

*Nuclear Power, Middle East and North Africa
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***The technology, economics and prospects
of nuclear desalination***

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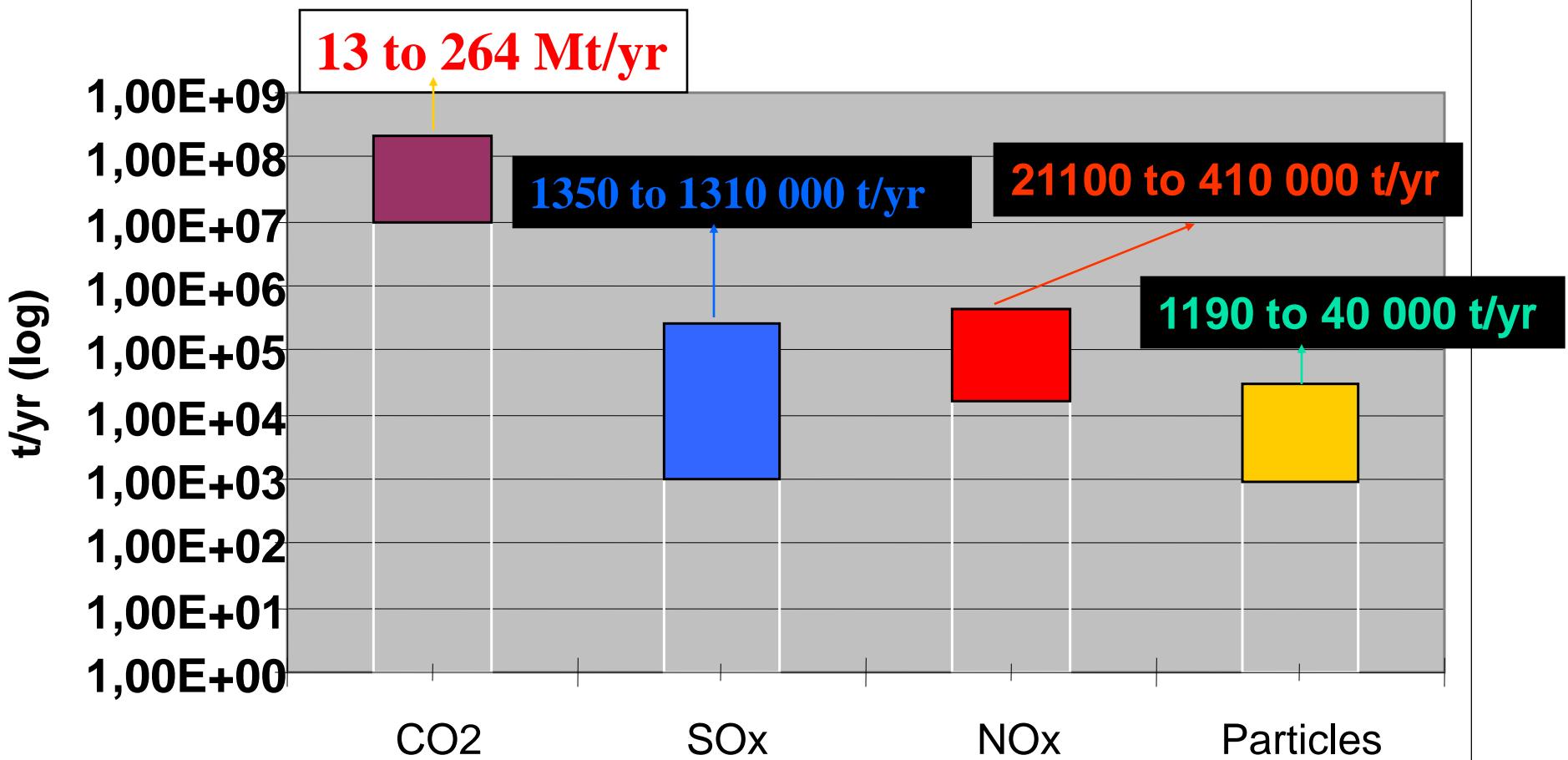


Why Nuclear Sea Water Desalination?

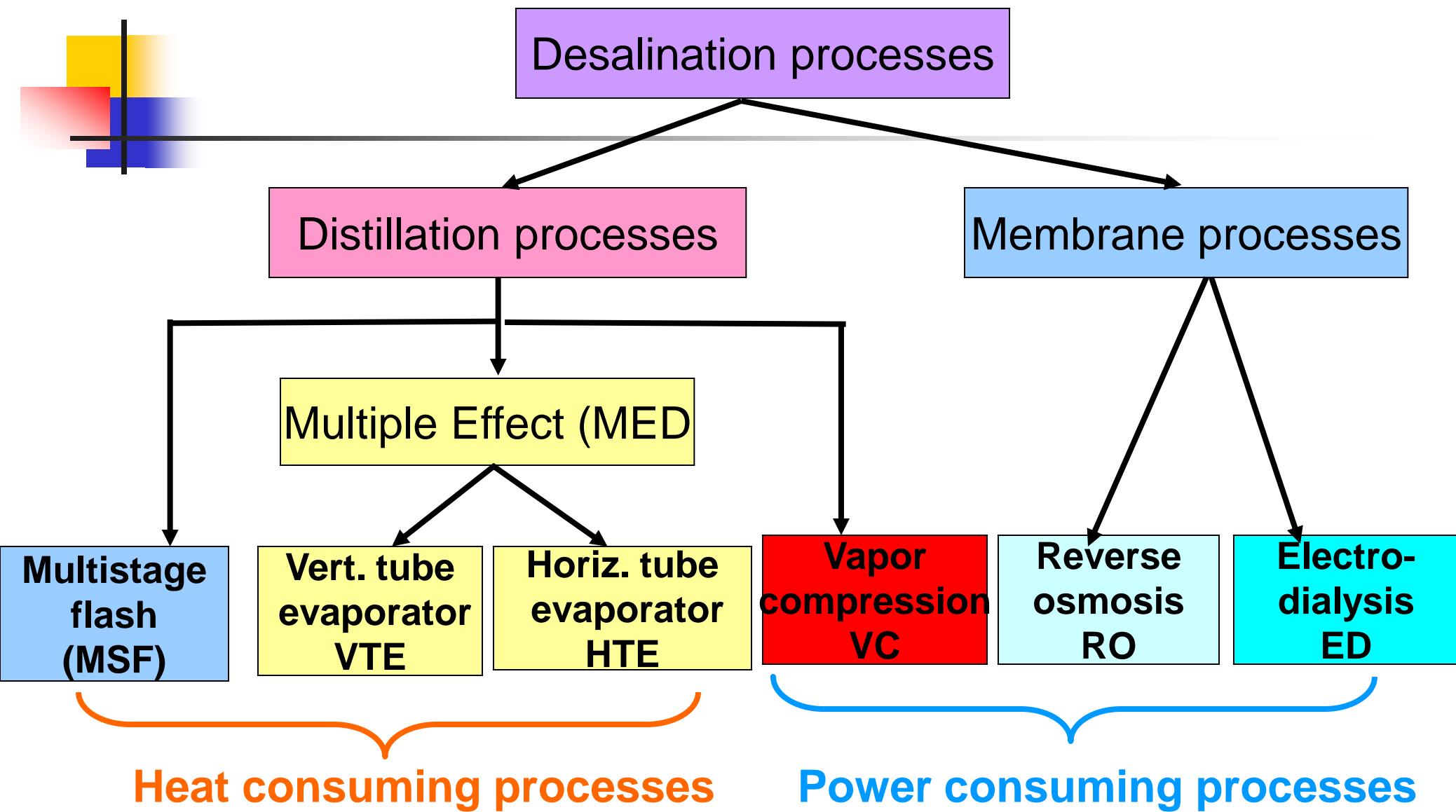
- ◆ Desalination is an energy intensive process. A future desalination strategy based solely on fossil fuel sources is not sustainable:
 - ◆ Fossil fuel reserves need to be conserved for other important applications
 - ◆ They will be increasingly costly in the future.
 - ◆ The energy dependence?

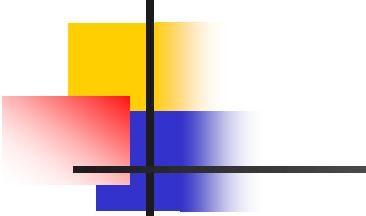
- The most important impact of fossil fuel based desalination is on the environment. Take an example:
 - It can be shown that, in 2020, for the Mediterranean region alone, one would require about 20 million m³/day of desalting capacity.
 - This is a pessimistic assumption, because it is assumed that only 2.5% of the needs would be covered by desalination.
 - However,

GHG emissions from desalination (Med region)



- On the world level, these figures would be almost tripled!!





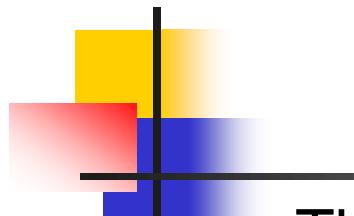
Energy consumption of desalination processes

| Process | kWth.h/m ³ | kWe.h/m ³ |
|---------|-----------------------|----------------------|
| MSF | 100 | 3 |
| MED | 50 | 2 |
| RO | - | 4.5 (3) |

- To produce 130 000 m³/day, MED would require 276 MW_{th} and 11 MW_e, and RO only 16 to 24 MW_e.
- Process operating temperatures : MSF 100-130°C; MED 60 à 100 °C ; RO 15 – 44°C
- No direct coupling with the reactor for RO ; necessary for MED, MSF

Nuclear reactors for desalination

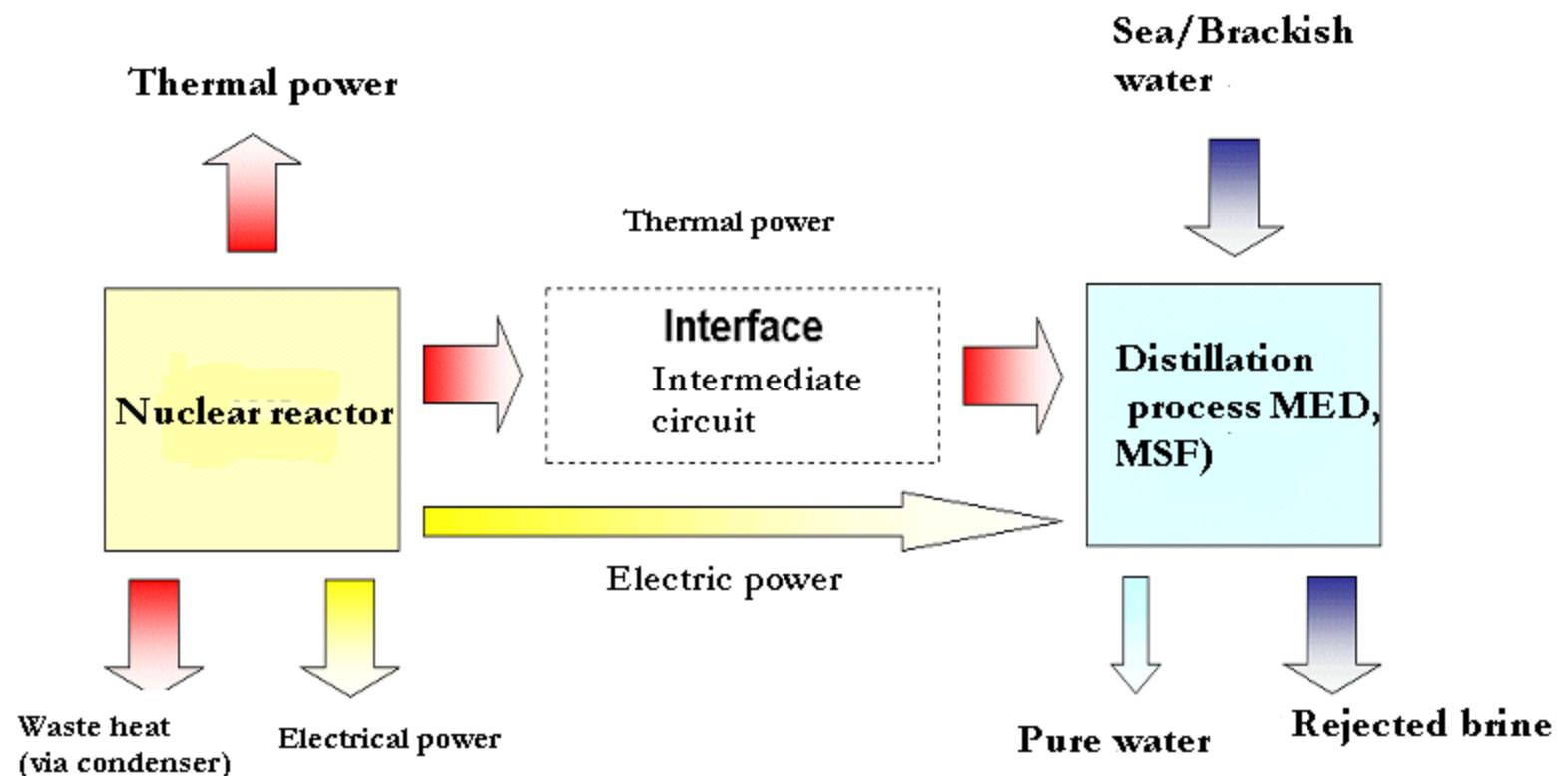
- There are no « special » nuclear reactors for desalination:
 - Dedicated heat only reactors (islands or isolated regions; HR-200)
 - Reactors in the cogeneration mode (EPR, AP-1000, ATMEA,)
- SMRS, in the cogeneration mode, more interesting for certain developing countries (GT-MHR, PBMR, IRIS)
 - Lower relative investment costs
 - Better optimisation of water and power production
 - Enhanced availability
 - potential for implantation near the cities ??



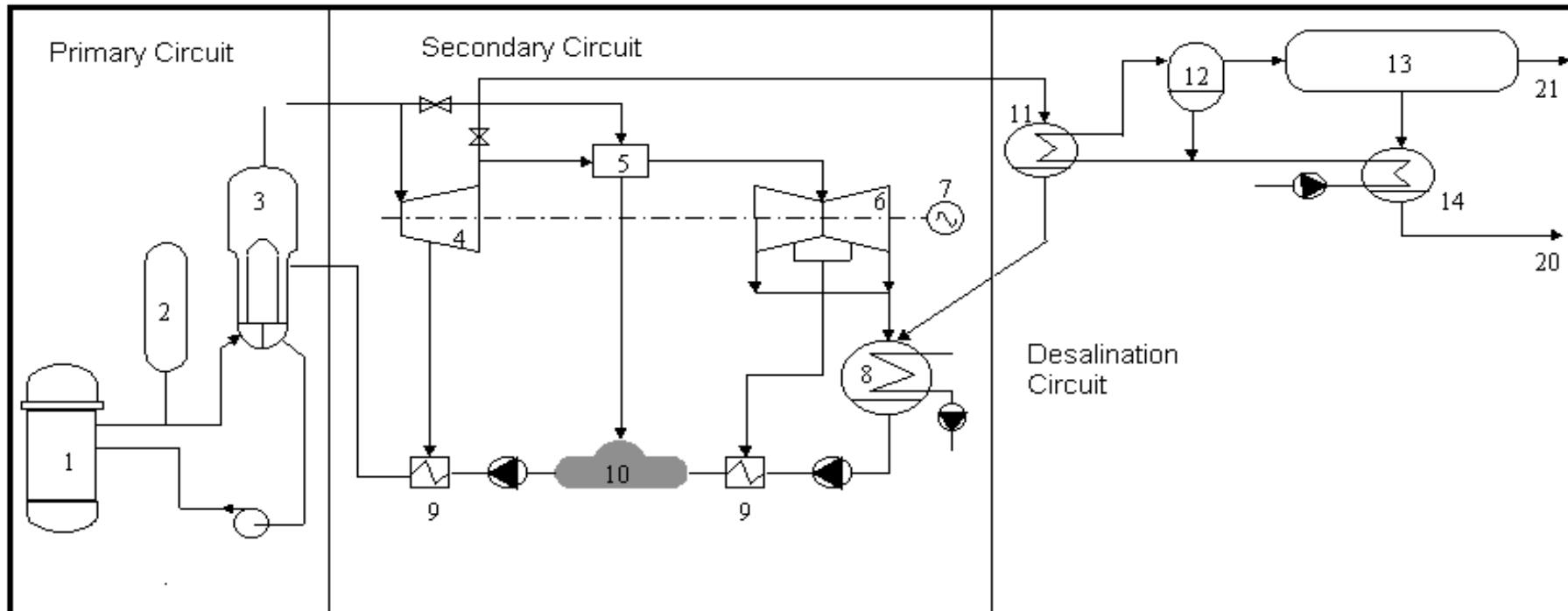
Operating experience

- ◆ The total nuclear desalination operating experience is about 150 reactor-years:
- ◆ BN350 at Aktau (Kazakhstan, 1973-1999)
 - ◆ Chronic availability problems
 - ◆ Rather a good tool for coupling scheme verifications
- ◆ 10 Japanese PWR still operating
 - ◆ MSF, MED, RO; 1000- 2000 m³/d
- ◆ PHWR (Kalpakkam, India)
 - ◆ RO module started operation in 2002
 - ◆ Hybrid MSF-RO; 6300 m³/d in 2008.

The principle of coupling (Nuclear reactor + distillation process)

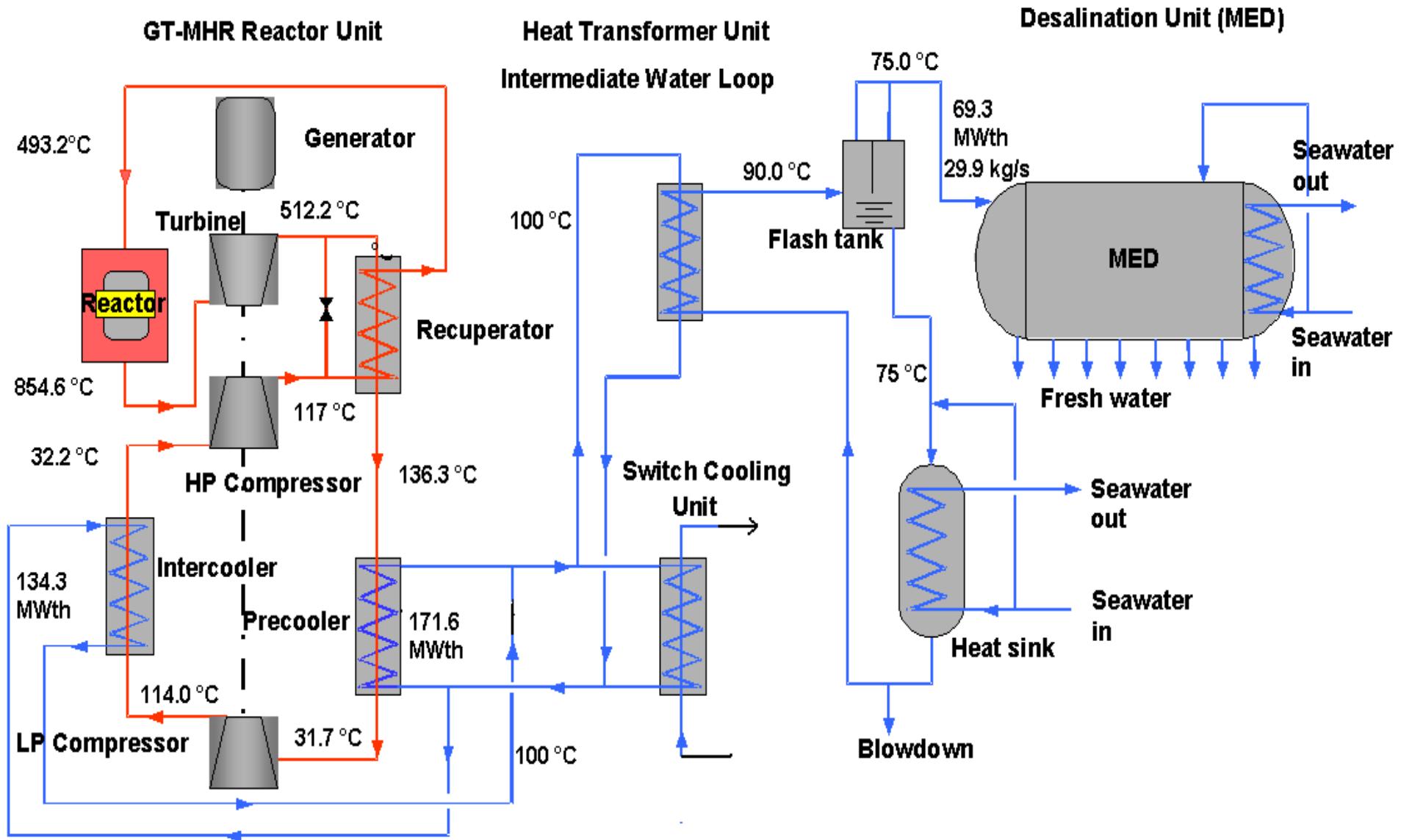


Coupling with a PWR, PHWR ...



The coupling requires bleeding of vapour from in between the turbine stages. Hence some loss of power
 With MED, 89.3 MWth, 42 kg/s (90°C), 11.3 MWe lost to produce 48 000 m³/jour.

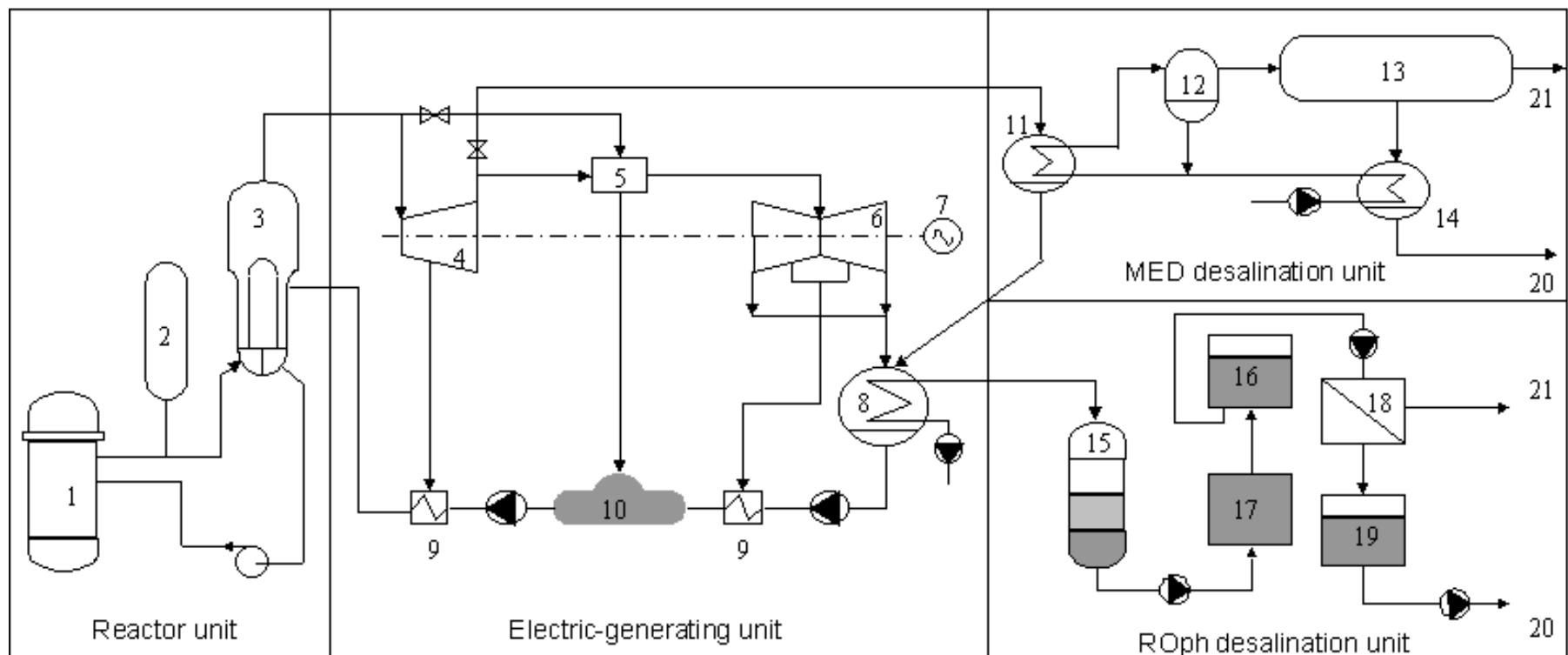
Innovation: utilise the waste heat from nuclear reactors



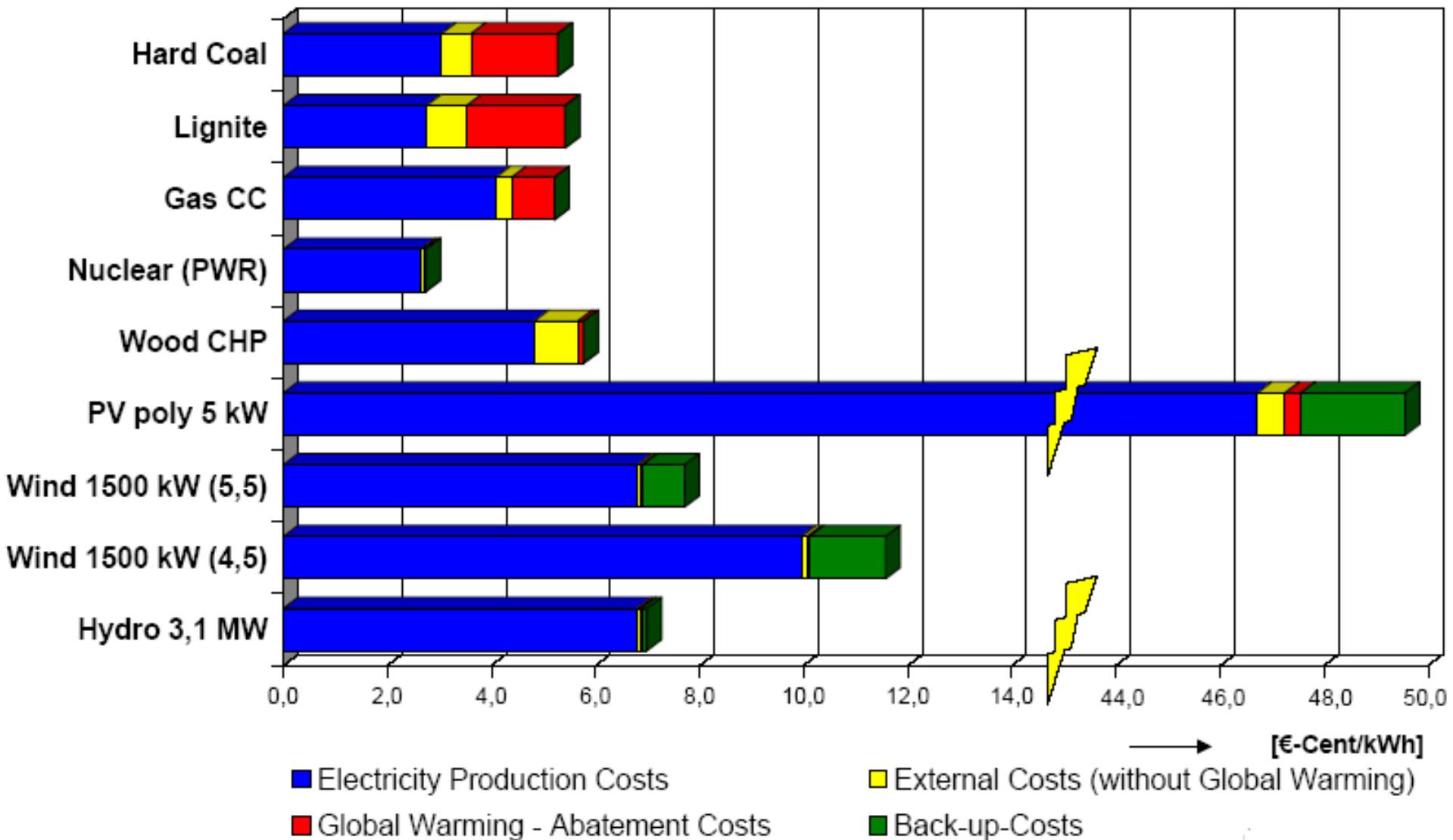
Optimised GT-MHR + MED coupling, utilising waste heat

Coupling with a PWR

The waste heat lost via the condenser can be used to preheat RO feedwater



Influence of env. costs in Germany



Economic Evaluation (EURODESAL, TUNDESAL projects)*

- 4 Nuclear reactors : PWR900, AP600, GT-MHR, PBMR
- 3 Fossil energy based systems: Coal (CFB-900), CC-900, OIL-500; with performances foreseen for 2015
- Two desalination processes; MED, RO with nominal capacities of 120 000 m³/day.
- DEEP-3, **with relevant modifications by NDS**
- Costs from reliable sources except for the HTRs (from the developers); all updated to 2006 US \$

(*S. Nisan, N. Benzarti, Desalination, (2008) 125-140)

*MED water costs **with/without**
internalisation of externalities in France and Germany;
8 % discount rate*

| | CFB-900 | CC-900 (Oil-500) | PWR-900 | AP-600 | GT-MHR | PBMR |
|-------------------------------------|---------|-----------------------|------------|------------|-------------|-------------|
| Water costs (\$/m ³) | 0.9487 | 1.3777 (1.5713) | 0.84505 | 0.8795 | 0.6418 | 0.6942 |
| Δ (%) | | +45 (+66) | -10 | -7 | -32* | -27* |
| Water costs E1 | 1.2378 | 1.4766 (2.0581) | 0.86447 | 0.8989 | 0.6490 | 0.7021 |
| Δ E1(%) | | +19 (+66) | -30 | -27 | -48 | -43 |
| Water costs E2 | 1.9147 | 1.7656 (2.6361) | 0.87458 | 0.9090 | 0.6528 | 0.7062 |
| Δ E2(%) | | -7.8 (+38) | -54 | -52 | -65 | -63 |

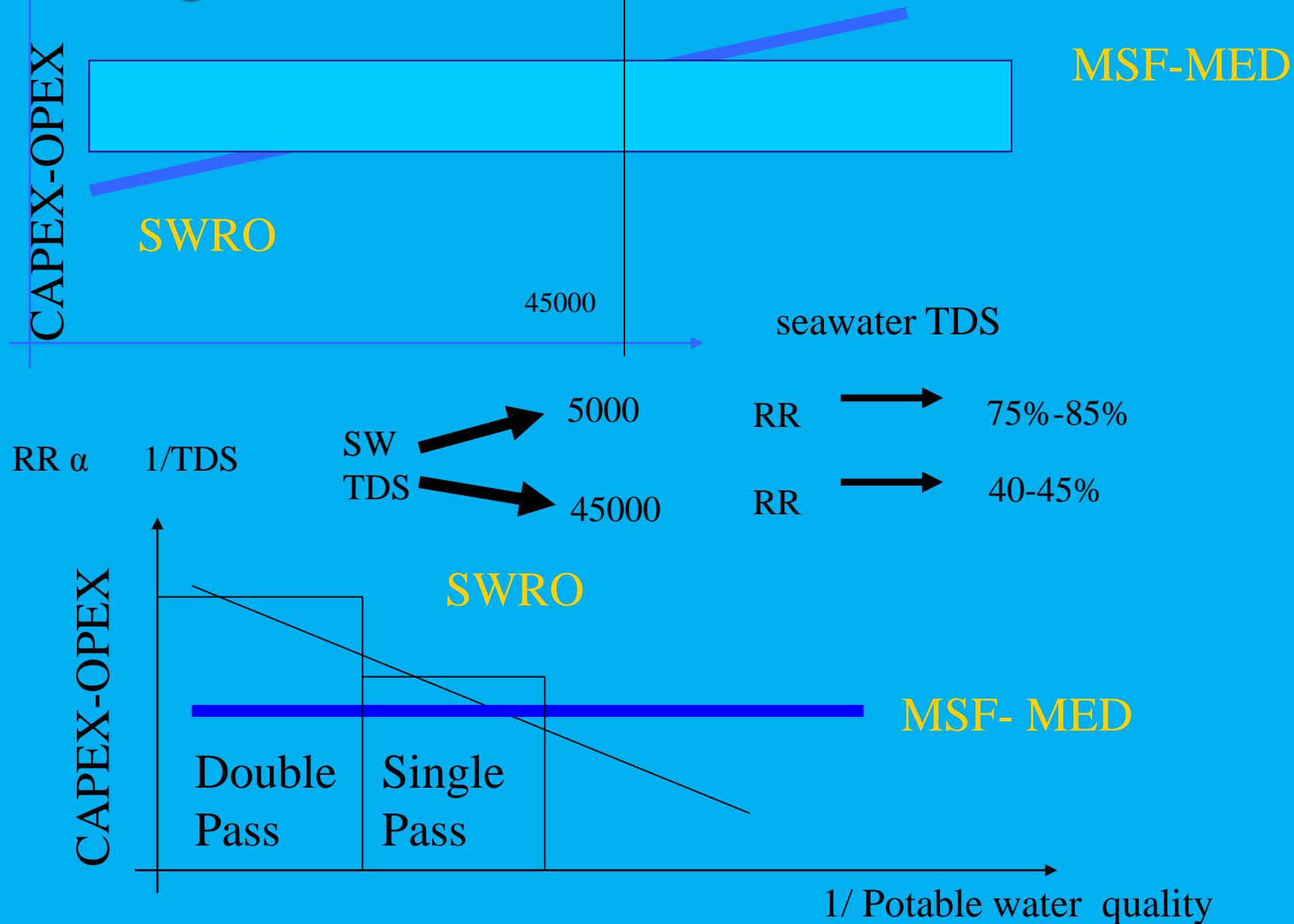
RO costs

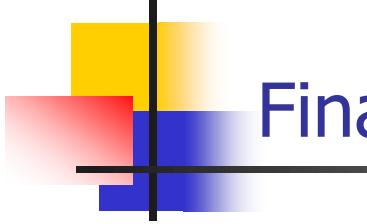
- RO costs are in general 20-40% lower than MED but....



- Single pass RO residual salinity 300-500 ppm (MED, MSF 25 ppm)
- Costs depend on feed water salinity

Technologies and differences :some rule of thumb



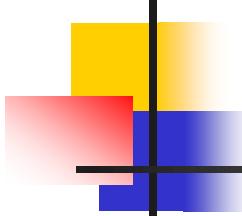


Financing aspects

| | PWR900 | | GT-MHR | CC-900 | |
|----------|--------|------|--------|--------|------|
| | MED | RO | MED | MED | RO |
| NPV, M\$ | 6326 | 6584 | 4896 | 3076 | |
| IRR, % | 26.9 | 27.5 | 43 | 37.3 | 41.7 |
| PBP, yrs | 9 | 9 | 6 | 6 | 6 |
| PI | 3.89 | 4.03 | 7.26 | 4.65 | 5.32 |

Investment cost PWR+MED= 2190 M\$; GT-MHR+MED = 782 M\$

PI= NPV/initial cash investment

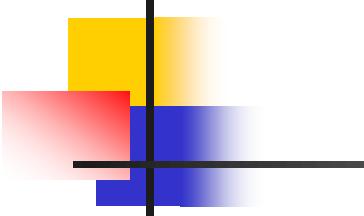


Opportunities and challenges

- Electricity demands in MENA are more than twice those in the EU
- It so happens that countries having the dearth of electricity are also those suffering from acute water shortages .
- Even if one has oil and gas resources, there is a good business sense in conserving these resources for other essential uses rather than burning them away, especially when the prices are so high



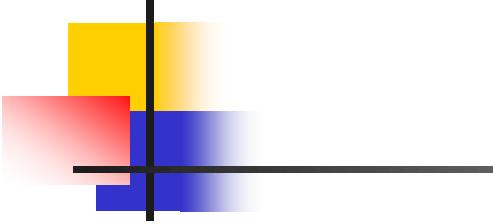
- The major challenge is financing of nuclear plants under the optimal conditions of low interest rates, long payback periods, maximum utilisation of local currency ►
- Above all, the five commandments for the introduction of nuclear energy!!!



The first nuclear power plant (the Five Commandments!)

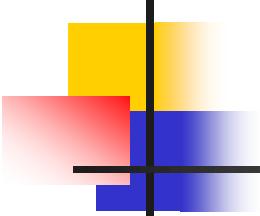
- A firm and prolonged commitment on behalf of the national/private authorities
- A capacity to evaluate technical options and bids
- An independent « safety authority » , capable of evaluating the country's local situation and needs
- A team of skilled personnel
- Adequate means (or plans) to finance a nuclear power plant project

Conclusions



- A future desalination strategy, based on the utilisation of fossil fuelled systems is not sustainable because of the considerable amounts of GHG rejected. At the moment, the only solutions would appear to be nuclear energy and wind energy.
- Integrated seawater desalination systems are likely to be deployed intensively in the future in view of the large water and electricity shortages in many regions of the world
- For large scale desalination, only nuclear energy is competitive





- For a discount rate of 8%, current fossil fuel prices, without external costs:
 - Compared to the CFB-900 +MED plant, the desalination costs by PWR+ MED and AP-600 +MED system are 7 to 10 % lower.
 - Those with the CC-600 +MED and Oil-500 +MED are 45 and 66 % higher.
 - In the same conditions, the next generation HTRs such as the PBMR and GT-MHR, utilising “free” waste heat with MED, lead 27 to 32 % lower desalination cost.