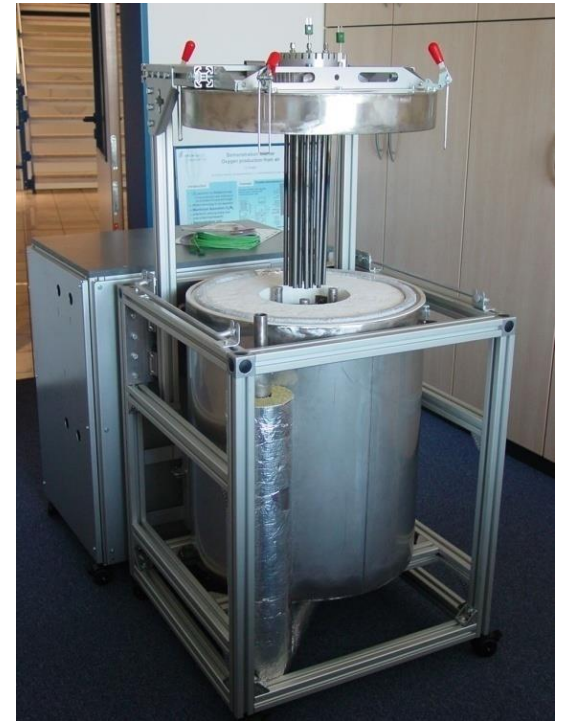
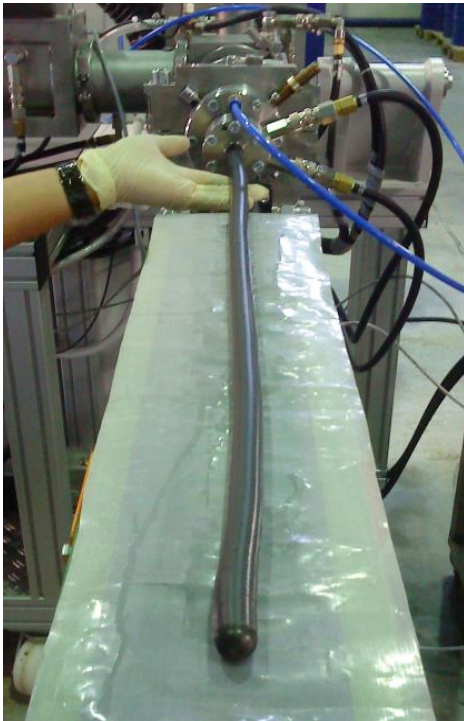


CeMSOS

Ceramic Membrane System for Oxygen Supply

Fraunhofer IKTS und RTM



1. Market: Oxygen Production and Application

Global production of O₂: **100*10⁶ t/a**¹ in 2001
(growing with ≈5.5 %/a²) **≈ 190*10⁶ t/a** in 2013

O₂ combustion (temperature↑, efficiency↑, **CCS**):

- steel (**94*10⁶ t/a**), glass, waste combustion, ceramics, cement, power plants

Chemical industry (**36*10⁶ t/a**): C₂H₄O, **GtL** fuels

- **O₂ gasification** of coal, biomass, waste water treatment, health care, fish breeding, welding ...

O₂ costs determine **market penetration** for:

- combustion, small GtL, gasification, on-site use

Potential for the future:

- O₂ used in air fired plants: **21*10⁹ t/a**³ in 2009



¹ J. Emsley: Oxygen, Nature's Building Blocks: An A-Z Guide to the Elements, Oxford UK 2001,
² <http://www.gasworld.com/oxygen-global-market-report/1277.article>; ³ CO2 emissions from fuel combustion . IEA 2009
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1. Market: Oxygen Production Technologies and Costs

Costs depend on technology, production rate, **electricity price**

Energy efficiency is exhausted for mature technologies

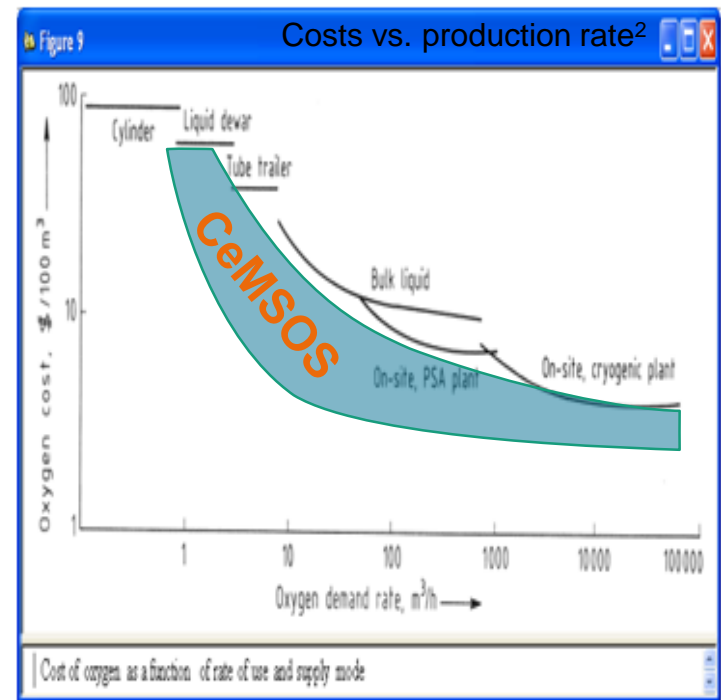
- **PSA - Pressure Swing Adsorption**
 $\geq 0.36 \text{ kWh}_{\text{el.}}/\text{Nm}^3$ (< 95 vol.-%)
- **cryogenic ASU - distillation of cold, liquefied air in an Air Separation Unit**
 $\geq 0.38 \text{ kWh}_{\text{el.}}/\text{Nm}^3$ (99.5 vol.-%)

minimal price at a very large plant:

- **$\geq 35 \text{ \$/t}_{\text{am. O}_2}$** ¹ ~ 29,7 €/t ~ 0.03 €/kg
- **$\geq 0.021 \text{ €/Nm}^3$** (but **1 €/Nm³** @ 1 Nm/h)

Market volume for tonnage production:

4,7 billion €/a expected for 2018³



CeMSOS: already competitive at lower production rates!

¹ G.O. Alptekin et. al., AIChE Annual meeting, Nov. 16-21, 2008, Philadelphia, USA; ² Ullmann's Encyclopedia of Ind. Chem., 5th Ed., > "Oxygen" > "Economic Aspects", Fig. 9; ³ www.culrav.org/pr/global-industrial-gases-market-will-reach-usd-58-4-billion-globally-in-2018-transparency-market-research.php

2. CeMSOS - Basics: MIEC Membranes for O₂ Separation

