

# **A Novel Design Concept to Increase Tubular Stack Volumetric Power Density and Fuel Efficiency**

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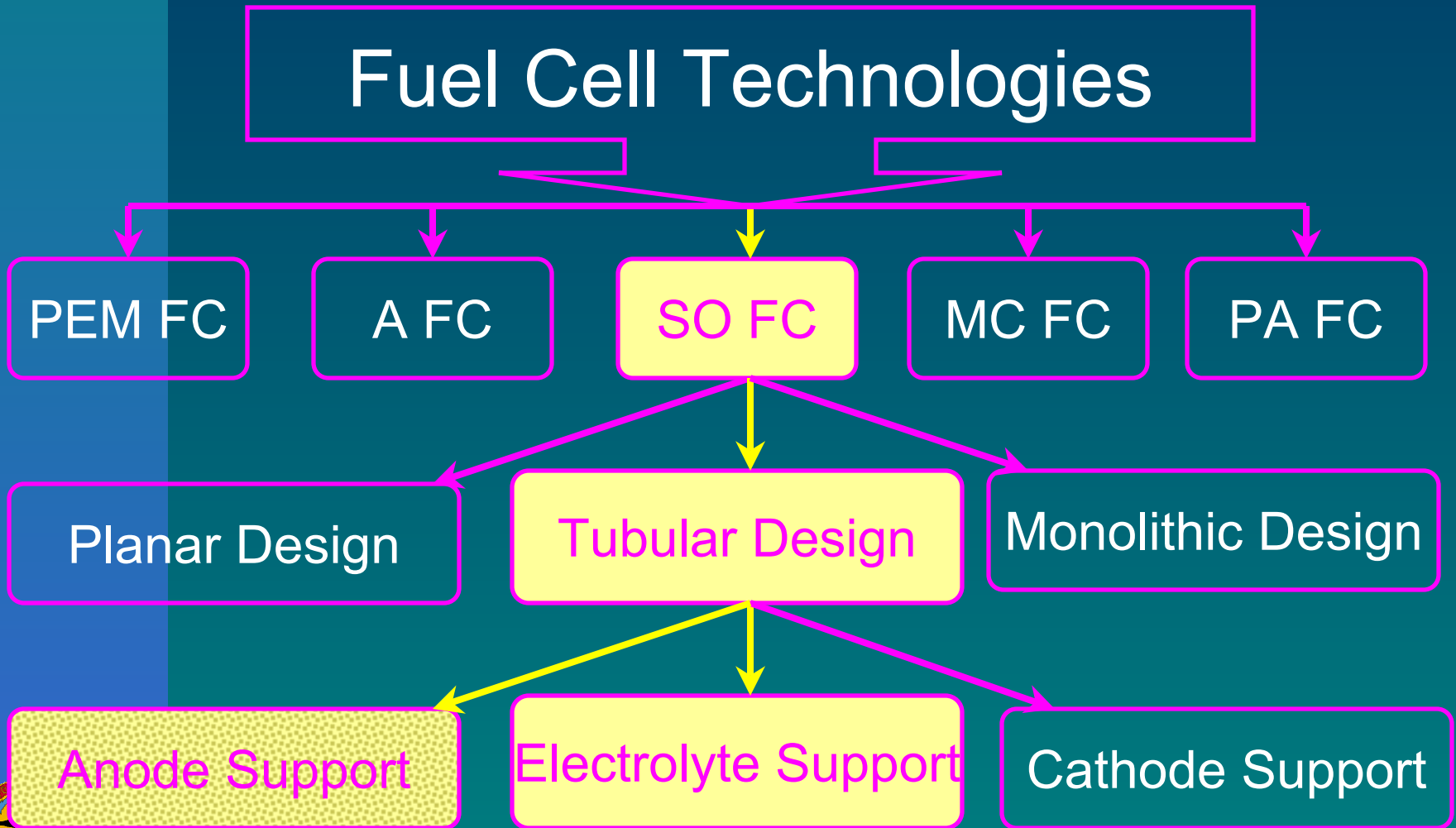
# Outline

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1. Introduction
2. Tubular or Planar?
3. New Design Concept
4. Benefits



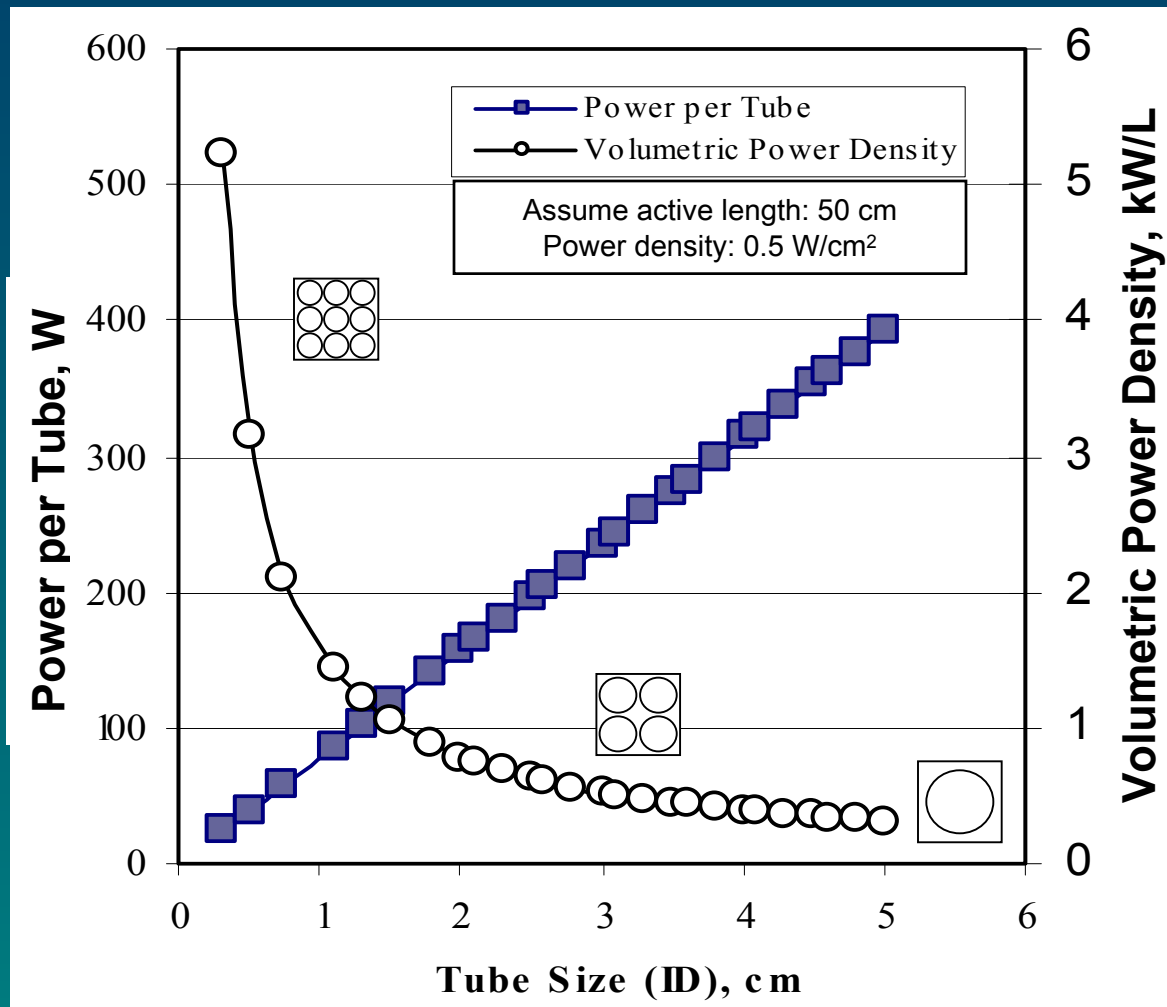
# Introduction



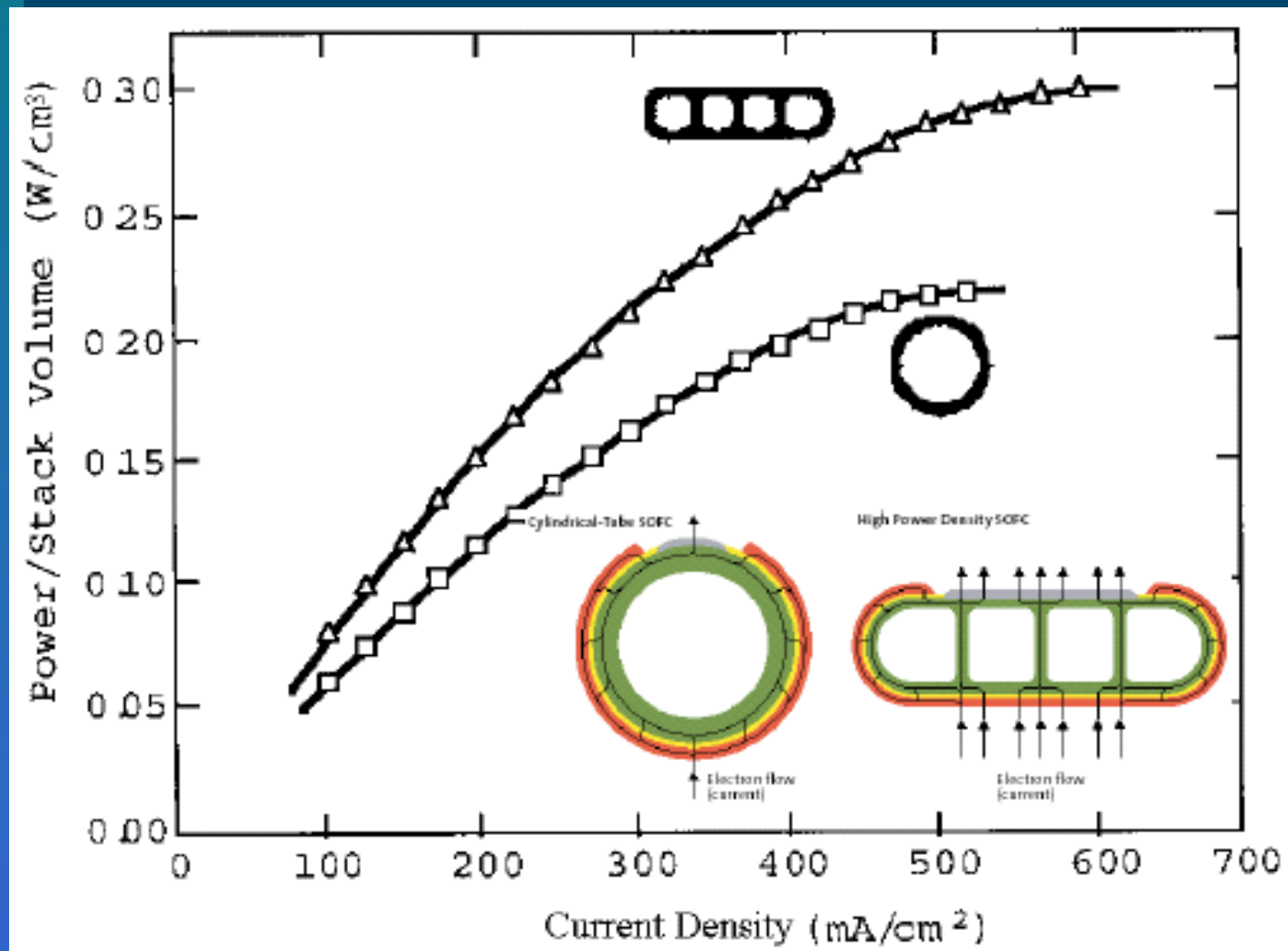
# Tubular? or Planar?

Cell design concept	Tubular design	Planar design
Power density	0.25-0.5 W/cm <sup>2</sup>	0.5-1 W/cm <sup>2</sup>
Volumetric power density	Low	High
Sealing	Less seal requirements	High temp. seal, difficult
Start-up/cool-down	Faster	Slow
Interconnect	Difficult	High cost
Fuel internal reforming	Simpler	Difficult
Manufacturing cost	High	Lower cost feasible
Examples (Siemens Westinghouse)	100 kW (1998) 1152-tube stack 200-250 mA/Cm <sup>2</sup> 1000°C 83% on natural gas	7.2 kW (1998) Two 50x4x4 stacks 400 mA/Cm <sup>2</sup> 900°C 30% on hydrogen

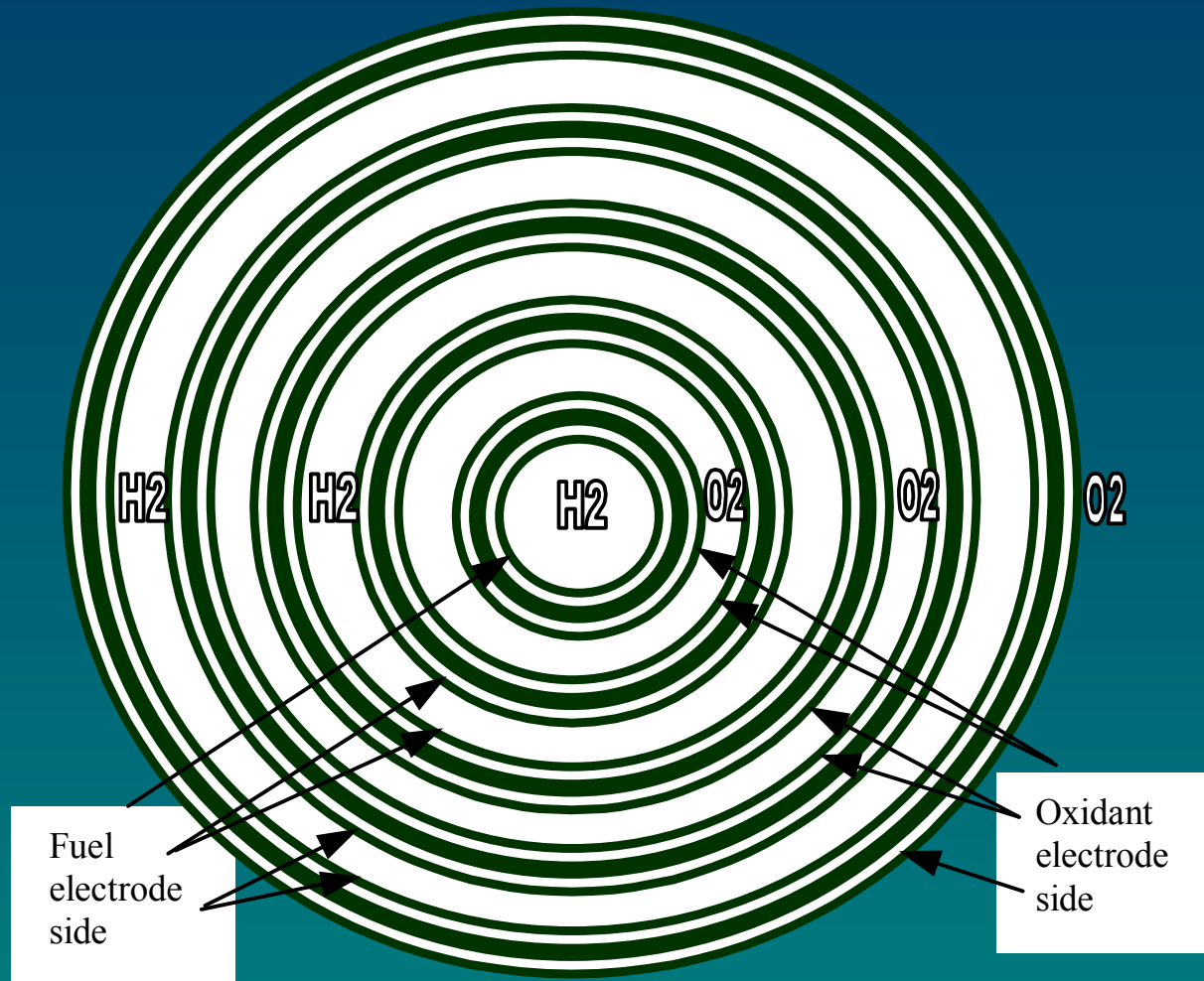
# Power Per Tube and Power Packing Density as a Function of Tube Size



# Siemens Westinghouse Flat-Tubular



# Novel Design to Increase Stack Volumetric Power Density



# Stack Volumetric Packing Density Is a Function of Fuel Cell Performance and Cell Design

$$P_v = \frac{4P_a n \left( d_1 + \frac{n-1}{2} \Delta d \right)}{\left[ d_1 + (n-1) \Delta d \right]^2}$$

$P_v$  = volumetric power packing density (VPPD), W/cm<sup>3</sup> (kW/L)

$P_a$  = cell area power density, W/cm<sup>2</sup>

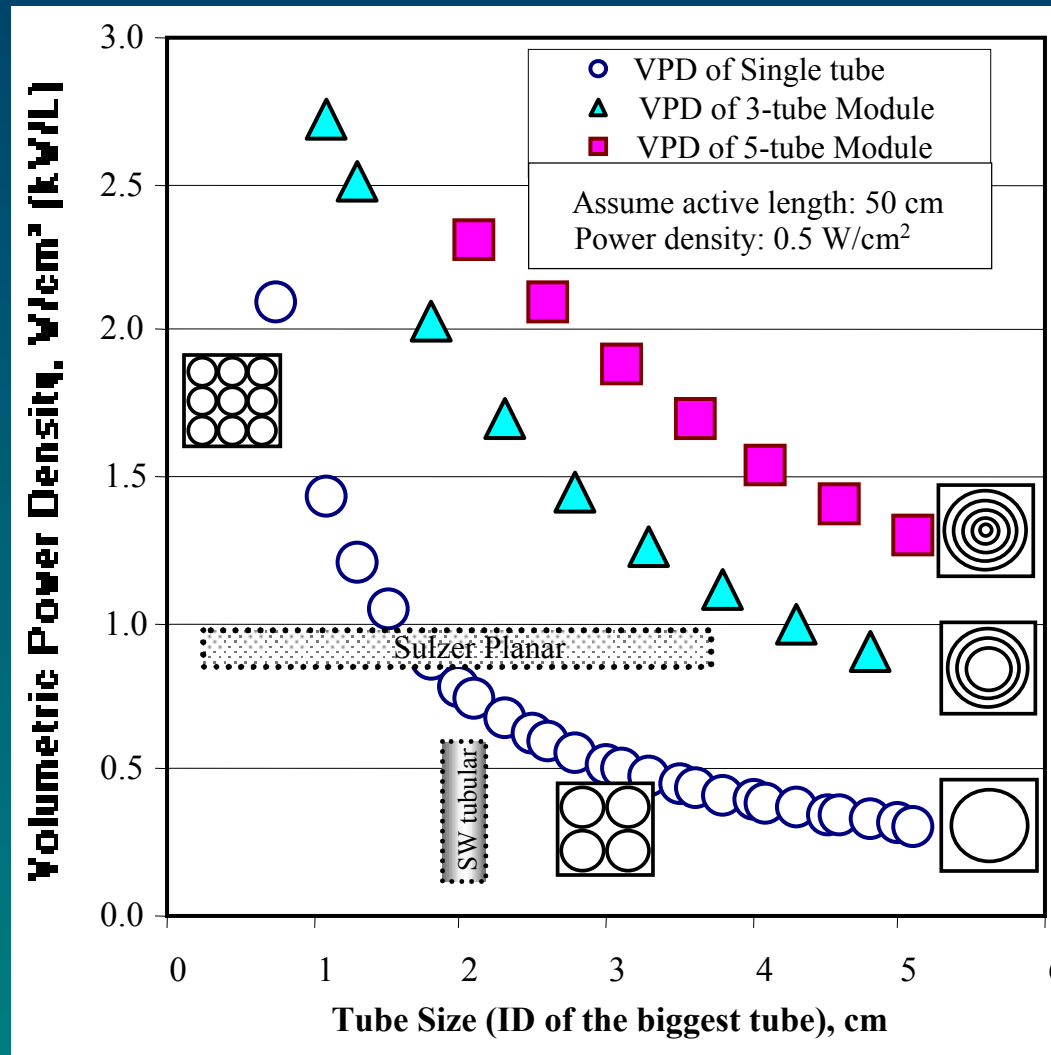
$d_1$  = smallest tube ID, cm

$\Delta d$  = ID difference between the two neighboring tubes, cm

$n$  = number of tubes in a module



# Novel Design with High Stack Volumetric Power Density



# Support Components



**Electrolyte Support**



**Extrusion**



**Anode Support**



# Summary

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- **Increase the volumetric packing power density by over 40% for a 2-tube assembly, over 80% for a 3-tube assembly;**
- **Increase fuel utilization/Fuel efficiency;**
- **Reduce stack size;**
- **A prototype to prove the concept in process**

