Technical Meeting on the User-Vendor Interface in Cogeneration for Electricity Production and Seawater Desalination
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PROPOSAL OF DESALINATION TECHNOLOGY SELECTION FOR NUCLEAR POWER AND DESALINATION PLANT

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Desalination Technology

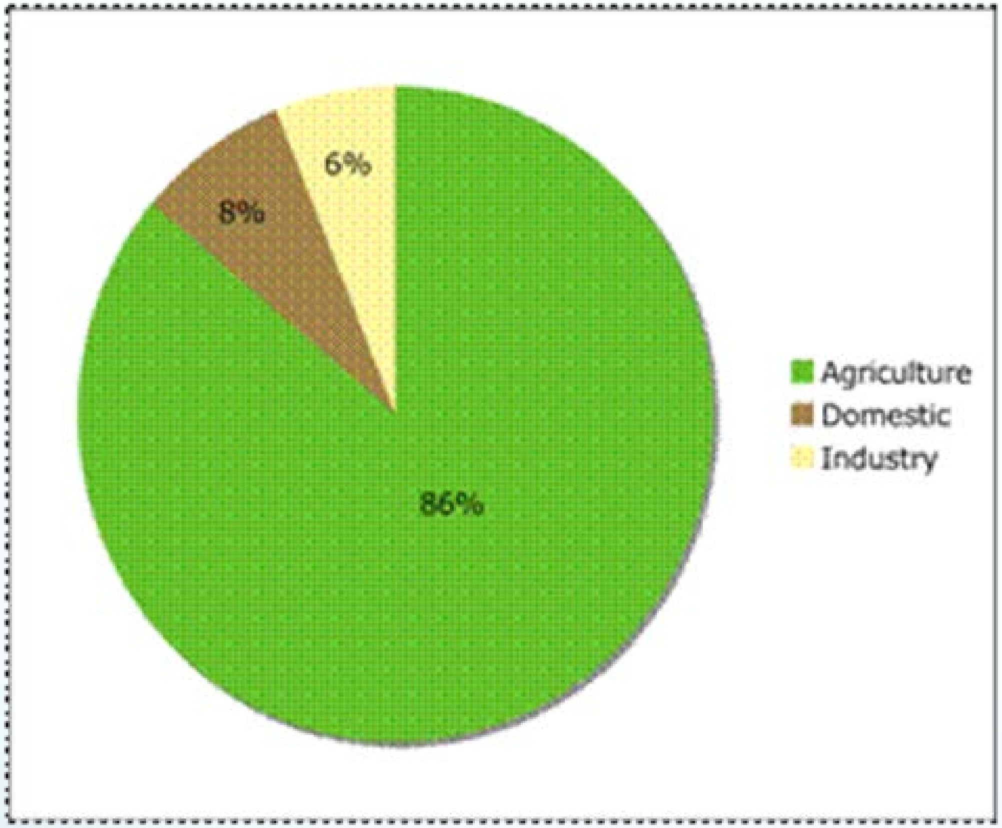
Expert meeting in Egypt in May 1999 for selection of desalination technology for El Dabaa Nuclear Desalination Plant recognized, that the most suitable desalination process for Nuclear Desalination Complex is hybrid technology:

- The feedwater temperature to the RO plant is optimized and controlled by using cooling water of MED Plants;
- A post treatment could be simplified by mixing the product water from both plants,
- With assistance of RO plant it will be easy to cover consumption peaks, leaving the MED to be operated in base mode;
- Improving the economy and harmonizing the electrical and water demand.

Plant Location

- El Dabaa region is located in Matrough Governorate of Egypt, in area with arid climate.
- Average year precipitation is about 119 mm/year.
- Amount of fresh underground water is very limited (684 m3/year)

Selection of the Desalination Plant Capacity

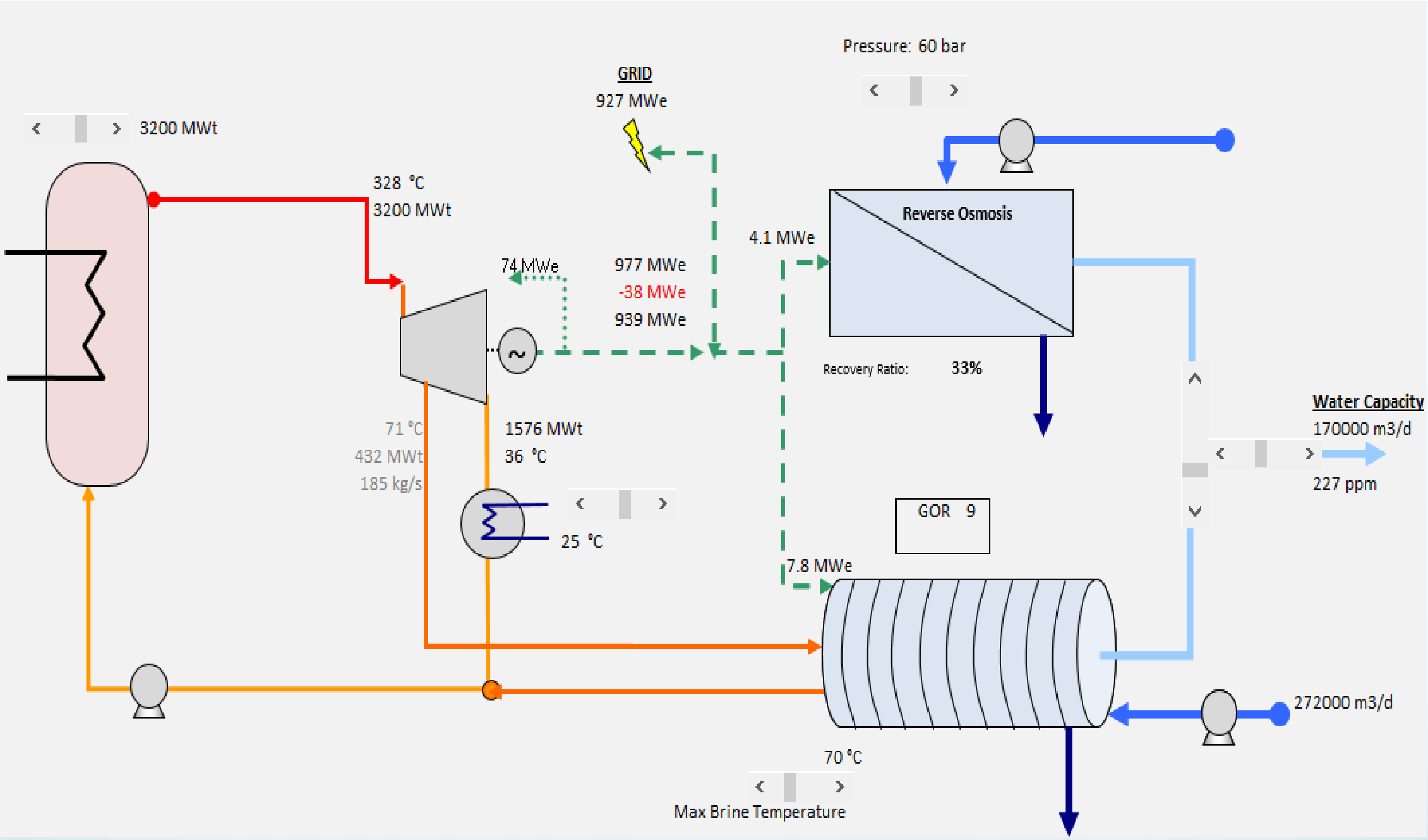


Typical structure diagram of water consumption in Egypt

Total required water capacity includes:

- Water for NPP construction;
- Water for NPP operation, including the preparation of feed water, showers, sanitary etc.;
- Domestic needs, taking into account increasing of population due to construction of NPP;
- City landscape irrigation;
- Agriculture;
- Reserve to cover the water consumption peaks.

Desalination Technology



Flow diagram for connection oh MED+RO desalination plant to NPP

Technical data of NPP AES-2006

Installed nominal output per one power unit, MWe	1197
Service life, years	60
Power plant efficiency, % (gross)	37. 0
Power plant efficiency, % (net)	34.5
House load consumption, %	7.0
Availability factor, %	92.0
Number of operating personnel (person/MW)	0.42
Fuel campaign duration (years)	4
Design fuel burn-up (average per fuel assembly) (MWd/kgU)	60
Period of refueling, months	18
Thermal Power of Reactor, MWth	3200
Temperature of water, ° C:	
Before reactor	298,6
After reactor	329,7
Uranium load, ton	66

Way to CAPEX reduction

- Installation of isolation loop to secure the emission of radioactive materials to drinking water increases the CAPEX of the Plant and put on some limitation for the extracted steam parameters.
- Isolation of desalination system could be done by complete separation of the first effect heating chamber from other effects of MED plant by reliable hermetization of heat exchange tubes with a welding, for example, and installation of separate system for removal of non-condensable gases
- Additionally control sensors for radioactivity should be installed in the second effect to provide the secondary protection barrier.

Technical data of NPP AES-2006

Option A. Steam extraction from standard turbine K-1200, Power Machines JSC:

Extraction Section No	III (left+right)	IV	V
Pressure of steam, MPa, abs	0,823	0,479	0,119
Flow Rate, ton per hour	140+100	275	95
Steam temperature, °C	170,75	149,47	135,7

Option B. Reconstruction of the turbine for achievement of following parameters

- Outlet pressure: 3-4 bar (abs);
  - Humidity less than 1 % (after separator);
  - Temperature: from 120 to 150 oC);
  - Flow rate up to 900 ton/hour.

Water Cost Optimization

$$C_w = [(\Sigma Capex_{add} - \Sigma Capex_{ex})\ \psi + F_{om}] / W_c / \tau_{eq} + \lambda_{th} \cdot Y_{th} + [\alpha\ \lambda_{el\_RO} + (1-\alpha) \bullet \lambda_{el\_RO}]\ Y_{el} + \alpha\ V_{om\_RO} + (1-\alpha)\ V_{om\_MED};$$

where:

$\alpha = W_{RO}/W_c$ - RO plant share in total capacity;

$\Sigma Capex_{add}$ – added capital cost to standard design of Nuclear Power Plant, including design, engineering and erection works;

$\Sigma Capex_{ex}$ – capital cost of equipment, excluded from standard design of Nuclear Power Plant, mainly related to pretreatment of feed water for steam generators and consumed for drinking and other needs of NPP;

λ_{th}- specific heat consumption (MJ/m^3);

λ_{el}- specific electrical power consumption (kWh/m^3);

Y_{th}- cost of heat (US$/ MJ);

Y_{el}- cost of electrical power (US$/kWh);

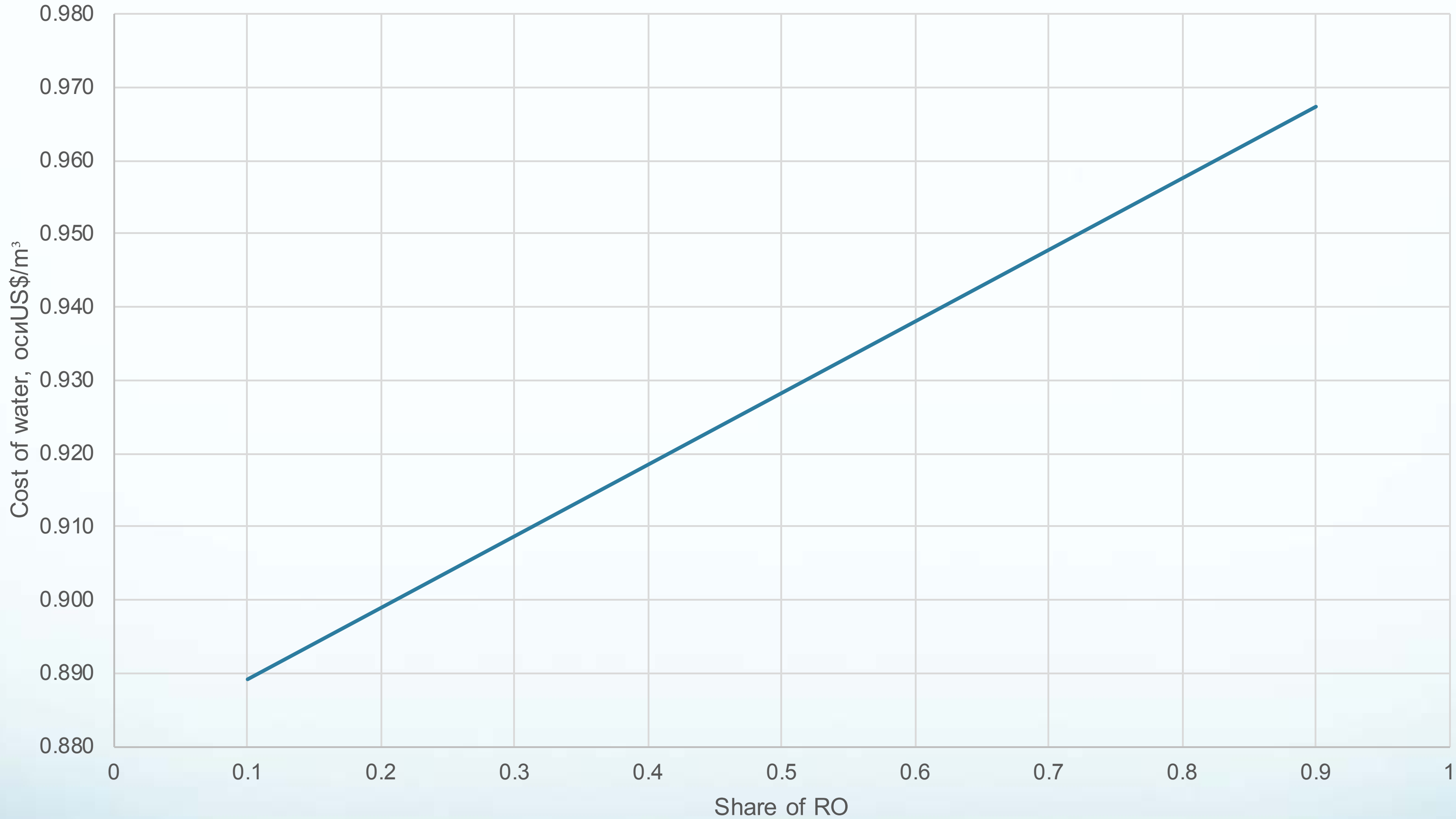
RO – reverse osmosis technology;

MED – multi-effect distillation technology;

F_{om} – fixed cost of operation, maintenance and administration (US$/a);

V_{om} – variable cost of operation, maintenance and repair/replacement (US$/$m^3$).

Water Cost Optimization



Changing the water cost with increasing of RO capacity in Hybrid MED+RO plant

Water Cost Optimization

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SCENARIO MANAGER

DEEP
Desalination Economic Evaluation Program

Main Menu | Flow Diagram | Sensitivity Analysis | Financial Analysis | Report | Scenario Manager | Expert Mode

Load Case from File

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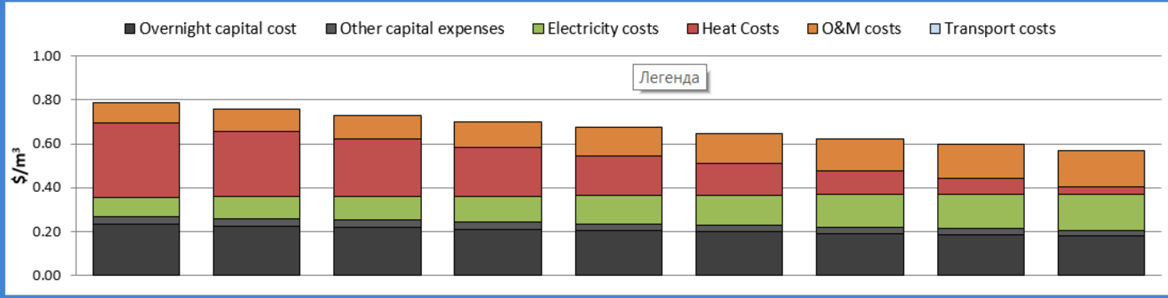

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Current model run : Outputs Summary			Base Case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Levelized Capital Costs	0.21	$/m3	0.27	**0.26**	**0.25**	**0.24**	**0.24**	**0.23**	**0.22**	**0.21**	**0.21**
Base plant overnight EPC	0.18	$/m3	0.23	**0.23**	**0.22**	**0.21**	**0.20**	**0.20**	**0.19**	**0.19**	**0.18**
Other	0.03	$/m3	0.04	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
Levelized operating costs	0.41	$/m3	0.55	**0.53**	**0.52**	**0.50**	**0.48**	**0.46**	**0.45**	**0.43**	**0.41**
Heat	0.04	$/m3	0.34	**0.30**	**0.26**	**0.22**	**0.18**	**0.14**	**0.11**	**0.07**	**0.04**
Electricity	0.16	$/m3	0.09	**0.10**	**0.11**	**0.12**	**0.13**	**0.14**	**0.15**	**0.16**	**0.16**
O&M	0.22	$/m3	0.12	**0.13**	**0.15**	**0.16**	**0.17**	**0.18**	**0.19**	**0.20**	**0.22**
Transport	0.00	$/m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lifecycle Emissions	228	Mtn/yr	228	228	228	228	228	228	228	228	228
Thermal Utilization	31%		44%	**42%**	**41%**	**39%**	**38%**	**36%**	**35%**	**33%**	**31%**
Power lost	4.7	MWe	42	**38**	**33**	**28**	**23**	**19**	**14**	**9**	**5**
Power used for desalination	19	MWe	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Power cost	57.5	$/MWh	57.5	57.5	57.5	57.5	57.5	57.5	57.5	57.5	57.5
Inputs Summary											
Power Plant Type	team Cycle		Steam Cycle	Steam Cycle	Steam Cycle	Steam Cycle	Steam Cycle	Steam Cycle	Steam Cycle	Steam Cycle	Steam Cycle
Fuel	Nuclear		Nuclear	Nuclear	Nuclear	Nuclear	Nuclear	Nuclear	Nuclear	Nuclear	Nuclear
Reference thermal output	3,200	MWth	3200	3200	3200	3200	3200	3200	3200	3200	3200
Reference electricity output	1,120	Mwe	1120	1120	1120	1120	1120	1120	1120	1120	1120
Electricity Production	7,871	GWh/y	7871	7871	7871	7871	7871	7871	7871	7871	7871
Desalination Type	MED RO		MED RO	MED RO	MED RO	MED RO	MED RO	MED RO	MED RO	MED RO	MED RO
Total Capacity	170,000	m3/d	170000	170000	170000	170000	170000	170000	170000	170000	170000
Feed Salinity	35,000	ppm	35000	35000	35000	35000	35000	35000	35000	35000	35000
Combined Availability	85%		85%	85%	85%	85%	85%	85%	85%	85%	85%
Water Production	56.63	10^6 m3/d	52.98	**53.43**	**53.89**	**54.35**	**54.80**	**55.26**	**55.72**	**56.17**	**56.63**

Changing the water cost with increasing of RO capacity in Hybrid MED+RO plant

Conclusion

- **Hybrid technologies was recognized as the most suitable due to combination of MED and RO advantages.**
- **Integration of isolation loop into desalination system decreases the capital cost of Desalination Plant.**
- **It was proposed to be focused only on the cost, reliability and safety of supplied water, taking into account, that available quantity of produced water is a factor forming the consumption with acceleration of regional development.**
- **Attempt to find optimal share between MED and RO technologies has shown, that simple solution is not visible and it requires detailed analysis of environment, regional, social and technical features.**

- **THANKS FOR ATTENTION!**