

Technologies for a more energy efficient Norwegian continental shelf



What about high temperature fuel cells (SOFC)?

*Björg Andresen, Managing Director, www.zegpower.com
NFR, August 25, 2015*

ZEG Power 

ZEG Power

High efficient co-production of **electricity and hydrogen** from hydrocarbon gases with integrated CO₂- capture

Unique patented technology



- ” R&D since 2001
- ” ZEG Power AS established in 2008
 - Joint Venture between IFE and CMR
- ” A 50kW demonstration plant using biogas fuels (**BioZEG**) is operational from 2014
 - 70% system efficiency
- ” Pre-engineering, upscaling from 50kW to 400kW



CLIMIT

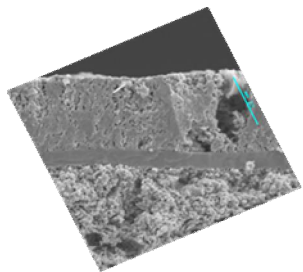
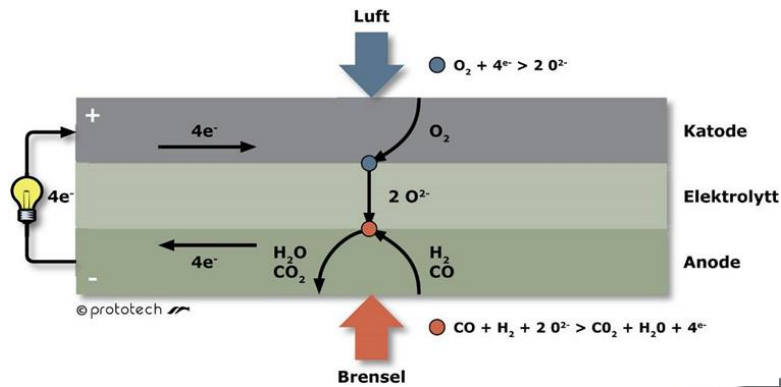


cmr Prototech

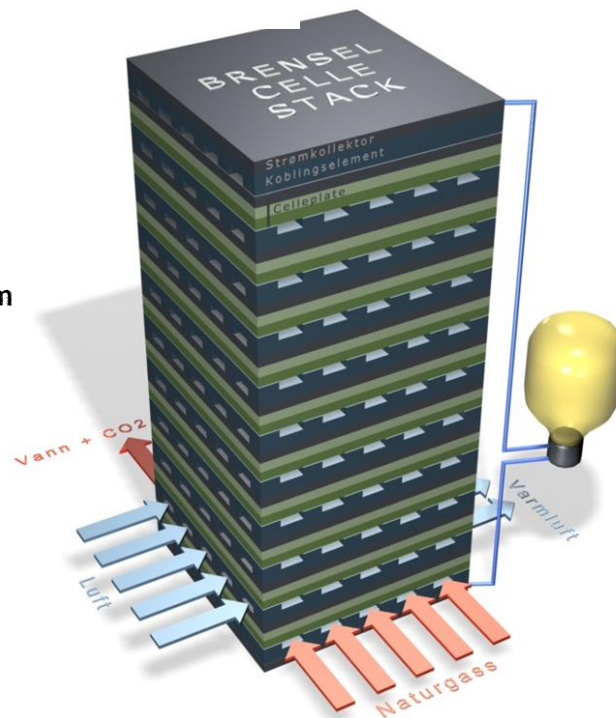
ZEG Power 

Why fuel cells?

Chemical conversion of fuel to energy



50 μm

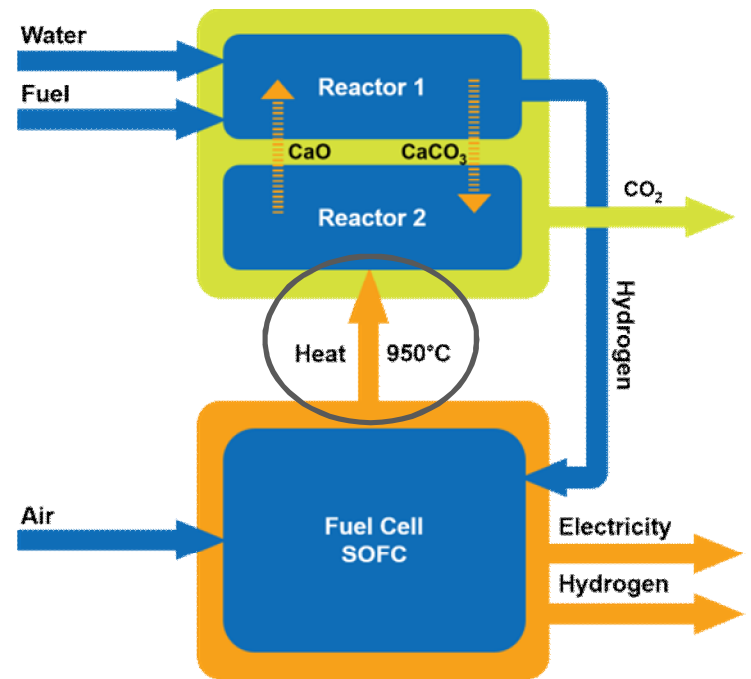


- High efficiency
- Low emissions
 - No NOx
 - No particles
 - (No CO_2)
- Fuel flexibility
- Power when you need it
- Power where you need it
 - Distributed power

The ZEG - technology (ZEG[®])

High efficient co-production of **electricity and hydrogen** from hydrocarbon gases with integrated CO₂- capture

- “ **Electricity** produced by high temperature solid oxide fuel cells (**SOFC**)
- “ **Hydrogen** production by sorption enhanced reforming (**SER**) using waste heat from the SOFC
- “ **CO₂** removed by a high temperature CaO-based sorbent in a carbonation reaction
- “ Close **thermal integration** in order to get overall high efficiency (> 75%)



ZEG Process Evaluation

ZEG Power HYSYS simulations

SER + SOFC	700 MW H ₂ + 400 MW el	50 MW H ₂ + 400 MW el	400 MW el
Efficiency (LHV)	78.5 %	81.3 %	77.0 %
CO ₂ Capture	~ 100 %	~ 100 %	~ 100 %



Statoil Aspen Plus simulations . 400 MW_{el} power plant:

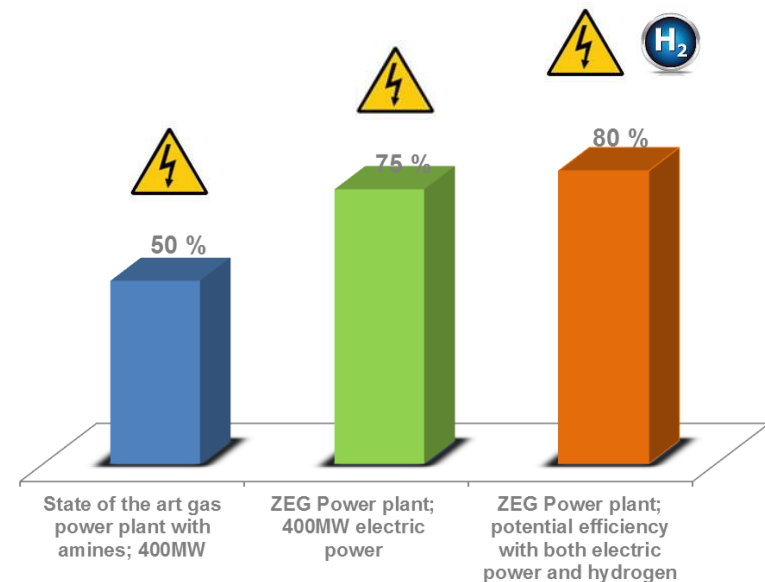
- . ZEG: 75 % energy efficiency (LHV) for stand alone power production including ~ 100 % CO₂ capture and compression of CO₂ to 110 bar.
- . Traditional amine based CO₂ capture: 48-50% energy efficiency (LHV)



ZEG Power

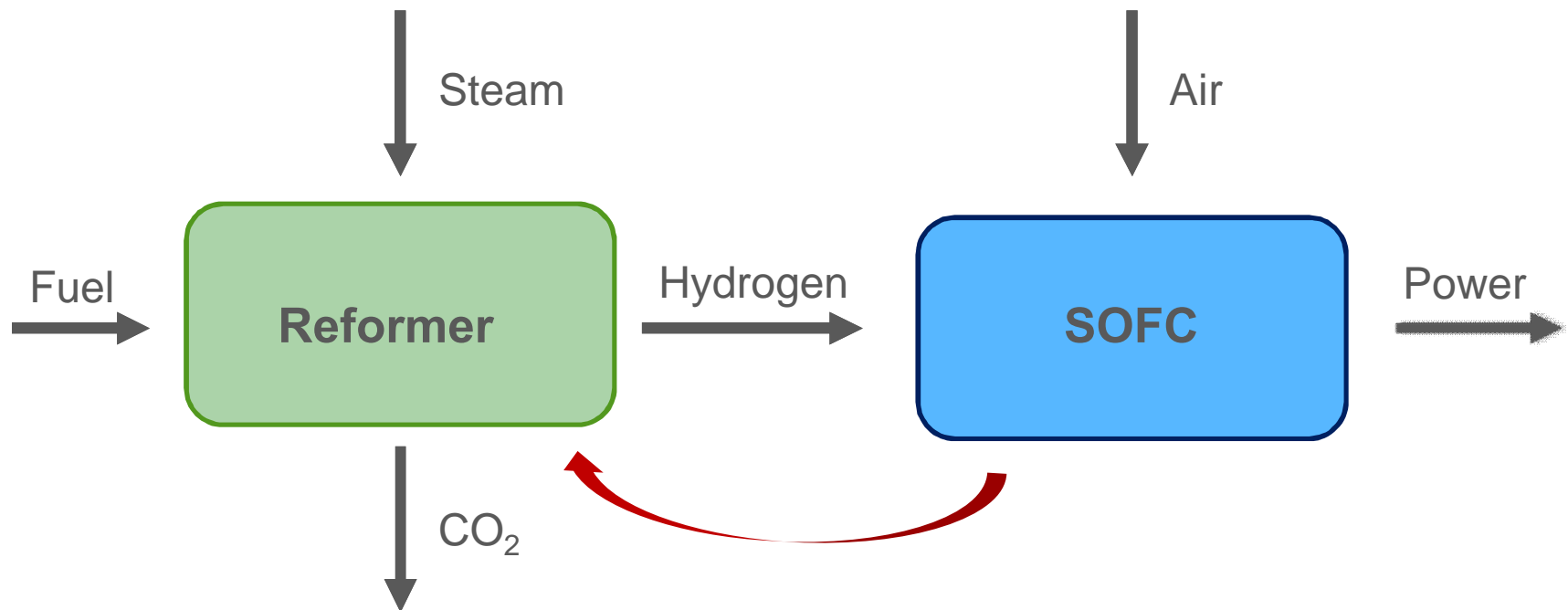
- more energy and less emissions

- “ Sustainable use of carbon based fuels
 - . Increased life span of fossil energy reserves
- “ No release of greenhouse gases
 - . CO₂ capture an integrated part of the technology
 - . No additional costs
- “ Sustainable solutions for an increasing energy demand
 - . Positive, varied market possibilities
 - . Phased technology deployment



For offshore application

ZEG – technology, alternative option:
SOFC + H₂ membrane reformer



Simple systems comparison

SIMULATION: 2 power systems (same electricity production); 3 oil&gas rigs (different size);

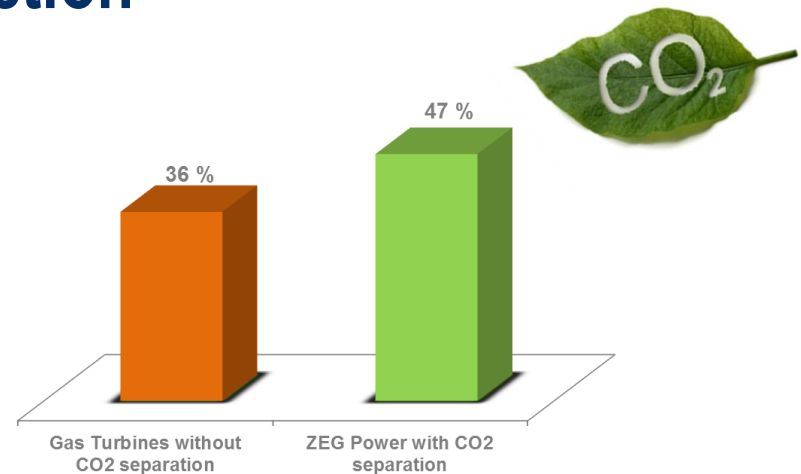
RIG	BIDEFORD DOLPHIN $P_{el} = 8.8 \text{ MW}$; FP = 7300 m ²			SONGA DELTA $P_{el} = 16.9 \text{ MW}$; FP = 9750 m ²			WEST VENTURE $P_{el} = 43 \text{ MW}$; FP = 8000 m ²		
Power System	η_{el} (%)	FP (m ²)	CO ₂ (tons/year)	η_{el} (%)	FP (m ²)	CO ₂ (tons/year)	η_{el} (%)	FP (m ²)	CO ₂ (tons/year)
GasTurbine	36	50	42 000	36	100	81 000	36	240	206 000
SOFC + H ₂ M	47	1 400	25 000	47	2 700	48 000	47	6 800	123 000

- “ Results for GT don't include CO₂ capture and compression
- “ Electrical efficiencies are significantly increased with SOFC and H₂ membrane reformer
 - “ Include 100% CO₂ capture and compression
 - “ Additional high temperature heat available in the system
- “ CO₂ emissions are significantly reduced even without capture

The ZEG – technology (ZEG[®])

High temperature fuel cell systems are a promising future option for offshore power production

- “ Fuelled with Natural Gas, on-site production
- “ High overall efficiency with Integrated CO₂ capture without additional cost
- “ High purity CO₂ delivered, pressurized and ready for EOR or storage
- “ Reduced emissions even without CO₂ -sequestration
- “ Module based for different scales



- “ Main challenges today:
 - . Still immature technology
 - . Scale and foot-print
 - . Life time and cost

ZEG Power as

Superior technology for high - efficiency energy production



For more information: *Björg Andresen, Managing Director*
bj@ife.no