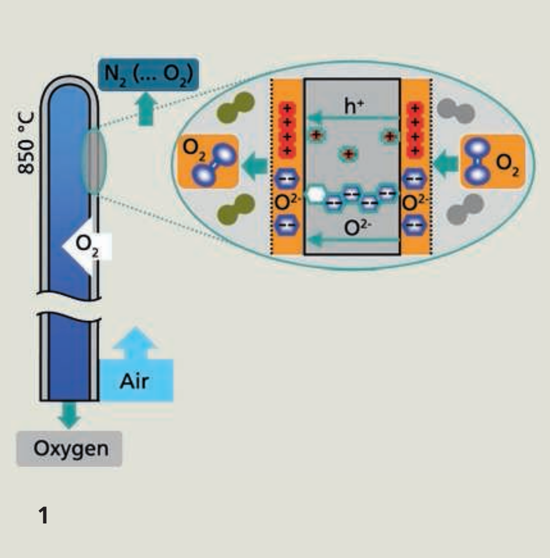

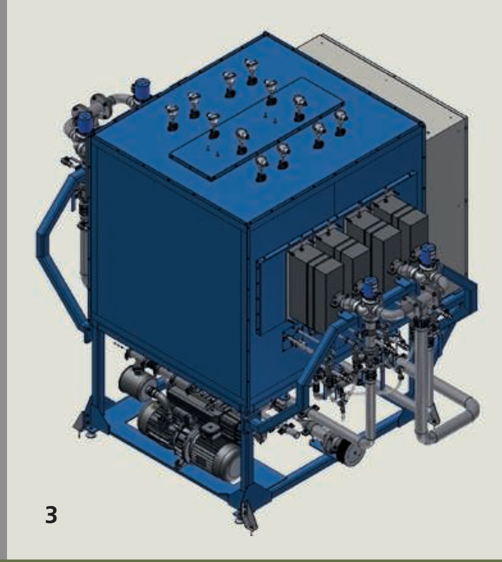

MORE EFFICIENT O_2 PRODUCTION USING CERAMIC MEMBRANES

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The global production of oxygen (O_2) currently amounts to approx. 530 million metric tons per year, corresponding to revenues of 34 billion euros per year. More than 90 % of the O_2 is produced by cryogenic air separation units (cryo ASUs) and must normally be delivered to the customer. For local O_2 production, pressure swing adsorption (PSA) or vacuum-PSA (VPSA) is typically used. The purity of the oxygen is usually restricted, or higher purity can only be attained with higher energy consumption. For a high O_2 demand, the price is dominated by the energy requirements, whereas the costs of logistics and transportation dominate the price for low amounts.

On-site O_2 production using ceramic membranes is a competitive option. The process is based on the coupled conductivity of the membrane materials for oxide ions and electronic charge carriers (electrons or holes) at high temperatures. For this reason, these membranes are called MIEC membranes (mixed ionic electronic conductor). Because only oxide ions can occupy the vacancies inside the crystal lattice, pure O_2 is always generated. The total energy requirements of the process consist of the heat needed to maintain the operating temperature and the energy needed for gas compression. The vacuum process developed by Fraunhofer IKTS requires approximately 0.2 kWh/Nm³ O_2 for the vacuum pump and approximately 0.25 kWh/Nm³ O_2 for heating and was already piloted up to a scale of 10 Nm³/h O_2. The table on the right-hand side shows a comparison of this process with the established processes.

The established processes require the energy completely in the form of electricity. In contrast, MIEC membrane plants can be heated by the combustion of gas or by waste heat from high-temperature processes. With the price of thermal energy produced by gas combustion typically amounting to just 25 to 33 % of the price of electricity, MIEC membrane plants heated by gas combustion or waste heat represent a significant cost-cutting potential. Additionally, CO_2 emissions are lower for O_2 production in MIEC membrane plants because much more CO_2 per kWh is generated in the production of electricity than in the combustion of gas. MIEC membrane plants can thus also be used beneficially in processes in which the established O_2 production methods are no longer feasible.

Process comparison in terms of energy costs and CO_2 emissions for the production of 1 Nm³ O_2

Process	kWh_{el} [a]	kWh_{th} [b]	€-Ct.	g CO_2
Cryo ASU	> 0.38		4.1[a]	290[c]
PSA	> 0.90[d]		9.0	540
Vacuum-PSA	> 0.36[d]		3.6	216
MIEC membrane plants according to heating method				
a) Electric	> 0.45		4.5	270
b) Gas	> 0.20	0.25	2.6	185
c) Waste heat	> 0.20		2.0	120

[a] 10 Ct/kWh_{el}, 600 g CO_2/kWh_{el}; [b] 2.5 Ct/kWh_{th}, 260 g CO_2/kWh_{th}; [c] incl. transport; [d] < 95 vol % O_2

1 Schematic diagram showing the working principle of MIEC membrane separation.

2 BSCF capillaries for O_2 production.

3 CAD drawing of a device producing 10 Nm³ O_2/h.

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