Produção +Limpa

VII Seminário sobre Tecnologias Limpas

20 e 21 de novembro de 2017

Inovação, Design, Reúso e Reciclagem

- **Fuel Cells**

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21st. november 2017

Local: SALA II • SALÃO DE ATOS • UFRGS

REALIZAÇÃO:

FIERGS SENAI · INSTITUTO SENAI DE TECNOLOGIA · UFRGS · ABES-RS

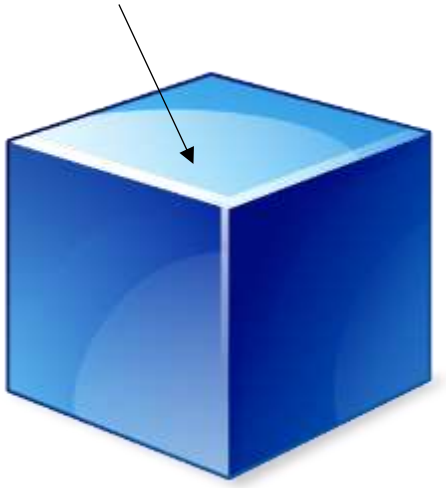
Common statement in *Cleaner Production* texts:

- be **energy-efficient** and use **renewable** energy;

- be **energy-efficient** and use **renewable** energy

Energy

$CH_4 + 2\ O_2 = CO_2 + 2\ H_2O \quad \Delta H_r = -8{,}9\ E\ 5\ [J]^*$



lower heating value (**LHV**)

1 [N m^3] = 44,6 [mol]

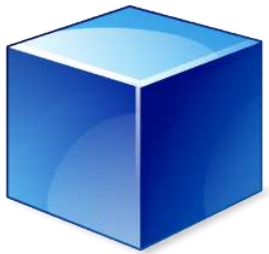
~36,0 [MJ/m^3]

Heat released by combustion

* http://www.ausetute.com.au/heatcomb.html

Energy

36,0 [MJ/m³]



Time: 2 [s]

Time

Power

1 [s] -> 36,0 [MW/m³]

2 [s] -> 18,0 [MW/m³]

3 [s] -> 9,0 [MW/m³]

... heat flow

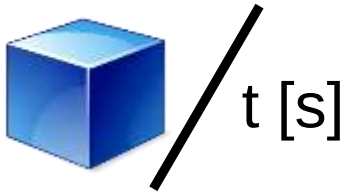
Power!

50 [kW] to
2,5 [MW]

Cidade Azul
3 [MW]

Pampa Sul
340 [MW]

Itá
1 450 [MW]



t [s]

1 [s] -> 36,0 [MW/m³]

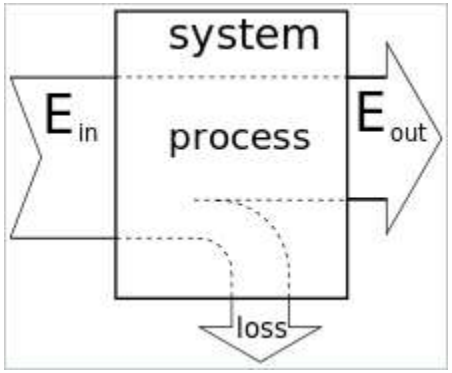
2 [s] -> 18,0 [MW/m³]

3 [s] -> 9,0 [MW/m³]

...

http://www.engieenergia.com.br/wps/portal/internet

Conversion



E_{out} / E_{in}

Efficiency

Water turbine	**Gravitational to electrical**	up to **90%** (practically achieved)
Wind turbine	**Kinetic to electrical**	up to **59%** (theoretical limit)
Solar cell	**Radiative to electrical**	**6–40%** (technology-dependent, 15-20% most often, 85–90% theoretical limit)

https://en.wikipedia.org/wiki/Energy_conversion_efficiency

Other Chemical potential → ???

Chemical potential

Heat flow from combustion

$$\text{Efficiency} = \frac{W}{Q_h}$$

Heat engine / Carnot cycle

Chemical potencial

Fuel cell

Energy from reaction

$$\varepsilon_{thermo} = \frac{\Delta G_{rxn}}{\Delta H_{rxn}} = \frac{useful\ E}{total\ E}$$

Bypassing the Carnot cycle results in higher efficiency:

- Fuel Cell efficiency: 50 to 60 %
- Heat engines have efficiencies from 40 to 60%

Some characteristics of SOFCs*:

No moving parts:

- Low noise;
- Low maintenance costs.

N_2 filtering effect of oxide membrane:

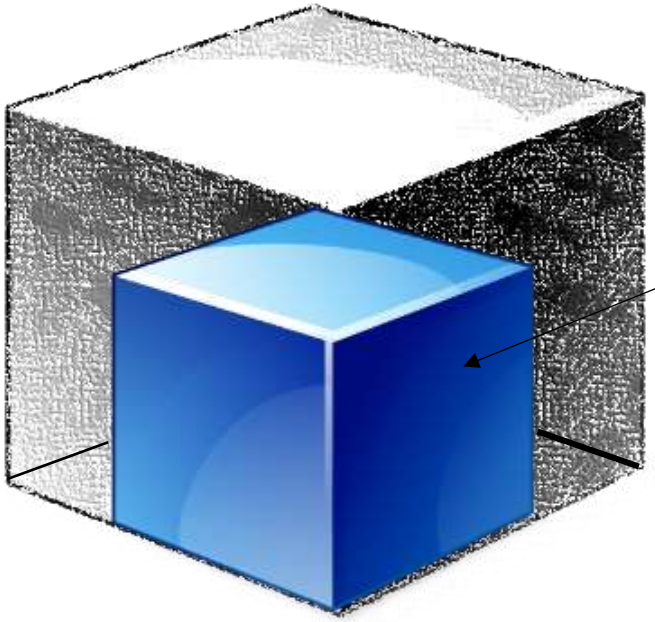
- Low Nox

High efficiency:

- Low CO_2 per kW

* Solid Oxide Fuel Cells

- be **energy-efficient** and use **renewable** energy



- BIOGAS
  ~ 60% CH_4
  (rest: CO_2)
- SYNGAS

Low noise: Hartford Hospital, Hartfort, **USA**

https://www.fuelcellenergy.com/wp-content/uploads/2017/02/Fuel-Cells-Healthcare.pdf

GLOBAL INSTALLED CAPACITY

In **2015** the global fuel cell industry comprised around 200 companies, with sales revenues of about $2.2bn, shipping 50,000 fuel cell systems with a total capacity of 180MWe.
The global installed fuel cell generating capacity is 1 GWe.
Major uptake continues in North America and Asia Pacific, accelerating more slowly in Europe.

MARCH 2016 | ENERGY IN BUILDINGS & INDUSTRY
SERIES **13** | MODULE **09** | **FUEL CELLS**

DoE: SOLID OXIDE FUEL CELL PROGRAM

The U.S. Department of Energy initiated the SOFC Program in 2000 to develop low-cost, highly efficient, environmentally friendly SOFC technology for smaller, modular-scale as well as large-scale power generation from natural gas or coal-derived synthesis gas. The specific goals of the SOFC program are: to meet a stack cost target of $225/kW and **a system cost target of $900/kW**; demonstrate lifetime performance degradation of less than 0.2% per 1,000 hours over an operating **lifetime of 40,000 hours**; and achieve an **efficiency of greater than 60%** without carbon capture and storage.

https://energy.gov/fe/science-innovation/clean-coal-research/solid-oxide-fuel-cells

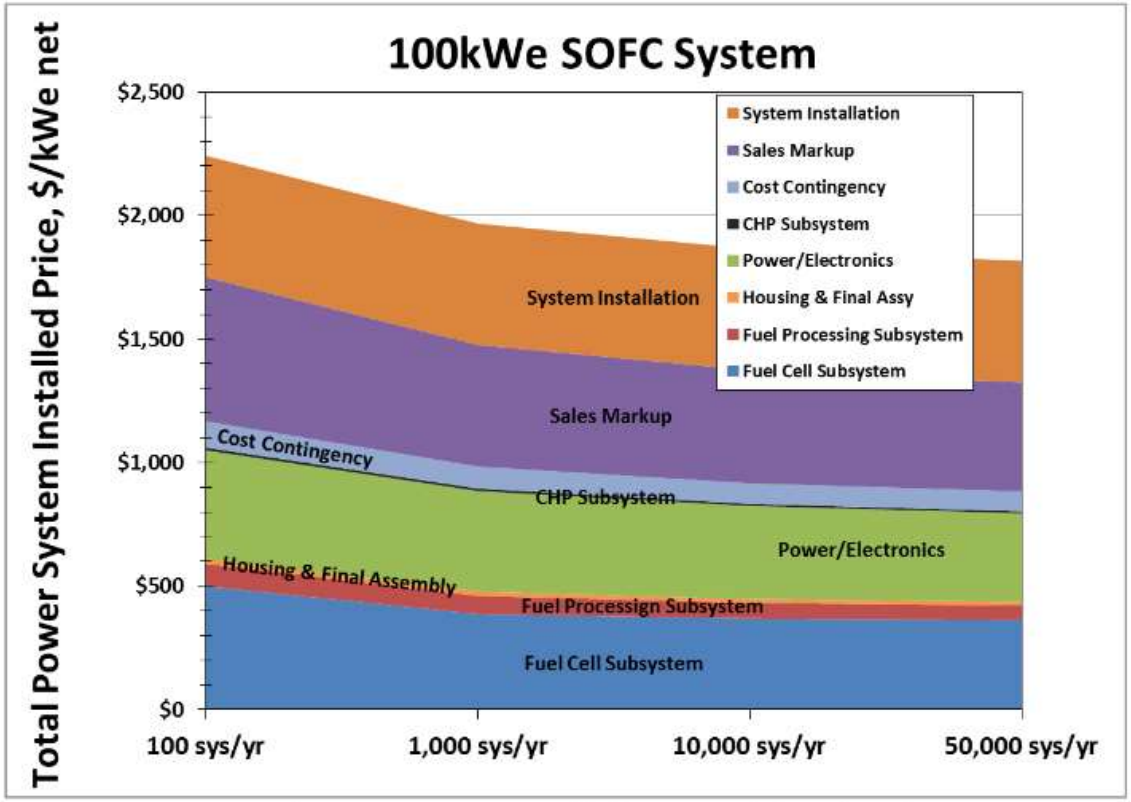


Figure 7. 100 kWe SOFC System Installed Price Breakdown by Subsystem

30 September 2015

https://www.sainc.com/assets/site_18/files/publications/sa%202015%20manufacturing%20cost%20and%20installed%20price%20of%20stationary%20fuel%20cell%20systems_rev3.pdf