Energy Efficiency in Reverse Osmosis Systems

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Energy required to desalinate seawater

- Theoretical minimum: \( \sim 1 \text{ kWh/m}^3 \)
- Simple distillation (theoretical): \( \sim 627 \text{ kWh/m}^3 \)
- Thermal desalination
  (Large MED, MSF & VC): 6 - 16 kWh/m³
- Typical RO: 3 - 8 kWh/m³
- Best practice RO: 2 kWh/m³
Seawater RO – Example

- High-pressure seawater feed
  - 3m³/h at 60bar

- Reverse-Osmosis Modules

- Concentrate Brine Reject
  - 2 m³/h

- Freshwater Product Permeate
  - 1 m³/h

- Recovery ratio 33%
Pumping requirements

Seawater

Pump $\eta = 90\%$

Motor $\eta = 90\%$

$3 \text{m}^3/\text{h}$ at 60 bar

Reverse-Osmosis Modules

Concentrate

Brine

$2 \text{m}^3/\text{h}$ at 59 bar

$1 \text{m}^3/\text{h}$

Freshwater Product Permeate

6.2 kWh/m$^3$
Pelton turbine energy recovery

- Motor $\eta = 90\%$
- Pump $\eta = 90\%$
- Pelton Turbine $\eta = 80\%$

**Seawater** -> **Pump** 60 bar -> **RO Modules**

- Concentrate Brine 59 bar
- Freshwater Product Permeate

- Only for medium and large scale

3.3 kWh/m$^3$
1000 - 1500 m³/day

Motor
Pump
Turbine
Direct energy recovery

Seawater → Direct energy recovery → Product

Motor

Concentrate Brine

RO Modules
DWEER

- Very efficient
- Large scale
- Very efficient
- Medium and large scale
• The Pelton turbine, DWEER and the ERI devices, and their similar competitors, help to achieve very low energy consumptions:
  – sometimes approaching 2 kWh/m³
  – in medium and large-scale systems.

• We now turn our attention to small-scale systems.
Clark Pump - Pressure Intensifier

- Very efficient
- Very small scale
- For sailing yachts
CREST
RO Test Rig

- PV or wind powered
- "Seawater"
- Energy recovery
  - Clark pump
- No batteries
- Variable flow
Sea Recovery - Ultra Whisper
Hydraulic Motor
eg: Danfoss Nessie

- Provides shaft power
- Swash plate
- Axial-pistons
Renewable energy powered RO

- Various researchers and companies worldwide have built demonstration systems employing these energy recovery devices in renewable energy powered RO systems, with varying success.
- Many small systems are still built without any energy recovery.
Enercon

• Sorry no picture!
• Energy recovery for seawater RO
• Three pistons
• Oil coupled
• Pressure intensifier
Brackish water

- Typically uses higher recovery ratio
- Smaller proportion of energy in brine
- Energy recovery less critical
- Notable exception: SOLCO:
  - 16% recovery ratio
  - Energy recovery integrated in pump
Conclusions

• Energy recovery
  – critical for efficient seawater RO
  – but does make designs more complex

• Proven devices available at large-scale

• Less so at small scale

Thank you