
SIDERA 30
Residential micro-cogeneration system with PEM fuel cells technology
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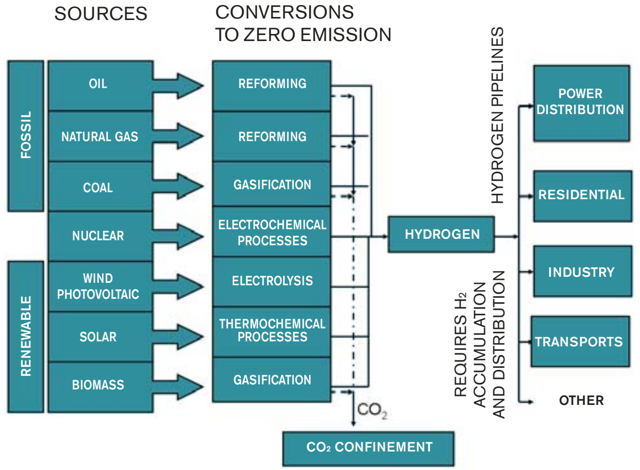
Residential micro-cogeneration system

How far have we come since the first residential applications of fuel cells?

A long way, because never before have we witnessed so many studies on these topics. A great many researchers scattered across the global are working on how to produce hydrogen, and from which sources. Hydrogen is clearly a carrier of energy but not a new source of energy. In the same way, fuel cells will clearly be the most rational way of storing and transporting this element. This brochure, in addition to presenting the Sidera 30 project, aims to provide a simple explanation of some aspects of this technology and to make us reflect over what can be done today in order to use hydrogen in the systems of the future.



[What is hydrogen?]

Hydrogen is the lightest and most abundant element in the universe. In its basic state it is quite rare on the Earth, where it is mostly found chemically bonded with other elements, such in water, hydrocarbons and practically all organic compounds.
In order to be used, it must be extracted and this operation can be performed by using different sources of energy: it can be extracted from hydrocarbons (in fact, it is the by-product of refineries and many chemical processes); it can be obtained through water electrolysis electrolysis ; it can be produced from biomass fermentation and treatment, and also by nuclear sources.

[Why hydrogen?]

Hydrogen means "generator of water"; in its basic state it is an odourless, colourless and extremely volatile non-toxic gas, that burns in the air (the chemical reaction is $H_2 + 1/2\ O_2 = H_2O$ + heat) producing only water and releasing heat.
Hydrogen has the highest energy/weight ratio among all the known fuels: 1 kg of hydrogen releases the same quantity of energy as 2.1 kg of natural gas and 2.8 kg of gasoline.

[How is it used?]

Hydrogen is ideal for use as a fuel or in fuel cells.
As a fuel it can be burnt in traditional heat generating systems, to run turbines or in internal combustion engines to produce power. Hydrogen combustion is not particularly problematic and polluting emissions are far lower than those produced by other fuels. Yet the real development of hydrogen as a carrier of clean energy will undoubtedly depend on fuel cells.

[Hydrogen and safety]

Hydrogen is less flammable than gasoline. The self-ignition temperature of hydrogen is approx. 550 °C versus 230-500 °C for gasoline.
Hydrogen is the lightest fuel and therefore disperses rapidly in open spaces. It burns very quickly, the flames rise upwards and have a very low thermal radiation and wavelength, therefore it is easily absorbed into the atmosphere.
Hydrogen is not toxic, unlike gasoline and oil which are extremely toxic and poisonous for human beings and nature if released involuntarily into the atmosphere.

[What is a fuel cell?]

A fuel cell is an electrochemical generator where the chemical energy of fuels is transformed directly into electricity without any combustion. The cell has two porous electrodes that are separated by an electrolyte. The electrodes act as catalytic sites for the hydrogen and oxygen reactants in the cell, producing water and creating a flow of electricity through the external circuit; the electrochemical transformation is accompanied by heat production.

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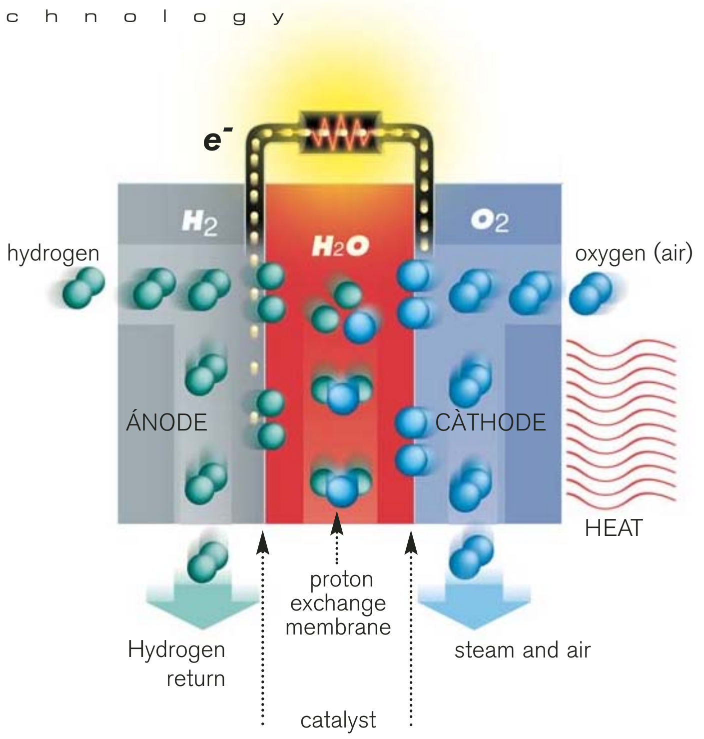
[How does it work]

A fuel cell works like a battery, since it produces electricity by means of an electrochemical process; however, unlike the latter, it consumes substances supplied from outside and therefore is able to be operated uninterruptedly, as long as the system is supplied by fuel (hydrogen) and oxidant (oxygen or air).
The fuel gas (hydrogen) and the oxidant gas (oxygen) are sent respectively to the anode and cathode and produce electricity as a result of the electrochemical oxidation of hydrogen and the electrochemical reduction of oxygen.

Why use a fuel cell?

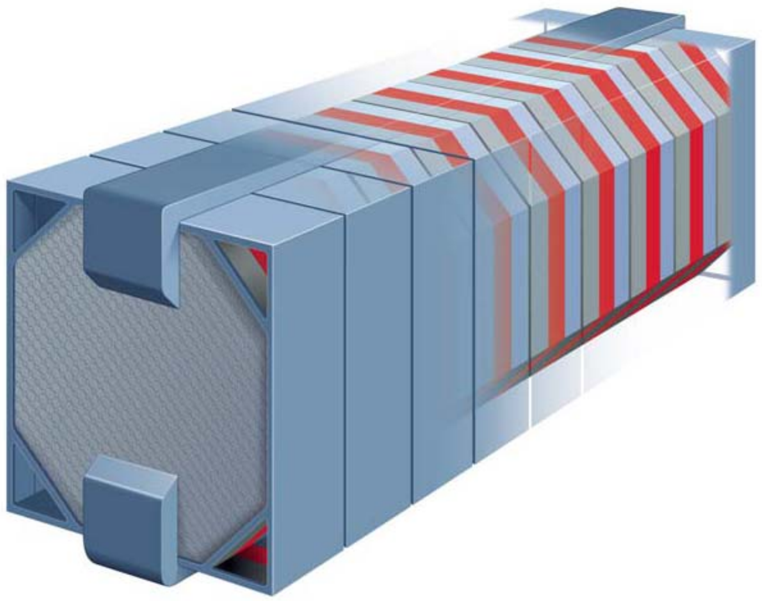
Fuel cells are considered to be very attractive for electricity production, because their energy and environmental characteristics make their use potentially advantageous.
They feature:

- High electric performance
- A wide range of fuels can be used
- Modularity, which allows the installed power to be increased as the demand for electricity rises
- Efficiency whatever the load and size of the plant
- Very low environmental effect
- Cogeneration (heating and electricity).



[The Stack]

A single cell normally produces approx. 0.7 Volts and between 300 and 800 mA/cm²; therefore, in order to obtain the desired power and voltage, several cells are placed in the middle of bipolar plates, forming a so-called "stack".
Stacks in turn are assembled in modules to obtain generators of the power needed.



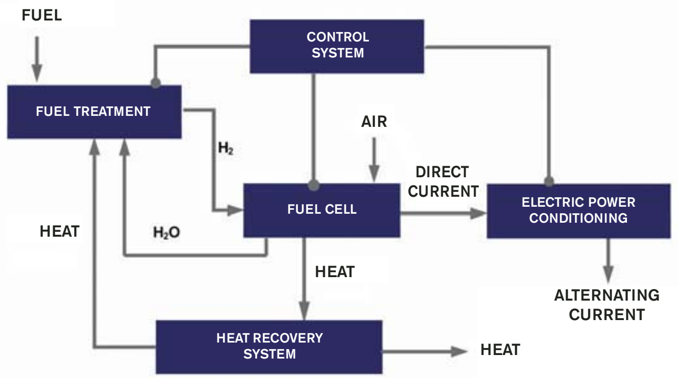
[Systems with fuel cells]

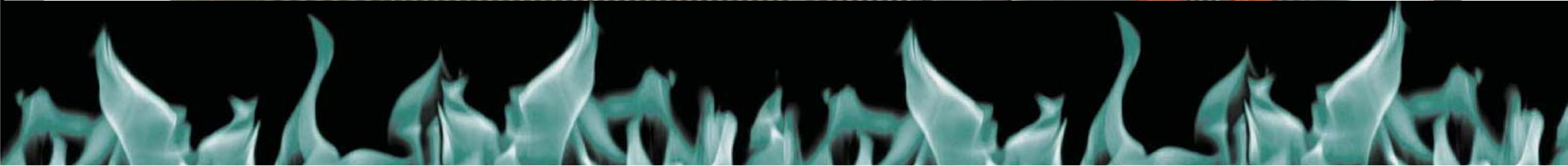
Systems with fuel cells consist of 3 main sections

By ENEA

- A fuel treatment section (natural gas, methanol, synthesis gases produced from coal gasification, biogas) which converts the fuel into a "syn gas" rich in hydrogen, which is purified as needed by the type of cell. This section is not necessary if hydrogen is used.
- An electrochemical section, consisting of cells that produce electricity by electrochemical process, through the reaction between the hydrogen fed to the anode and the oxygen fed to the cathode; the electrochemical transformation is accompanies by heat production.
- An electric power conditioning system which transforms the energy, produced under the form of direct current, into alternating current. There is also a heat regulating and recovery system that can be used inside the unit for cogeneration, as well as for controlling and coordinating the different sections of the unit.

Scheme of a unit with fuel cells





[Polymer electrolyte cells]

PEMs (Proton Exchange Membrane) operate at temperatures ranging from 70 to 100 °C and use a perfluorinated sulphuric membrane with high proton conductivity as electrolyte.
They offer a series of advantages over other cells:
• High power density at the stack (currently >1kW/kg)
• No corrosion which is typical of other kinds of cells with a liquid electrolyte
• Relatively simple to construct
• Fast cold starting (about one minute)

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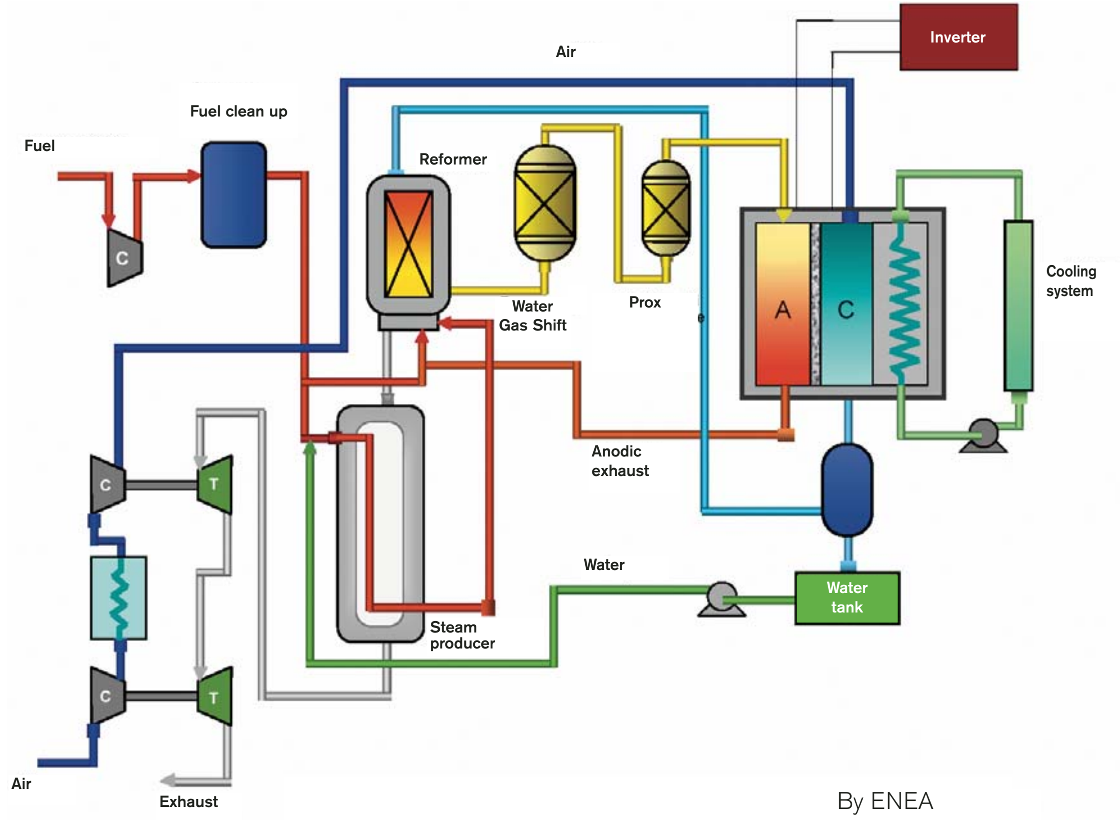
PEMs, developed in the early 1960's for applications in space, have recently attracted interest for their use in stationary applications.

[Stationary application]

Polymer electrolyte cells have stationary applications for household (2-50 kW) and commercial (250-500 kW) power generation.

The figure shows a natural gas system.
After being compressed, the fuel is sent to a desulphurisation unit . The purified gas is then mixed with water in a vapouriser and fed into a reformer. The resulting mix is rich in hydrogen and enters into a shift reactor first and then into a selective oxidisation reactor, to reduce the CO level to below 10 ppm.
The process gas goes to feed the anode section of the cells, where it reacts with the compressed air that is fed to the cathode. The thermal energy needed for the reforming process is provided by the combustion of residual gases from the electrochemical module; water is removed from the cathode exhaust, part of which is sent to the vapouriser to humidify the fuel before it enters the reformer.
The direct current produced by the stacks is converted into an alternating current by the inverter, connection to the net electrical worker or for stand-alone generation.



By ENEA

Cogeneration for commercial use

The energy needs of homes, apartment buildings and stores – which are fundamentally electricity, heat and cold – have been traditionally met through the separate supply of electric and thermal energy.

The traditional model used to meet these needs involves generating electricity in large thermoelectric power plants, which are distant from the metropolitan user basin, and subsequently transferring it through a network of distribution to single users. Thermal energy, on the other hand, is generated by the single user (whether a home or apartment building) by means of combustion heating systems. Last, cooling energy is generated by means of compression systems that are powered by the same electricity system. This tried-and-tested model has several disadvantages, first among these a low thermodynamic efficiency overall (if all the three needs above are considered as energy outputs), as well as polluting emissions that are by no means negligible and the need for an efficient electricity distribution network, which is expensive in terms of investments and operating costs. For the end user, all this leads to rather high energy costs.

The classic alternative to the model described above is large district-heating networks powered by relatively large cogeneration plants, that combine electricity production with heat and/or cold generation in a centralised manner. In this way, some of the problems above are eliminated, but the problem of emissions remains as does the need for a double network, with its related costs for the thermal energy and electric power distribution.

Over recent years, technology is giving greater importance to the so-called "distributed generation" of electricity, cold and heat in a territory.

The result is major changes to the role of the existing electricity network as well as to combustion/compression systems for heat/cold production.

The distributed generation model involves installing a large number of high-performance micro-plants for cogeneration that satisfy a significant portion of energy consumption (electrical, heating and air conditioning) for the domestic, commercial and service sector. By combining the well-noted thermodynamic benefits of cogeneration with the expected high-performance levels of the most promising micro-generation systems, this would lead to a more rational use of energy resources and would drastically simplify the infrastructures required to carry the energy.

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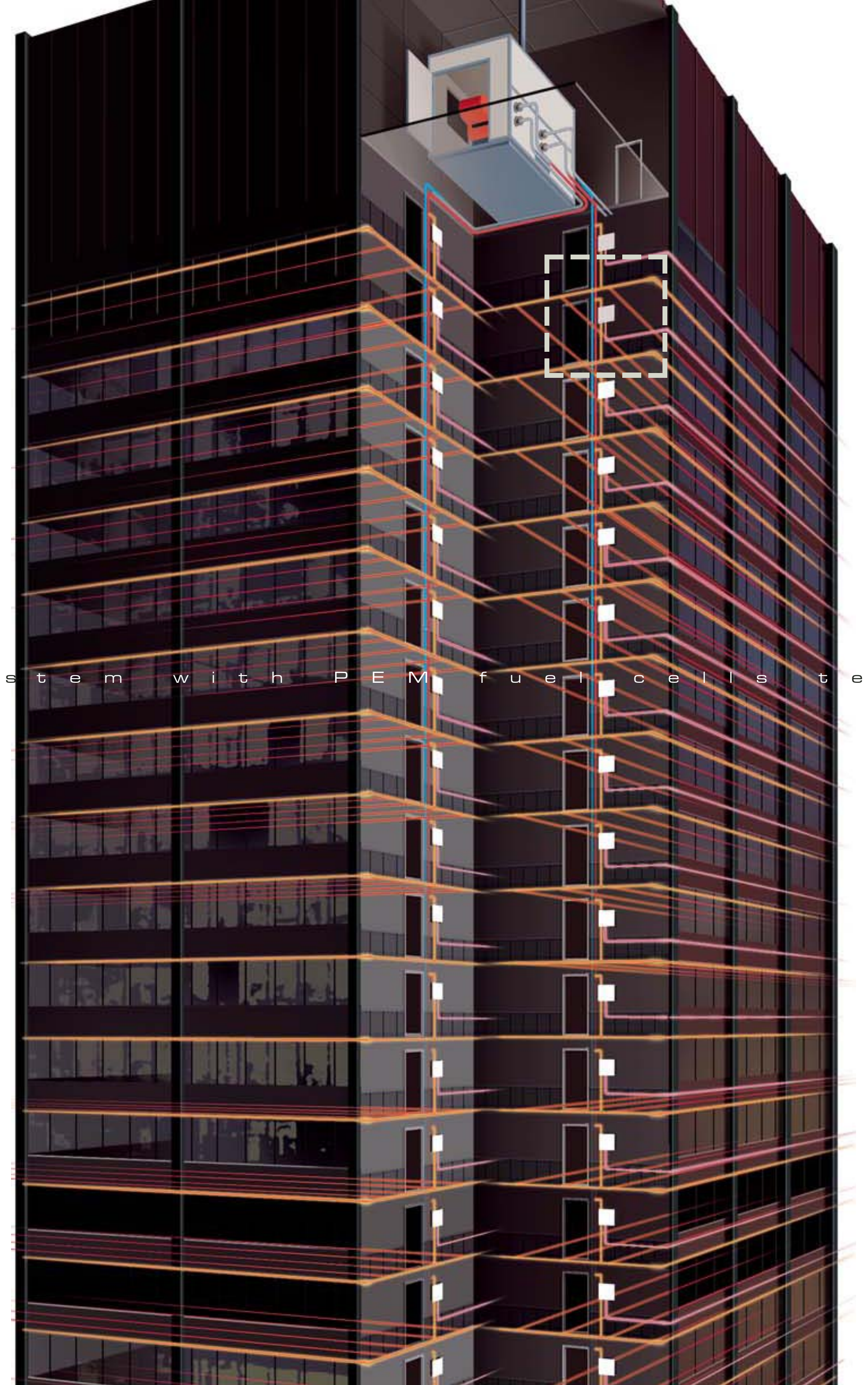


Sidera 30

There are many district-heating projects in modern European cities. This demonstrates the need to return to centralised production in order to avoid waste, guarantee the appropriate maintenance and remove the dangers of fuel from homes. In the more advanced projects, and wherever this is possible, there is talk of cogeneration and distance heating plants using biomass and renewable energy sources. The reason for this is that, along with the need for home heating, there is a growing need for electricity.

The Sidera 30 micro-cogeneration project using fuel cells, that is being developed by ICI Caldaie, is the perfect solution. This machine can replace boilers in centralised units by taking over their functions and integrating the production of electricity The more recently the installed system is, the simpler the changeover.

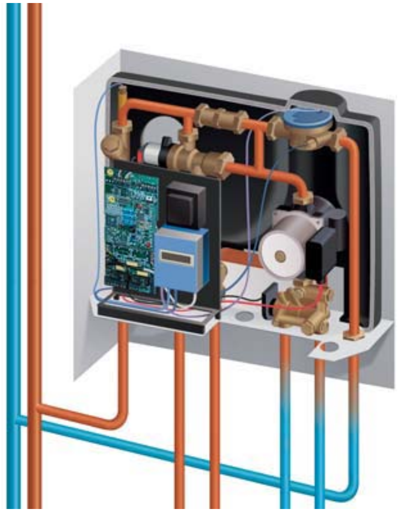
The machine consists of a reforming unit to transform methane into hydrogen, four stacks for electricity and heat production, a condensation boiler to integrate the thermal requirements and a refrigerator (optional) for the production of refrigerated water. When hydrogen will become directly available as a fuel, the reformer will simply be eliminated.

The presence of this element will allow for the easy introduction of the system on the market because it will be sufficient to connect Sidera 30 to the gas system, heating system and electricity meter, combining energy consumption in a central production unit.

With the installation of a Sidera 30, apartment buildings can be self-sufficient in terms of energy production, have zero polluting emissions and sell excess electricity; all of this with a machine that does not have any moving parts and therefore without any noise emissions. More than one unit connected together could replace large electric power plants that are increasingly more difficult to position and would be in the city centre, directly connected to the user, thereby simplifying distribution problems. These benefits justify choosing these products because of their simplified logistics and environmental impact.

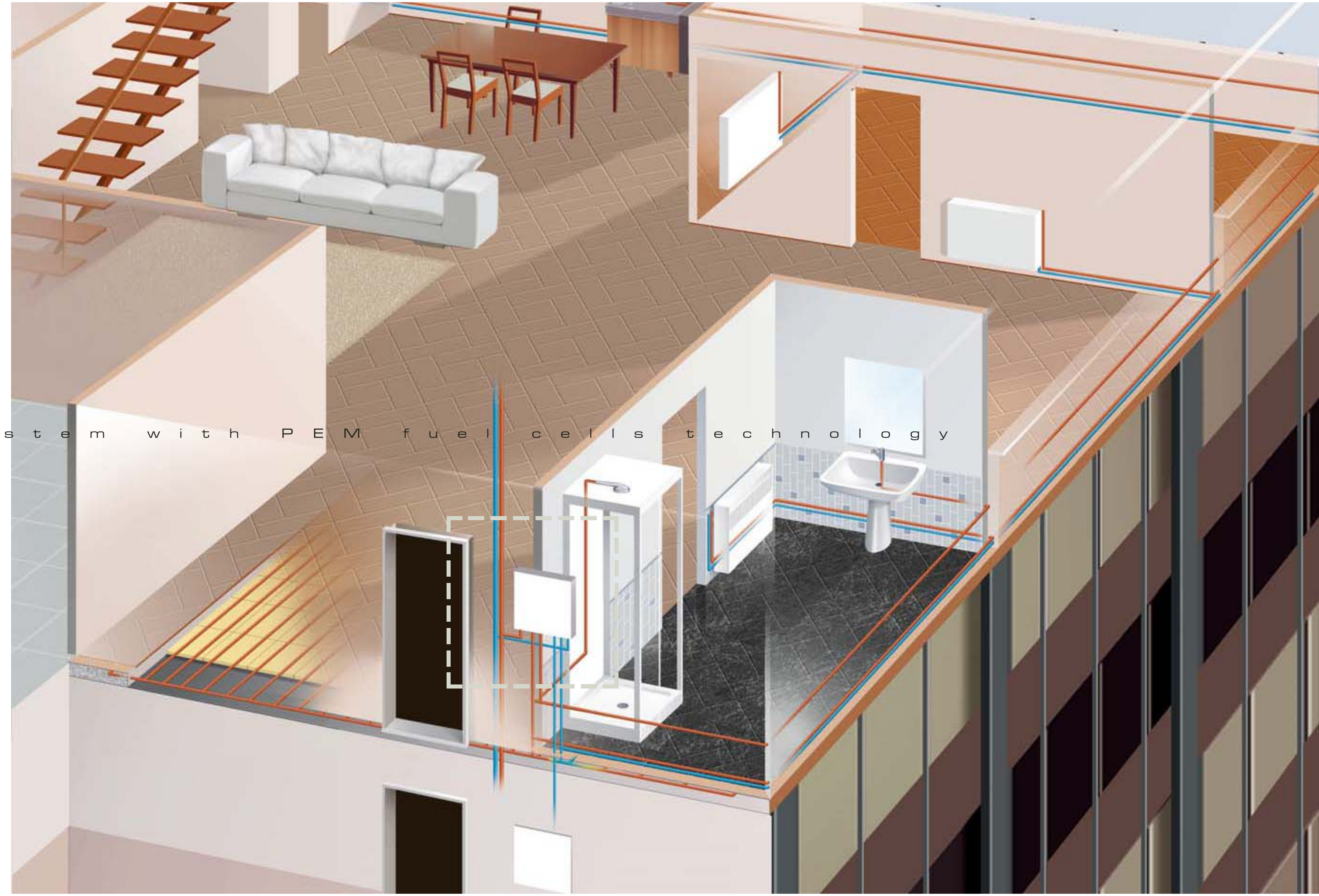
[How can units be adapted for this new technology?]

The answer lies in distributing heat through thermal satellite modules which are a response to the recent demand for products that can combine the versatility and autonomy of independent boilers with the simple operations and high performance of centralised production.
The thermal satellite module receives the primary fluid from the heat plant and quantifies all the energy that enters in a single apartment, thus allowing each user to manage his own consumption and his own expenditure. Plumbing and subsequent adjustment allow heat to be produced for heating and hot domestic water production. The electronic control panel allows each single module to monitored and adjusted. The modules are available in the recessed version and for outdoors, fitted with calorifier or instant response for domestic hot water and distribution of cooled water. In the more complex versions, the modules can also manage units with different temperature levels (mixed floor systems) and summer/winter inversion for summer cooling.



The application of the system comprising condensation boilers (today and fuel cell systems in the future) and meter modules is the ideal solution for modern apartment buildings, offices, public buildings, and other buildings by combining the need for independent use with centralised production.

RADIAX BOX MODULE



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ICI Caldaie has been working for more than 40 years in the professional heating industry by designing and producing heat generators for commercial and industrial use. The solutions based on the power range span from 30 kW condensation boilers to 10.000 kW steam generators; offering very high level solutions to heat users. Innovation is a distinguishing feature of ICI Caldaie and can be documented throughout its history.
Its recent products for commercial use include low-return temperature and condensing hot water boilers with a strong focus on high energy savings.
The recently-approved Sidera 30 project is an example of innovation: a stationary application for fuel cells for the production of heat and electricity.
The use of hydrogen in the nearby future is no science-fiction; it is rather a concrete solution for the systems that we presently design.

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