



The Abdus Salam  
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**"Recent Model Developments for the IAEA  
Desalination Economic Evaluation Program  
(DEEP)"**

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**Recent Model Developments For  
The IAEA Desalination Economic  
Evaluation Program (DEEP)**

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**International Atomic Energy Agency**

**ICTP Workshop on Physics for Renewable Energy**

**Oct 27, 2005**

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# **SCOPE OF DEEP**

- **SPREADSHEET TOOL FOR PERFORMANCE & COST ANALYSIS OF VARIOUS CO-GENERATION STRATEGIES (POWER+DESALINATION)**
- **PROGRAM FREELY AVAILABLE UNDER LICENSE AGREEMENT FROM INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)**

# **WHAT IS NEW IN VERSION 3**

## **DEEP-3 FEATURES UPGRADES IN**

- 1. THERMAL MODEL**
- 2. RO MODEL**
- 3. COUPLING CONFIGURATION MATRIX**
- 4. USER INTERFACE**

# **THERMAL MODEL UPGRADE**

- 1. GENERALIZATION OF LOST SHAFT WORK TO COVER**
  - **EXTRACTION SYSTEMS**
  - **BACKPRESSURE SYSTEMS**
- 2. IMPROVEMENTS IN DISTILLATION THERMAL BALANCE & GOR MODEL**
- 3. THERMAL VAPOR COMPRESSION (TVC) OPTION ADDED**



# **RO MODEL UPGRADE**

## **1. NEW & VALIDATED CORRELATIONS**

- **FEED PRESSURE**
- **PERMEATE SALINITY**
- **RECOVERY RATIO**

## **2. EFFECTS OF FEED SALINITY, TEMPERATURE & FOULING INCLUDED**

# **UPGRADE OF COUPLING CONFIGURATION MATRIX**

- **COUPLING SCHEMES FOLLOW**
- **TURBINE DESIGN (STEAM VS. GAS)**
- **CO-GENERATION FEATURES (DUAL-PURPOSE VS. HEAT-ONLY)**



# ENERGY SOURCE OPTIONS

- **FOSSIL POWER**
- **NUCLEAR POWER**
- **RENEWABLES**



# DESALINATION TECHNOLOGY OPTIONS

- **MED**
- **MSF**
- **RO**
- **HYBRID**
  - **MED-RO**
  - **MSF-RO**

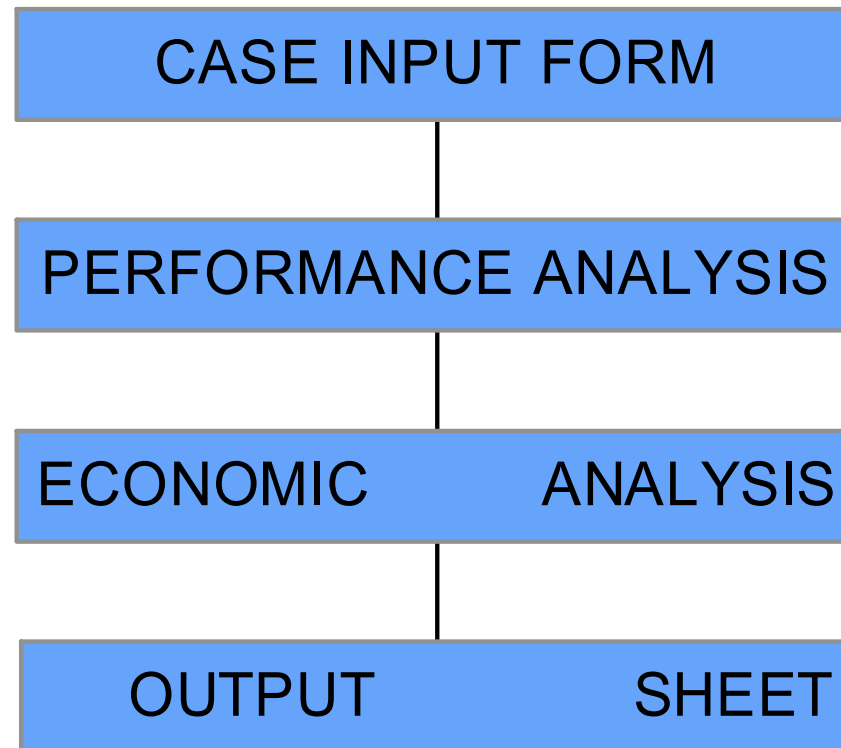


# **UPGRADE OF USER INTERFACE**

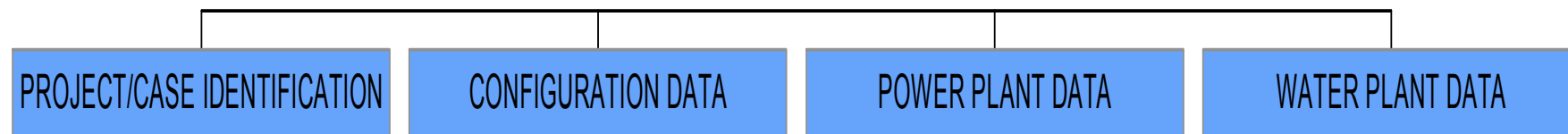
- **UI REFURBISHED & MADE USER-FRIENDLIER**
- **NEW CASE INPUT FORM**
- **IMPROVED INPUT/OUTPUT SHEETS**



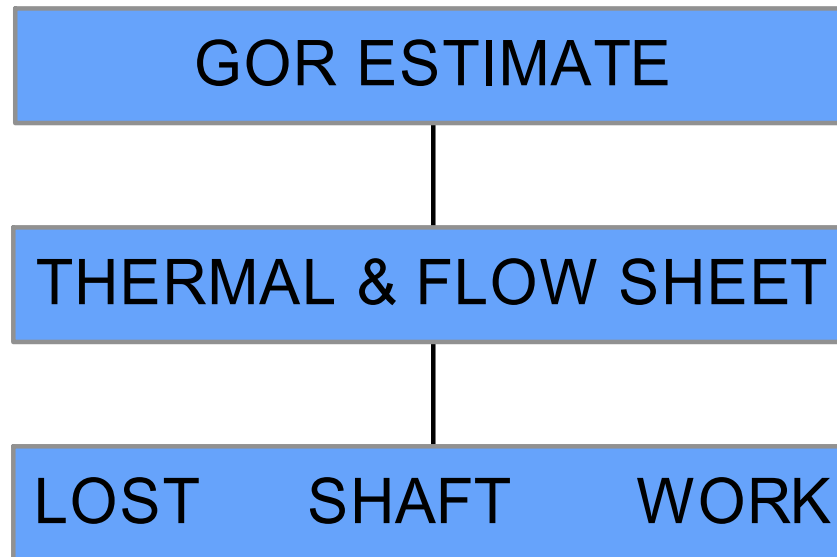
# OVERALL DEEP FLOWCHART



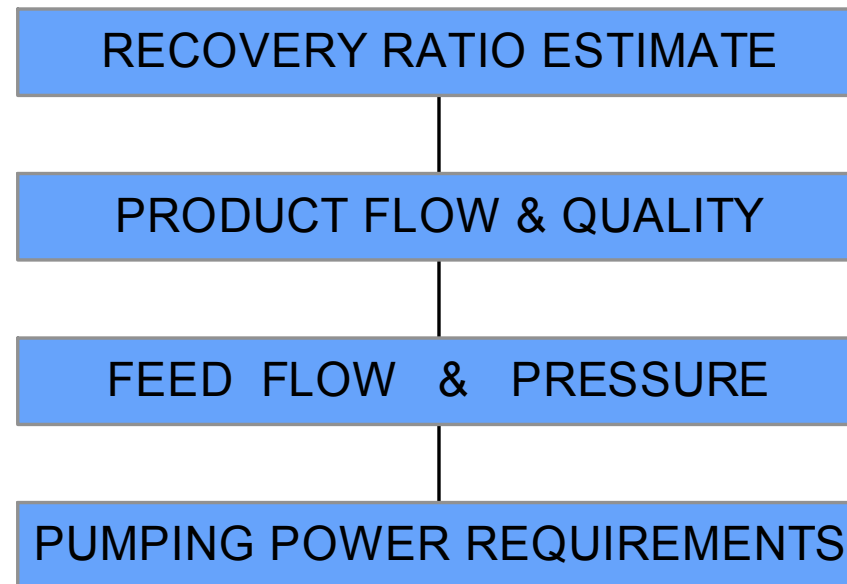
# INPUT DATA FLOWCHART



# THERMAL MODEL FLOWCHART



# RO MODEL FLOWCHART



# VIEW OF CASE INPUT FORM

**Specify Case and Configuration Data**

Project: Beta Version Test - Aug. 15, 2005      Case: Hybrid Case: CC + MED-RO

Water Plant Capacity  
 Total Capacity: 100000 m<sup>3</sup>/d    Distillation part 50 %

Feed Salinity 35000 ppm      Feed Temperature 30 deg C  
 Interest Rate 5 %      Purchased Electricity Cost 0.06 \$ / kWh

Power Plant Data		Distillation Plant Data		Reverse Osmosis Plant Data	
Thermal Power	1200 MWt	Maximum Brine Temperature	65 deg C	Energy Recovery Fraction	30 %
Net Electric Power	600 MWe	Steam Temperature (optional)	0 deg C	Recovery Ratio (optional)	0 %
Fuel Cost	50 \$/boe	Specific Construction Cost	900 \$ / (m <sup>3</sup> /d)	Design Flux	13.6 1 / (m <sup>2</sup> h)
Specific Construction Cost	700 \$ / kW			Specific Construction Cost	900 \$ / (m <sup>3</sup> /d)

**First, select a coupling configuration from the matrix of supported energy sources and desalination technologies**

	MED	MSF	RO	MED-RO	MSF-RO
<b>NUCLEAR</b> NUCLEAR STEAM TURBINE	NSC+MED	NSC+MSF	NSC+RO	NSC+MED-RO	NSC+MSF-RO
NUCLEAR GAS TURBINE	NBC+MED	NBC+MSF	NBC+RO	NBC+MED-RO	NBC+MSF-RO
NUCLEAR HEAT	NH+MED	NH+MSF			
<b>FOSSIL</b> STEAM CYCLE - COAL	COAL+MED	COAL+MSF	COAL+RO	COAL+MED-RO	COAL+MSF-RO
STEAM CYCLE - OIL	OIL+MED	OIL+MSF	OIL+RO	OIL+MED-RO	OIL+MSF-RO
GAS TURBINE / HRSG	GT+MED	GT+MSF	GT+RO	GT+MED-RO	GT+MSF-RO
COMBINED CYCLE	CC+MED	CC+MSF	CC+RO	CC+MED-RO	CC+MSF-RO
FOSSIL HEAT	FH+MED	FH+MSF			
<b>RENEWABLE</b> RENEWABLE HEAT	RH+MED	RH+MSF			
STAND-ALONE RO			SA-RO		

MED-RO  
CC

File Name: New CC+MED-RO

O.K.      Cancel

**Configuration Switches**

Steam Source  
 Extraction / Condensing  
 Backpressure

Thermal Vapor Compression  
 Yes  
 No

Backup heat source



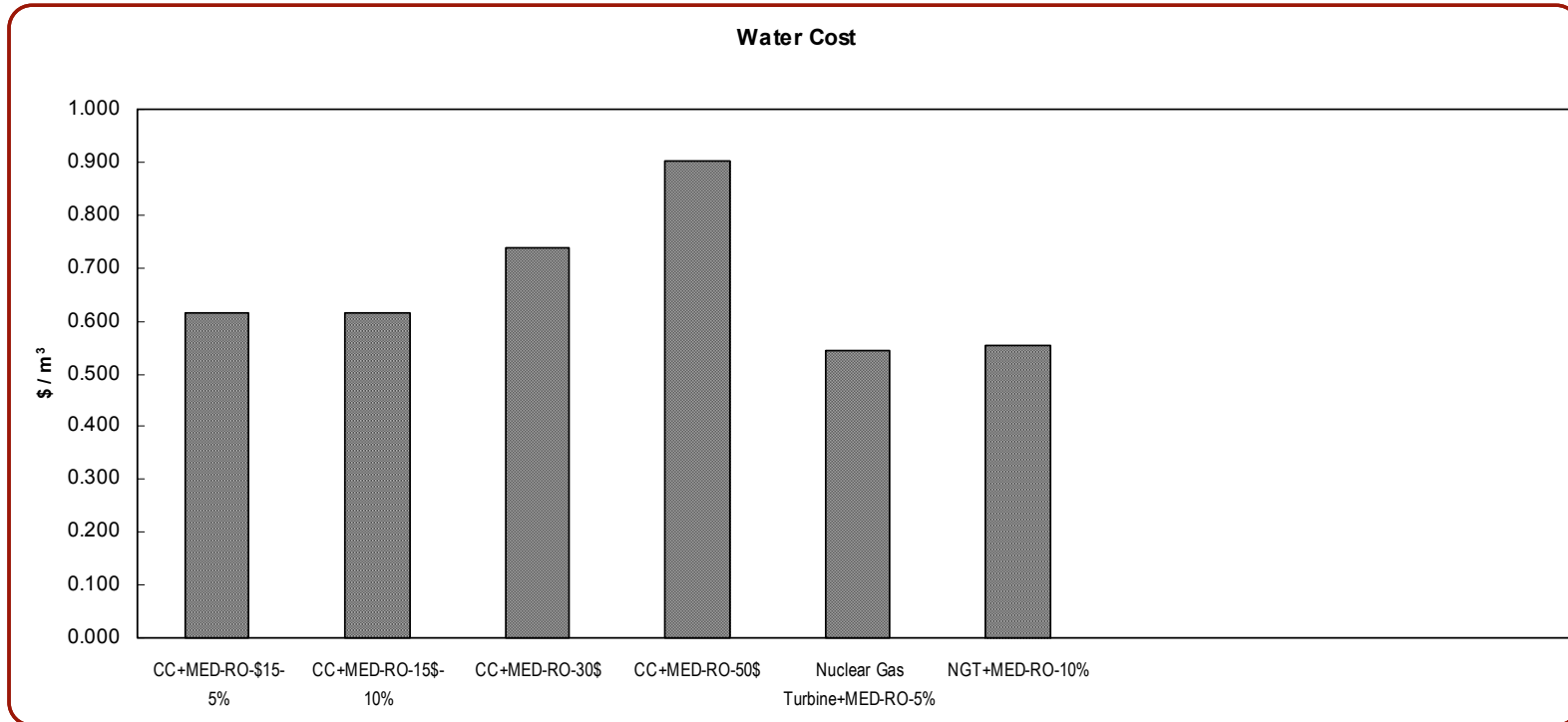


# VIEW OF OUTPUT SHEET

Summary of Performance and Cost Results					Close
<b>Main Input Parameters</b>					
<b>Project</b>	Beta Version Test - Aug. 8 2005		<b>Case</b>	CC+MED-RO	
<b>Power Plant Data</b>			<b>Water Plant Data</b>		
Type	CC		Type	MED-RO	
Ref. Thermal Power	1,200	MW	Required capacity	100,000	m <sup>3</sup> /d
Ref. Net Electric Power	600	MW	Hybrid Dist. Capacity	50,000	m <sup>3</sup> /d
Construction Cost	700	\$/kW	Dist. Construction Cost	900	\$/ (m <sup>3</sup> /d)
Fuel Cost	50	\$/BOE	Maximum Brine Temp.	65.0	°C
Purchased Electricity Cost	0.06	\$/kWh	Heating Steam Temp.	0.0	°C
Interest Rate	5	%	Dist. Feed Temp.	30	°C
			Seawater Feed Salinity	35000.0	ppm
<b>Configuration Switches</b>			Hybrid RO Capacity	50,000	m <sup>3</sup> /d
Steam Source	ExtrCon		RO Construction Cost	900	m <sup>3</sup> /d
Intermediate Loop	N/A		RO Recovery Ratio	0.00	
TVC Option	N		RO Energy Recovery Fraction	0.30	
Backup Heat	N		RO Design Flux	13.6	l / (m <sup>2</sup> hour)
			RO Feed Temp.	30.0	°C
<b>Performance Results</b>					Close
Lost Electricity Production	10.0	MW			
Power-to-Heat Ratio	3.5	MW <sub>e</sub> /MW <sub>t</sub>			
Plant Thermal Utilization	62.8	%			
<b>Distillation Performance</b>			<b>RO Performance</b>		
# of Effects/Stages	9				
GOR	8.0		Recovery Ratio	0.42	
Temperature Range	20	°C	Permeate Flow	50,000	m <sup>3</sup> /d
Distillate Flow	50,000	m <sup>3</sup> /d	Feed Flow	120,000	m <sup>3</sup> /d
Feed Flow	100,000	m <sup>3</sup> /d	Feed Pressure	57.4	bar
Steam Flow	72.20	kg / s	Product Quality	352	ppm
Brine Flow	50,000	m <sup>3</sup> /d	Brine Flow	70,000	m <sup>3</sup> /d
Brine salinity	70,000	ppm	Brine Salinity	60,000	ppm
Specific Heat Consumption	80.67	kWh / m <sup>3</sup>	Specific Power Consumption	4.69	kWh / m <sup>3</sup>
<b>Cost Results</b>					Close
<b>Specific Power Costs</b>			<b>Specific Water Costs</b>		
Fixed charge	0.008	\$/ kWh	Fixed charge	0.244	\$/ m <sup>3</sup>
Fuel cost	0.075	\$/ kWh	Heat cost	0.195	\$/ m <sup>3</sup>
O&M cost	0.006	\$/ kWh	Plant electricity cost	0.288	\$/ m <sup>3</sup>
Decommissioning cost	N/A	\$/ kWh	Purchased electricity	0.017	\$/ m <sup>3</sup>
			O&M cost	0.158	\$/ m <sup>3</sup>
Levelized Electricity Cost	<b>0.088</b>	\$/ kWh	Total Specific Water Cost	<b>0.902</b>	\$/ m <sup>3</sup>



# VIEW OF COMPARATIVE PRESENTATION



	CC+MED-RO-\$15-5%	MED-RO-15\$-10%	CC+MED-RO-30\$	CC+MED-RO-50\$	Nuclear Gas Turbine+MED-RO-5%	NGT+MED-RO-10%	Unit
Water cost	0.614	0.614	0.737	0.902	0.545	0.553	\$/m³

# **HOW TO OBTAIN DEEP-3**

- **VISIT**  
**[WWW.IAEA.ORG/NUCLEARDESALINATION](http://WWW.IAEA.ORG/NUCLEARDESALINATION)**
- **FOLLOW DOWNLOAD INSTRUCTIONS**