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ECONOMICAL EVALUATION OF NUCLEAR WATER DESALINATION IN TUNISIA

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Tunisia

- Population: 10 million
- Area: 164,418 km^2
- Capital & largest city: Tunis (1.7 million).
- 56 persons per km^2
- Arid central and southern parts:
  - 70% of total area
  - < 30% of population.

Scope

- Extension to the TUNDESAL Project done by
  - CNSTN, STEG, SONEDE (Tunisia)
  - CEA (France)
  - IAEA.
    - ➔ technical study (optimizing the nuclear-desalination plants coupling)
    - ➔ economical assessment (using DEEP2)
- Update the economical study using DEEP3

CURRENT SITUATION IN TUNISIA

- Water needs
- Energy situation
- Electricity generation

Tunisia's Water Needs (1)

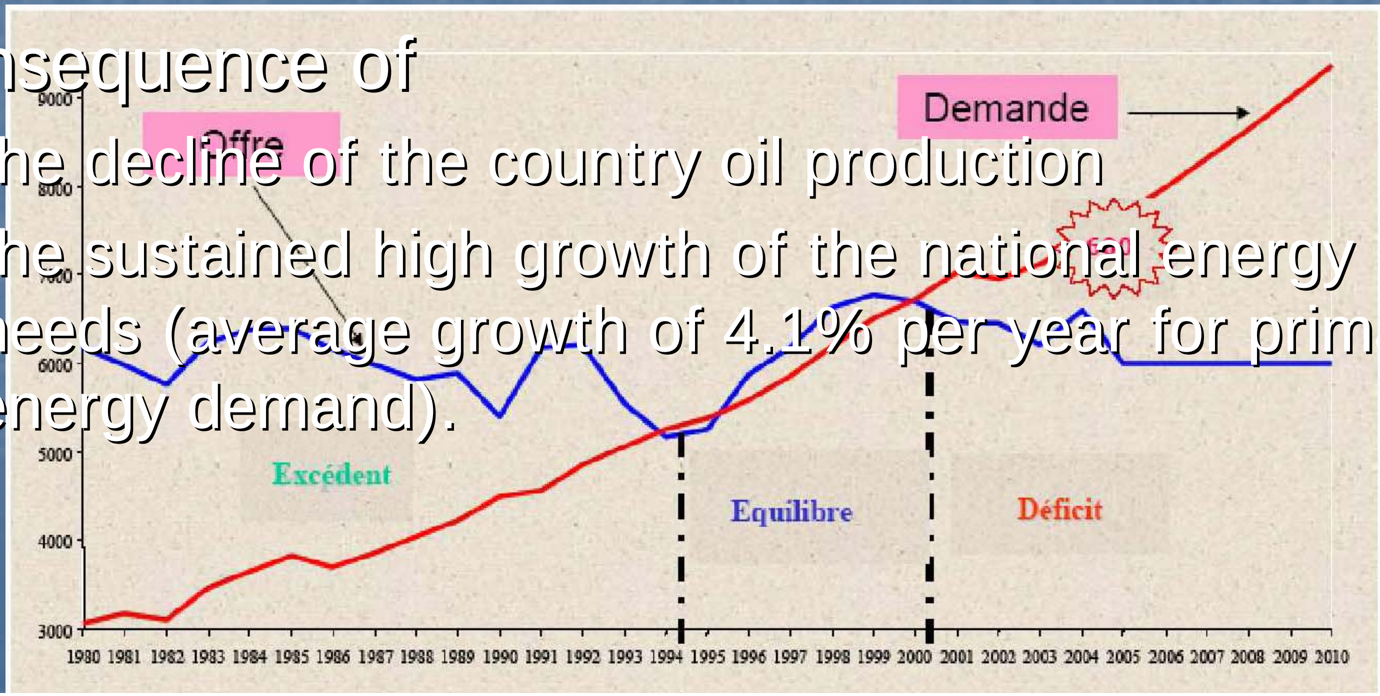
- Tunisia is among the 80 countries experiencing water scarcity.
- The average drinking water supplies are currently 4,5 million m^3/year
  - i.e. around 450 m^3/year and per capita
  - below the poverty threshold.
- Approximately 40% of these resources are underground waters, with salinities between 0.5 and 3.5 mg/m^3.
- The salinity of the entire resource is relatively high with only 54 % having salinities lower than 1.5 mg/m^3.
- 84 % of these good quality drinking waters are located in the north of the country.

Tunisia's Water Needs (2)

- Tunisia started using desalination since the 1980s.
- 4 stations: Kerkennah, Jerba, Gabes & Zarzis
- Total capacity: 58 800 m^3/day+ 8,500 under construction
- All use Reverse Osmosis
- Input water quality: 3.2-6 mg/m^3
- Produced water quality: 0.15-0.75 mg/m^3
- North-south Aqueducts.

Tunisia’s Energy Situation

- Tunisia changed status during the last decade
  - In 1980s production surplus (3 Mtep)
  - Net importer of energy (0,6 Mtep in 2004).
- Consequence of
  - the decline of the country oil production
  - the sustained high growth of the national energy needs (average growth of 4,1% per year for primary energy demand).



Electricity generation

Installed capacity: 2 893MW, peak demand 2 124 MW (2004)

- By technology:
  - 40.2% Combined cycle
  - 52.7% steam cycle
  - 15.3% Gas Turbine
  - 1.5% hydro
  - 0.3% wind
- Fossil fuel:
  - 97,3% natural gas
  - 0.9 oil
- By provider:
  - 82.8% STEG (state owned)
  - 17.2% private companies (produce 22%)

Electricity demand for 2020

- **Economical performance of Tunisia (6.8%/y GDP growth)**
  - **⇒electricity demand expected to grow by an average 6.5 % per year**
  - **⇒reach 31 260 GWh in 2020 with consumption peak of 5920 MWe**
  - **⇒Tunisian electrical network would support a 600MWe power plant around 2020**
- **Tunisian utility, STEG, plans the introduction of the 600 MWe power plant level in 2018.**
- **April 2006: Government instructed the utility to start feasibility studies for a nuclear plant for 2016-2020**

Electricity production alternatives

Several solutions can be considered :

- **Conventional power plants:**
  - **1 Combined cycle plant (600 MWe)**
  - **1 steam cycle plant (600 MWe)**
- **Nuclear power plants:**
  - **1 PHWR or AP(600 MWe) or 1 PWR (900 MWe) since network is interconnected with neighboring countries.**
  - **2 modules of the innovating GT-MHR reactor (if commercialized).**
  - **3 modules of the PBMR reactor (if commercialized).**

Water demand for Skhira 2020

- Evaluation for the area of Skhira (most likely where the nuclear power plant would be built) :
  - *1st scenario:* use the current resource assessments for drinking water and project the resource needs for 2020.
    - ⇒ deficit of 150,000 m^3/day.
  - *2nd scenario:* Account for planned projects
    - ⇒ deficit of 48,000 m^3/day

Desalination alternatives

Several solutions can be considered:

- **Distillation:**
  - **MED**
- **Membrane processes:**
  - **RO**

Power and desalination plants coupling:

- **For MED:**
  - **extract steam from turbine**
  - **Use waste heat**
- **No optimization done here**

DEEP input parameters

- **Skhira site related parameters:**

  Sea water average temperature: 21 °C

  Sea water salinity : 38375 ppm

DEEP input parameters

- **Hypotheses related to the desalination process**

Parameters	**Units**		
Desalination plant type		**MED**	**RO**
Reference year		2006	
Interest rate	%	5 - 8 - 10	
Reference unit size	m^3/d	24 000	
Specific construction cost	$\$/m^3/d$	900	800
Average salary	$/year		
Management		20 000	20 000
labor		7 000	7 000
Availability		0.91	0.91
Construction lead time	month	12 + nbr of units	12 + nbr of units

DEEP input parameters

- **Hypotheses related to power plants**

Parameters	Units				
Power station Type		GTMHR	PWR	CC600	TV600
Reference year		2006			
Interest Rate	%	5 - 8 – 10			
Total power plant net output	MW_e	286	951	600	600
Total power plant thermal power	MW_{th}	600	2 882	1 069	1 538
Number of power plants units	-	2	1	1	1
Efficiency	%	48	33	51	39
Availability	%	90,2	90,2	90,2	90,2
Construction lead time	Years	4	5	2	3
Specific construction cost	$/kWe	975	1417	713	1135
Power plant life span	Year	60	40	25	30
Fossil fuel cost	$/bbl			70, 100, 120	
Fossil fuel annual escalation rate	%/year	-	-	2	2
Specific nuclear fuel cost (interest rates of 5, 8 and 10%)	$/MWh	6.48 ; 6.48 and 6.54		-	-

Economical evaluation

- Power-desalination plant couplings:

	MED	RO
GT-MHR	X	
PWR 900	X	X
CC 600	X	X
TV 600	X	X

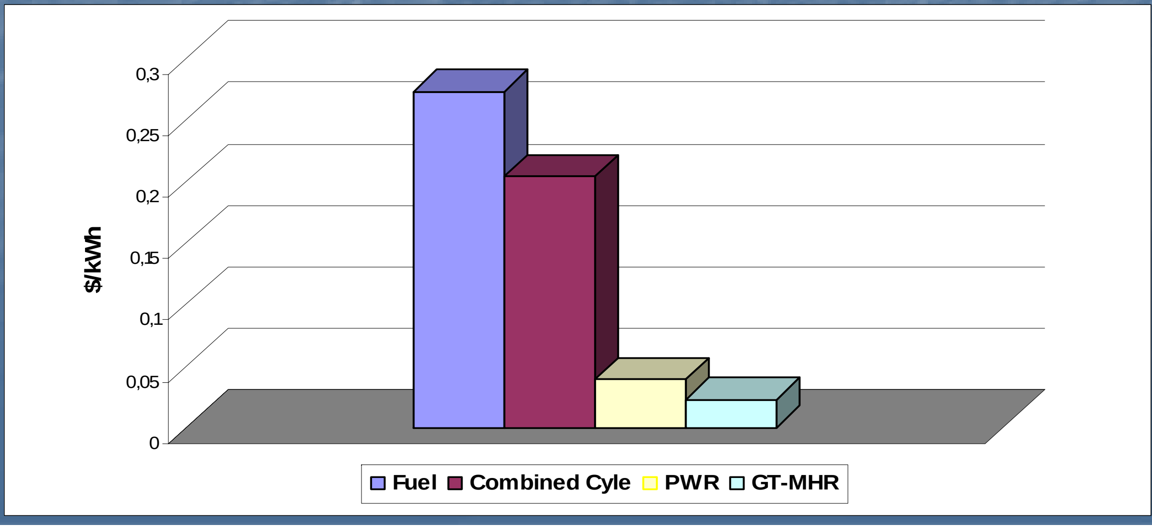
- Varied oil price, interest rate and desalination capacity.
- Considered hybrid installations : MED + RO
- For MED: considered steam extraction and waste heat

Main Results

Electricity cost

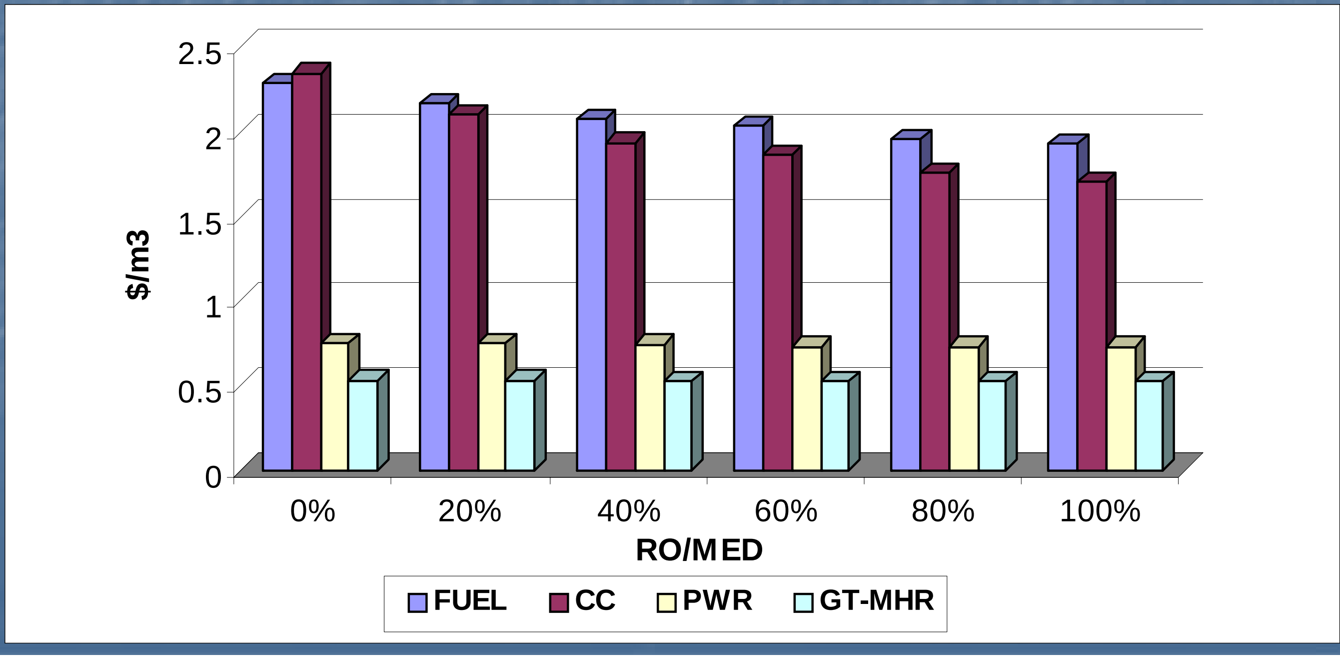
- lowest for the GT-MHR.
- Nuclear is in general much lower than fossil
- Difference depends on fossil fuel prices and interest rates
- *Example: PWR kWh is 81% lower than that of CC600*

(for 100 $/bbl and 8% interest rate)



water cost

- Reverse osmosis offers a desalination cost lower than that of MED.
- Nuclear is in general lower than fossil
- *Examples:*
  - CC + RO is 60% less expensive than CC + MED
  - PWR+ RO is 26% less expensive than PWR + MED
  - PWR + RO is 37% less expensive than CC + RO



Comparison with DEEP2 results

- Trends are the same.
- For MED, DEEP3 yields higher estimates.
- For RO, DEEP3 yields lower estimates
- *Examples:*
    - FUEL+MED: DEEP3 cost is 14% higher than DEEP2's
    - PWR+MED: DEEP3 cost is 21% higher than DEEP2's
    - FUEL+RO: DEEP3 cost is 41% lower than DEEP2's
    - PWR +RO: DEEP3 cost is 7% lower than DEEP2's

Conclusions

- DEEP is a simple and yet powerful tool
- The study showed the clear advantage of integrating the nuclear option to meet Tunisia’s water and electricity needs for year 2020.

THANK YOU