) and others.

5.2 STIRLING ENGINE

The Stirling engine is a reciprocating piston engine that uses external combustion to produce heat which is transferred via heat exchanger into the sealed working fluid of the engine. It is small, quiet, cheap and has low maintenance requirements. Because of the external combustion, it is readily adaptable to a wide range of fuels including biomass. Some residential Stirling manufacturers are Whispertech, Sunpower, ENATECH and Sigma. The Stirling engine is near market-ready but is not yet in mass production. Extensive product proving via field trials has occurred with utilities in the UK and Netherlands based on a size of about 1 kW electric and 5 kW thermal. These systems are seen primarily as boiler replacements that also produce electricity and it is expected that they will be marketed as such. Residential Stirling systems have operated for 10,000 hours without problem and life is projected to 20,000 hours or more. In addition to use in urban areas, the multi-fuel capability makes the Stirling attractive for remote applications.

Utility researchers in the UK project that 13 million residential Stirling CHP systems could be in place in the UK by 2025. This would result in a combined electrical capacity equal to all the present nuclear generating systems in the UK. The environmental benefit would be huge as high-emitting coal-fired generating stations in the UK could be displaced. UK utility researchers expect that residential Stirling CHP systems will be available on the market in the UK in 2002.

5.3 MICROTURBINES

There is no activity on micro turbines in the single-family residential area as single-family residential scale units (below 10kW) are not considered to be technically or economically feasible. No one is presently proposing to develop turbines at this scale. The prime non-industrial focus for micro turbines is multi-residential and commercial applications of 30kW and above and there are demonstrations underway in Canada and elsewhere. The turbine technology is market ready although development is continuing on heat recovery and noise reduction. Some manufacturers are Capstone, United Technologies/ DTE and Turbec.

6. BUILDING INTEGRATION

Fuel cells and Stirling engine generation systems produce heat as a by-product of the electrical generation. It is vital to use this heat to achieve high system efficiency and thus derive the economic and environmental benefits. Efficiencies are in the order of 85 to 95% for the combined heat and power systems.

Because the system simultaneously produces electricity and heat, it poses a new challenge of how to optimally integrate its operation into the electrical, heating (HVAC) and control systems of buildings. For example, should the self-generator CHP system be controlled by heat demand or by electrical demand? How should any excess of the uncontrolled product be handled? What sort of electrical or thermal storage or grid connection will be required? Fuel cell manufacturers are grappling with these issues now and different approaches/philosophies are being explored. Experience will show if there is a single optimal approach for residential installations or whether a number of different systems are needed to satisfy different requirements. Concepts vary from small self-generation systems to augment the electricity supplied by the grid to large systems that operate completely independently of the electricity grid.

7. CANADA

Canada is well placed in the residential fuel cell race with manufacturers at or near the world forefront of residential fuel cell development in both the PEM and SOFC technologies. Some Canadian manufacturers are Ballard, Fuel Cell Technologies, Global Thermoelectric and Hydrogenics. Canadian government activities are focussed on bringing Canadian residential self-generation products to market faster by supporting development of the core technology, by developing computer simulation tools, grid connection protocols, building integration techniques and thermal cooling.

Building integration issues will be resolved using a unique R&D facility that consists of two identical test houses build side-by-side with intensive monitoring and simulated occupancy. These houses will be used to test and compare self-generation systems under controlled and programmable residential conditions. These houses provide an excellent R&D tool to use as a first stage to test/ integrate new technologies into houses before moving into field trials in occupied houses (which of necessity have a number of uncontrolled variables).

8. CHALLENGE/OPPORTUNITY FOR HEAT PUMPS

Residential self-generation systems will pose a challenge for residential heat pumps by competing for the residential space and domestic water-heating load. Residential self-generation systems may be especially attractive to homeowners because of the perceived need for independent electrical generation for security of supply. They may also offer environmental benefits to make self-generation CHP systems attractive to governments trying to meet the Kyoto Agreement requirements. How will the heat pump industry respond to the challenge?

The heat pump industry should be aware of the development of residential self-generation CHP systems as they will change the competitive marketplace for home heating. The heat pump industry should examine ways to respond by competing directly or by working with residential self-generation systems.

As an example of an opportunity, depending on the sizing of the self-generation unit, there may not be enough heat produced to satisfy the house requirements. This may create an opportunity for a thermally driven heat pump such as an absorption heat pump. The heat to drive it would be derived from the thermal output of the self-generation unit. A smart control system would allow the self-generator thermal output to be used directly for domestic water heating when the heat pump was not operating. Or the smart controller could allow the self-generator heat to go directly to space heating (by-passing the heat pump) whenever the thermal output could meet the house heating demand.

Another opportunity for heat pumps has to do with space cooling. The residential self-generation system will result in a new opportunity for the heat pump industry by creating the need for thermally driven residential space cooling systems.

In warm weather, the thermal output of the self-generator is not needed for space heating but the electrical requirements of the house will likely result in the production of more heat than is needed for domestic water heating. The efficiency of the self-generation systems depends strongly on making use of all the heat produced.

In warm weather, there is a need for space cooling. The ideal situation would be to use the thermal output of the self-generator to drive some form of thermally driven cooling. This would keep the self-generator system efficiency high. Can some kind of thermally driven residential space cooling system be developed to make use of this heat in the summer or to extend the self-generation product to warm climates dominated by the requirement for space cooling rather than space heating? At the present time, the leading contenders for thermally driven residential cooling are absorption systems and desiccant dehumidification systems.

The developers of self-generator CHP systems are well aware of this opportunity and are very interested in obtaining/developing thermally driven cooling systems. Heat pump manufacturers and developers may benefit from examining this area and perhaps working with the self-generator CHP developers.

The example opportunities described here are only a few possibilities. I believe that the heat pump industry would be well advised to take a close look at the self-generation CHP area to see where the opportunities for heat pumps lie.

9. CONCLUSIONS

Residential self-generation systems are being aggressively developed worldwide. If the development is successful, these systems will compete directly with heat pumps for the residential space and water heating market while offering additional benefits such as independent electric generation and environmental benefits. The challenge for the heat pump industry will be to compete head-on with this new product or to find ways to integrate with it to supplement or improve its performance.

Potential opportunities for heat pumps to integrate with residential self-generation systems involve the use of thermally driven heat pumps driven by the thermal output of the self-generation system to provide space heating and cooling.