DME S-006-2013 – Lecture 07

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GERMAN DESALINATION

Renewable Energies and Desert Desalination in North Africa

Claus Mertes – DME GmbH

DME - Seminar

Key Solutions for Key Markets

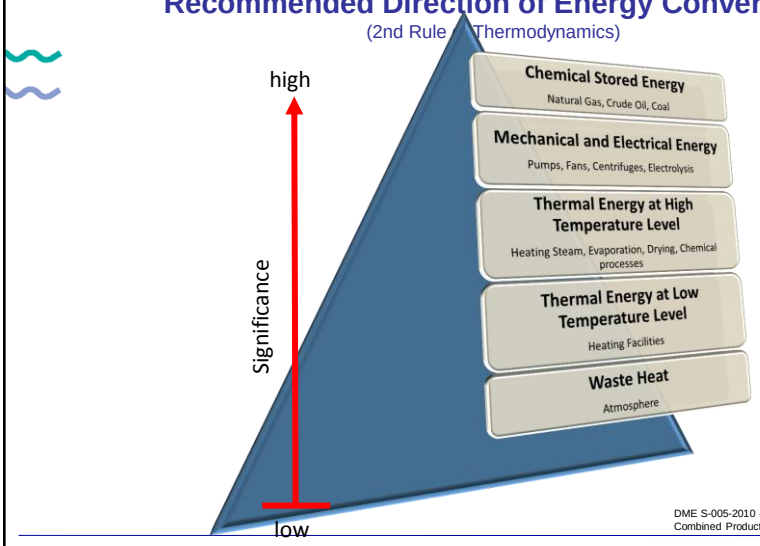
December 03rd, 2013

Jeddah – Saudi Arabia

1-3 DECEMBER 2013, JEDDAH HILTON, SAUDI ARABIA
SWPF 2013 المنتدى السعودي للمياه والطاقة SAUDI WATER & POWER FORUM

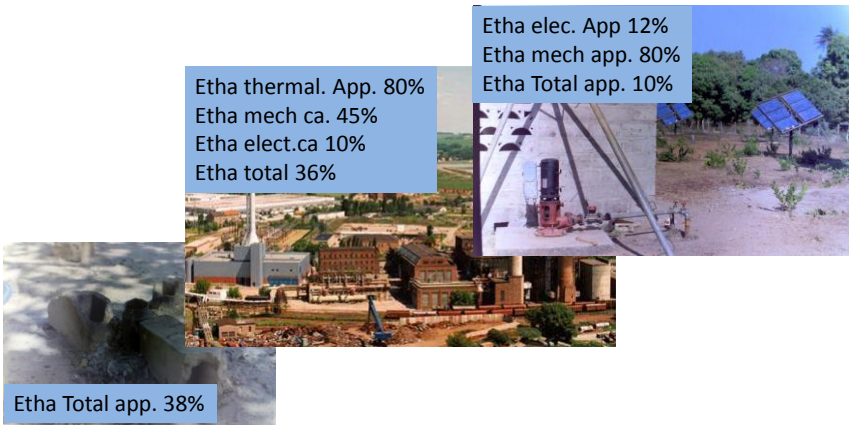
Recommended Direction of Energy Conversion

(2nd Rule of Thermodynamics)

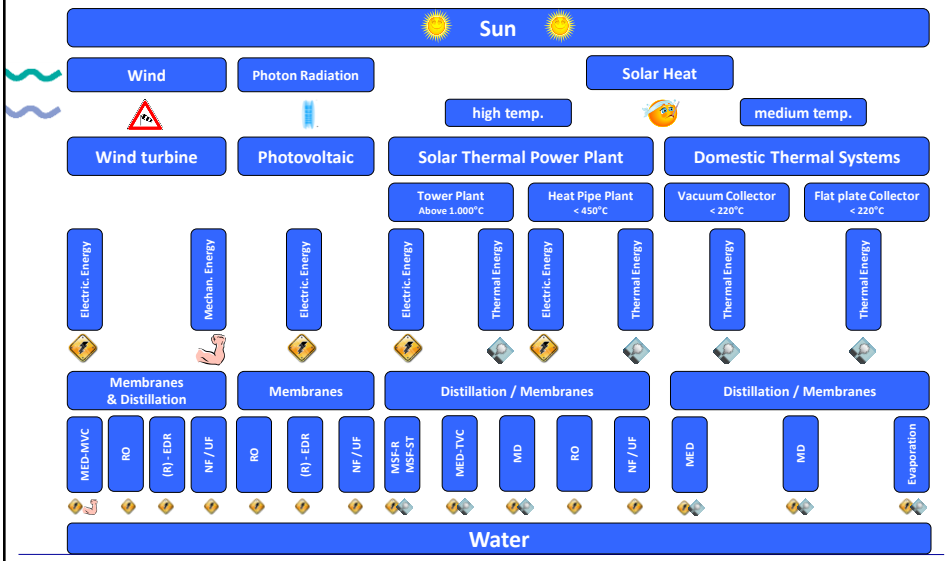


DME S-005-2010 – Lecture 05
Combined Production of Power and Water

A Question of Efficiency



Sun to Water Processes



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Primary energy demand = Exergy of non-produced power

Multi Stage Flash (MSF)

$$\frac{\dot{E}x_{TH,MSF}}{\dot{m}_D} = \left[\frac{1}{N} + \frac{\Delta T_{TTD} + \Delta T_{BPE} + \Delta T_{NE}}{\Delta T_0}\right] \cdot \frac{\Delta h_V}{\eta_{PP}} \cdot \frac{T_T - T_{MIN}}{T_T} \cdot \eta_T + \frac{P_{AUX,MSF}}{\eta_{PP} \cdot \dot{m}_D}$$

Turbine efficiency

Power plant efficiency

Carnot efficiency

Multiple Effect (MED)

$$\frac{\dot{E}x_{TH,ME}}{\dot{m}_D} = \left[\frac{1}{N} + \frac{CF}{CF-1} \cdot \frac{c_P}{\Delta h_V} \cdot \left(\Delta T_{HT} + \Delta T_{TTD} + \Delta T_{BPE}\right)\right] \cdot \frac{\Delta h_V}{\eta_{PP}} \cdot \frac{T_T - T_{MIN}}{T_T} \cdot \eta_T + \frac{P_{AUX,ME}}{\eta_{PP} \cdot \dot{m}_D}$$

Reverse Osmosis (RO)

$$\frac{\dot{E}x_{TH,RO}}{\dot{m}_D} = \left[\frac{1}{\rho} \cdot \left(\frac{\Delta p_{RO} + \Delta p_{LOSS} + b \cdot w_F \cdot CF}{1 - 1/CF} \cdot \frac{1}{\eta_P} - \frac{\Delta p_{RO} + b \cdot w_F \cdot CF}{CF-1} \cdot \eta_{ERT}\right)\right] \cdot \frac{1}{\eta_{PP}} + \frac{P_{AUX,RO}}{\eta_{PP} \cdot \dot{m}_D}$$

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Primary energy demand

Reverse Osmosis

Power plant efficiency	$\eta_{PP} = \frac{P_{el}}{\dot{m}_{Fu} \cdot LHV}$
Exergy flow = Lower heating value of fuel	$\dot{E}x = \dot{m}_{Fu} \cdot LHV$
Spec. primary energy demand	$\frac{\dot{E}x}{\dot{m}_D} = \frac{P_{el,RO}}{\eta_{PP} \cdot \dot{m}_D}$
Power plant efficiency	$\eta_{PP} = 0.4$
Specific electricity demand	$\frac{P_{el,RO}}{\dot{m}_D} = 5.0 \frac{kWh_{el}}{m^3}$
⇨ Spec. primary energy demand	$\frac{\dot{E}x}{\dot{m}_D} = \frac{5.0}{0.4} \frac{kWh_P}{m^3} = 12.5 \frac{kWh_P}{m^3}$

Key Data used for Desal Plant

Capacity of the Plant: 30.000m³/d at 38.000 ppm

CAPEX:

- RO: 875 €/m³/d, EDR: 1.150 €/m³/d, MVC: 1.250 €/m³/d, MED: 1.200 €/m³/d, MEH: 2.000 €/m³/d

OPEX:

- RO: 0,83 €/m³/d, EDR: 1,46 €/m³/d, MVC 1 €/m³/d, MED 1 €/m³/d, MEH: 0,5 €/m³/d

Specific electrical Energy consumption:

- RO: 3,2 kWh/m³, EDR: 1,42 kWh/m³, MVC 9 kWh/m³, MED 0,6 kWh/m³, MEH: 0,3 kWh/m³

Specific thermal Energy consumption (Factor 3:1 to electr):

- MED 65 kWh/m³, MEH: 70 kWh/m³

Key Data used for CSP Plants (no electrical Power produced!)

Renewable fuels:

Solar Power (DNI): 2.637 kWh/m², Wind: 4,86 m/s @18m

CAPEX:

PV: 1.200 €/kWp, Wind: 1.500 €/kW,
Solar Tower 1.520 €/kW, CSP 170,00 €/m²

OPEX:

PV:1,00 %/a, Wind 0,017 €/kWh,
Solar Tower 4%/a, CSP 2,00 %/a

Economical and financial Key Data

- Interest Rate: 7,5 %
- Lifetime of the total Plant: 20 Years
- Local price for electricity: 0,12 €
- CO2 Grid emission factor: 0,5 t CO2/MWh
- CO2 gas emission factor: 0,202 t CO2/MWh

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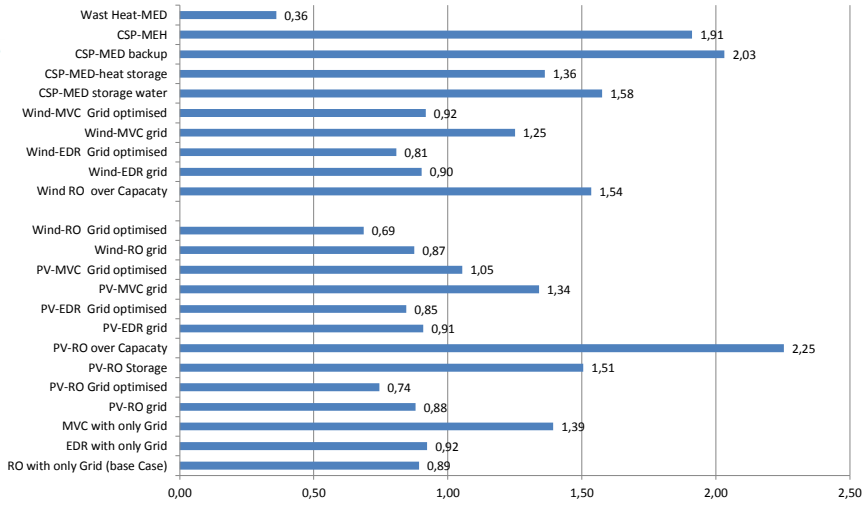
LWC €/m³



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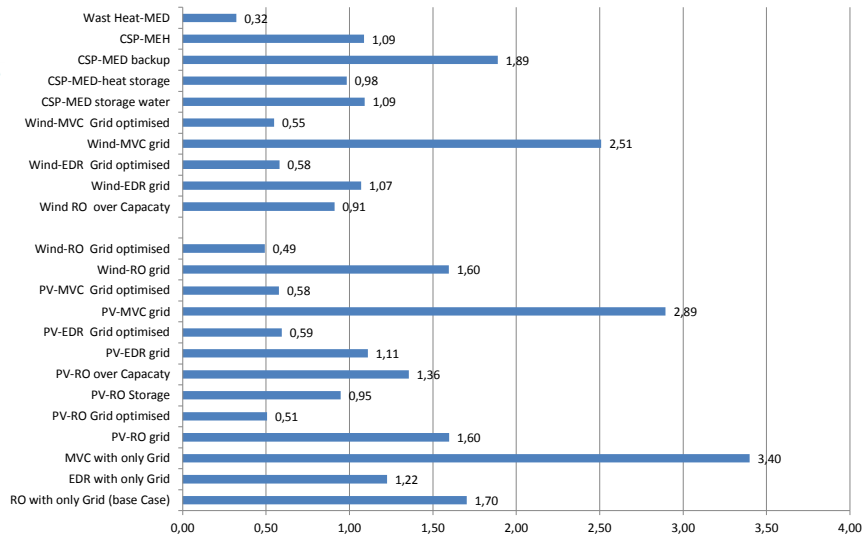
LWC €/m³ @ US$60 incl. CO2 and 1% Interest Rate



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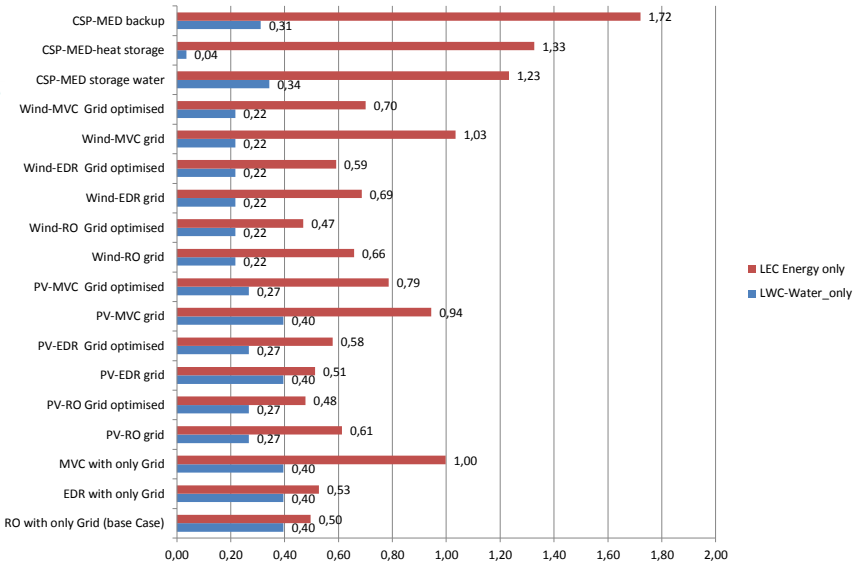
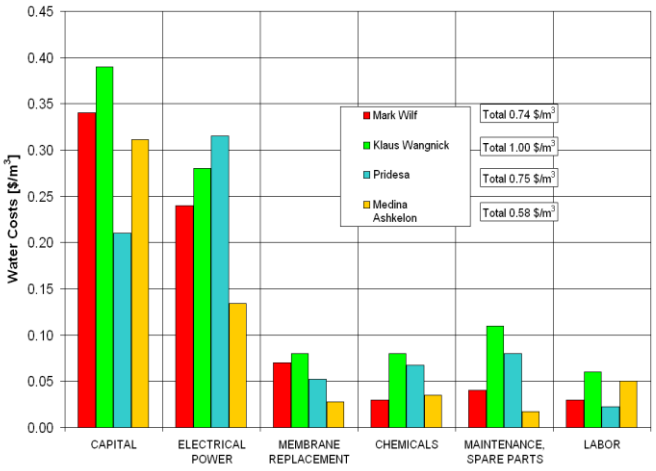


Actual water costs

The costs of water produced in a RO seawater desalination plant can be divided as follows:



The diagram shows clearly that costs of water produced in RO plants depend heavily on local conditions, scope and size of plants

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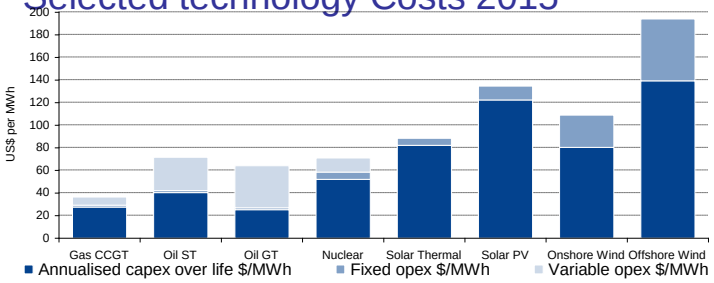
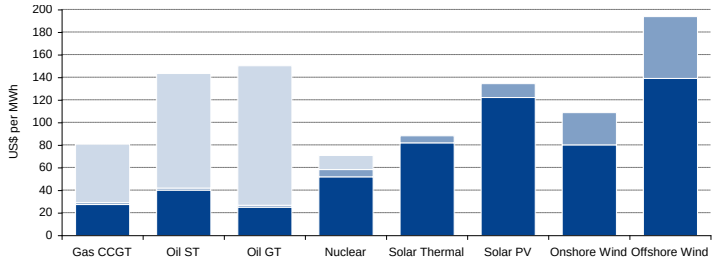
Selected technology Costs 2015

Opportunity cost fuel prices
Oil = $16/bbl
Gas = $0.7/mmbtu



Full International fuel prices
Oil = $60/bbl
Gas = $8/mmbtu



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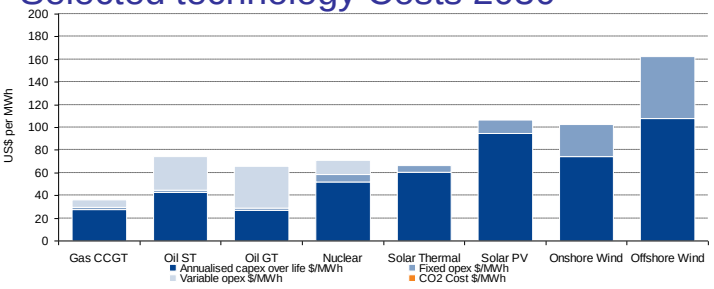
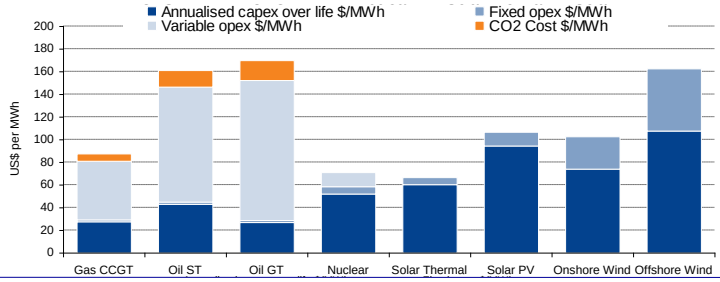
Selected technology Costs 2030

Opportunity cost fuel prices
Oil = $16/bbl
Gas = $0.7/mmbtu



Full International fuel prices
Oil = $60/bbl
Gas = $8/mmbtu
CO2 tax = $20/tCO2



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Thank you for your attention

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