REPORT ON SWIM-SM

TRAINING COURSE ON MODELING THE COST OF DESALINATION

25 – 27 June 2013
Muscat - Oman

(SWIM-SM Work Package 2, Activity 2.11)

Table of Contents

1. BACKGROUND AND OBJECTIVES

1.1 Introduction

Within the scope of work package 2 (WP2) – "Capacity Building" Activity 2.11, the EU-funded "Sustainable Water Integrated Management – Support Mechanism SWIM-SM" project organized, as part of its year 2 work plan, a 3 days training on "modeling the cost of desalination" in collaboration with the Middle East Desalination Research Center (MEDRC) in Muscat, Oman. The training falls under the "Non-conventional Water Resources" thematic pillar of the SWIM-SM project.

This training was organized within the framework of the SWIM-SM by LDK; the leading company in the SWIM-SM consortium and was open to representatives from other Gulf countries who were invited at no cost to SWIM-SM by MEDRC. The language of the training course was English, with French simultaneous translation. A total of 21 representatives from seven SWIM Partner Countries (Algeria, Egypt, Israel, Jordan, Lebanon, Palestine and Tunisia) participated in the training. These included managers from relevant water and environment ministries, research centers and water utilities, involved in the design, implementation and operation and maintenance of desalination projects in the SWIM countries. The detailed list of participants is included in Section 7.

1.2 Objectives

The training aimed to develop the capacity of water resources managers in the SWIM countries, to better understand the aspects influencing the cost of desalination including the factors and functions for modelling these aspects to estimate the associated cost under different scenarios.

The specific objectives include:

1) Develop the capacity of the participants in the aspects affecting the cost of desalination including: (i) Capital costs drivers such as selection of intake & brine discharge, quality of feed water at intake, quality of desalinated water, complying with regulations, project delivery methods and financing mechanisms, proximity to power supplies, skilled labor and environmental mitigation, etc. (ii) Capital cost breakdown including annualized cost, amount financed, interest rate, loan period, depreciation, inflation, etc. (iii) Operation and management cost breakdown including cost of regular and periodic maintenance, cost of complying with environmental monitoring, reporting and renewal of permits, cost of labor, chemicals, supplies, power, etc. (iv) cost for enabling community participation in preventing noncompliance with water and environment noncompliance.
2) Familiarize the participants with the use of the Cost Models for planning purposes to facilitate cost analysis of desalination projects using various scenarios.

2. Learning Objectives

1) Introduce the participants to the structure of the fundamental costs of Desalination Plants
2) Familiarize the participants with the aspects affecting the cost of desalination
3) Provide overview of commonly applied software for desalination plant cost estimating. Present alternative desalination cost planning models and familiarize the participants with the use of the Cost Curve Models for planning purposes to facilitate cost analysis of desalination projects using various scenarios.
4) Familiarize participants with the most recent cost and energy use trends associated with the implementation of desalination projects.
5) Enhance participant knowledge on alternative sources and mechanisms of funding for desalination projects.
6) Gain understanding of key project implementation and technological risks and their impacts on desalination plant funding, capital and production costs.
7) Learn in interactive setting of how to determine the capital and O&M costs and water production costs of a new desalination project.

3. METHODOLOGY AND STRUCTURE OF THE TRAINING

The training was participatory and interactive; making use of professional learning tools such as:

- Presentations by the leader of the course
- Discussions on emerging topics
- Cost estimation exercise involving workgroups (using case studies from the Middle East and North Africa (MENA) region)
- Personal and/or National perspectives

The training took into account the heterogeneity in desalination experience in the region and provided opportunities to accommodate pressing interests that were identified during the sessions.

An electronic copy of the toolbox of graphic and numerical models for estimating costs of Seawater Reverse Osmosis (SWRO) desalination projects was sent by email to the participants prior to the workshop. While the electronic copies of the presentations in both English and French were provided during the training. A certificate of attendance was awarded to all participants at the end of the course. The detailed agenda is available in Section 6 of this report.

4. COURSE STRUCTURE

The training course was structured in 3 modules to achieve the course objectives:

- Module 1: Desalination Plant Operation and Performance Monitoring
- Module 2: Total Capital Costs and Operation and Maintenance Expenditures
- Module 3: Desalination Project Costs – Trends and Examples

5. SUMMARY OF TRAINING ACTIVITIES

5.1 Day 1: Desalination Plant Operation and Performance Monitoring

The **morning sessions** of Day 1 provided an overview of the desalination project cost estimation and definitions of the costs components. The methodology for preparing the cost estimates, the types of cost estimates and their respective accuracies and information needs were introduced. The most important models in cost estimations were presented together with the key challenges. The participants were introduced to the different factors affecting the cost of desalination projects within and outside the control of the project with special emphasis on reverse osmosis; being the most commonly used technology nowadays; yielding water at lower energy use and costs than other conventional desalination technologies.

The **afternoon sessions** addressed the costs associated with the construction of the different components of the systems involved in desalination projects; intake, pretreatment, Reverse Osmosis (RO), post treatment and brine management, etc. Cost curve models reflecting real-world costs and Sea water Reverse Osmosis (SWRO) Projects completed during the past five years were presented for each system to guide the estimation of the respective costs.

All the presentations were supported with several examples from the region and worldwide. It was followed by a number of questions that touched upon various issues including:

- Impact of tendering procedures on cost.
- The relationship between the installed capacity of a desalination plant and its design capacity,
- The effect of brine discharge into landfills and means and costs of mitigating its environmental impacts.
- The lack of standardization in the membrane pretreatment designs which reduces flexibility in the procurement of cheaper or more technologically advanced elements.
- The effect of the design of pre-treatment system on its cost
- The effect of shallow sea water intakes on pre-treatment costs.
- The tradeoff between the cost of constructing more expensive offshore intakes with long intake source water conveyance piping s to access deeper seawater of better quality, and the high pretreatment costs associated with the construction of less costly near-shore or onshore intakes that have shorter source water intake piping but collect more inferior quality shallow sea water.

- The cost of common types of building designs

5.2 Day 2: Total Capital Costs and Operation and Maintenance Expenditures

This day witnessed closer examination of the different elements comprising the direct and indirect capital costs, the operation and maintenance costs, and desalinated water production, together with the range of costs associated with the different elements and components. The presentations triggered a lot of interest and questions from the floor regarding the following issues:

- The impact of good engineering design on the total costs (A good design pays off, since its overall contribution to the total costs is insignificant).
- The importance of pilot testing in planning of large desalination plants, especially in shallow sea water, to reduce the risks associated with uncertainties in water qualities (algae blooms, ship traffic, oil spills, etc.). It was pointed out that where the size of desalination plant is smaller (less than 100,000 m3/day), source water quality testing would be still required.
- The factors affecting the complexity of the design of desalination plant
- The types of subsidies offered by the governments
- The incremental energy-saving potential as a result of technological advances in membrane technology and the present limitations in the commercial utilisation of Concentrated Solar Power technology in desalination (Technology improvements are key to its use in the future).
- The maximum ratio for mixing brackish brine with seawater brine to minimise environmental impacts (ratio should not exceed 1:40)
- The recommended practices to control/reduce and ensure balanced costs during the proposal evaluation and negotiation and later during operation of the desalination plants including energy costs, costs of risks, financing costs, material, and replacement costs. Suggested ways to reduce cost include:
  - examination of the contractor's financial model,
  - sharing risk with the contractor,
  - adequate selection of equipment and building materials,
  - procurement of membranes replacement from the original suppliers,
  - minimizing risks including addressing environmental issues in advance
  - refinancing the project at lower interest rates after one year of operation as uncertainties get eliminated
  - Effect of technological advancements on cost of desalination during the life of the project and factoring the possibility of associated cost reductions in the contracts
- The components of the O&M and total production costs that should still be paid for the contractor in case there was no demand on the produced desalinated water during a given period. These refer to the fixed O&M and total water production costs which are incurred to keep the plant running.
- The factors affecting the financing costs of desalination projects

5.3 Day 3: Desalination Project Costs – Trends, Examples and Interactive Session

The **first session** during day 3 presented recent trends in production costs of SWRO desalination plants, together with the common features of low-cost desalination projects and main reasons behind the disparity between high end and low end cost projects. The types of project deliveries and their impact on cost were presented including examples from the region. The presentations also introduced the participants to the effect of expected technological advancements in desalination on the costs during the coming two decades.

The example of SWRO project cost estimation offered during **the second session** was followed with a group exercise involving the use of the toolbox (cost curve models) provided during the training to estimate the costs of real projects in the MENA region. The costs estimated by the workgroups were found to be within 10-15% of the actual projects costs.

6. TRAINING EVALUATION, FINDINGS AND RECOMMENDATIONS

At the end of the training the participants filled an evaluation form to express their opinion and feelings about the efficiency, effectiveness and soundness of both the organization and delivery of the training. The

form is divided in 2 parts (A and B). Part A evaluates the planning for the workshop and the organizational and administrative issues before and during the workshop. While part B is related to the execution of the workshop. The forms were thereafter analyzed to extract lessons and recommendations for follow-up activities.

6.1. Part A: Organizational and administrative issues before and during the workshop

Table 1 below is a list of the criteria used to evaluate the organizational and administrative issues usinga scoring scale from 1 to 5, with 1= ''Strongly disagree'' or the lowest, most negative impression and 5=''strongly agree'', or the highest, most positive impression.

Table 1: List of Criteria – Part A

A1	Good Handling of Invitations, Visa Support, Information Sharing and Smoothing Obstacles
A2	Smooth flow of programme, efficient handling of emerging needs and attentiveness to participants concerns
A3	Efficient Logistics: Accommodation, Transportation, Tools and Equipment
A4	Efficient and Effective Communication of Objectives, & Expectations from Participants
A5	Efficient and Effective Follow-up of Preparations and Progress towards the Event
A6	Clarity, Coverage and sufficiency of concepts, Objectives, anticipated outputs and outcomes
A7	Procedural issues: Selection and Design of Methodology, Programme/Daily Agenda and Work Rules
A8	Presentations Correspond and contribute to the Planned Objectives and Conducive to Enhanced shared Understanding and participation of Relevant Issues

Figure 1 below illustrates the average points obtained on each of the questions in part A. The average score for this part is 3.82. Most of the complaints recorded were related the short training duration considering the amount of information and knowledge provided, not distributing the presentations in hard copies during the training, or sending them to the participants by email to print them in advance, or providing computers to be used during the cost estimation sessions. This has affected the evaluation of parts A4, A5, A6 and A7 (communication of expectations to the participants, efficient follow up of preparations, clarity of coverage and design of the program agenda; respectively (**See figure 2**). Other complaints were related to lack of social activities organised by the project (joint dinner or site seeing).

5.1 Part B: Executing the workshop

The same scoring scale was used to assess the second set of criteria related to the execution of the workshop. **Table 2** below is a list of the criteria used to evaluate the workshop execution aspects with the results reflected in **Figures 3 and 4** below.

Figure 1: Average number of points obtained for the questions on Part A

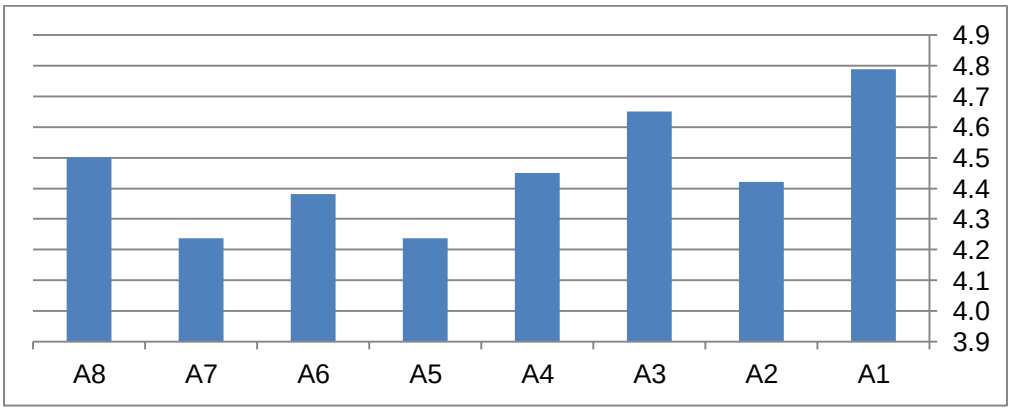


Figure 2. Results of the evaluation of the organizational and administrative issues (Percentage for each score)

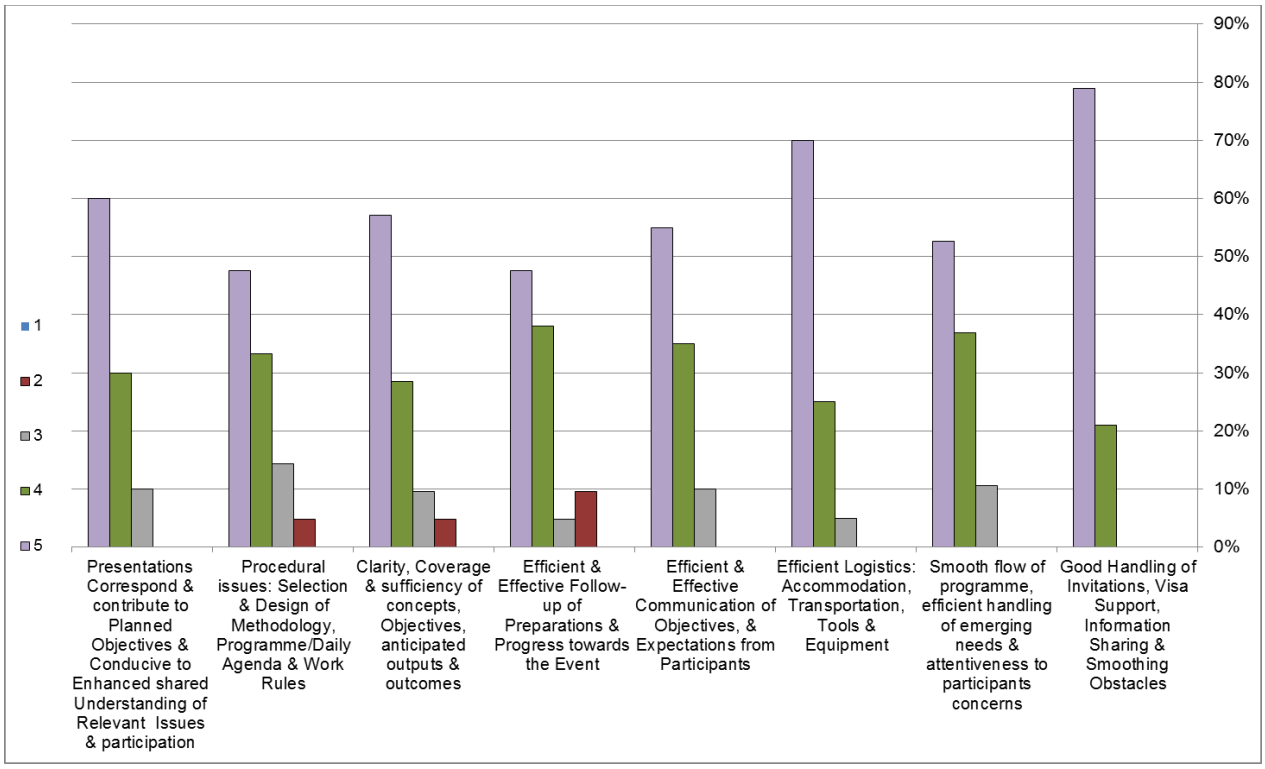
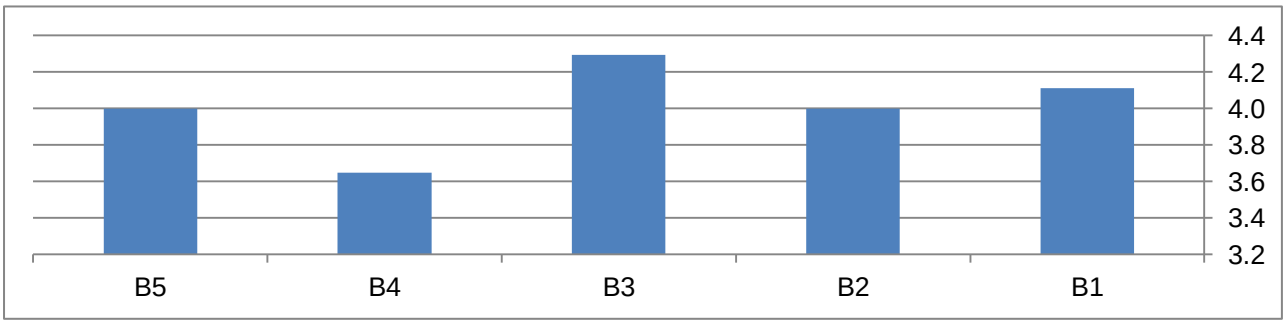


Table 2: List of criteria B1-B5

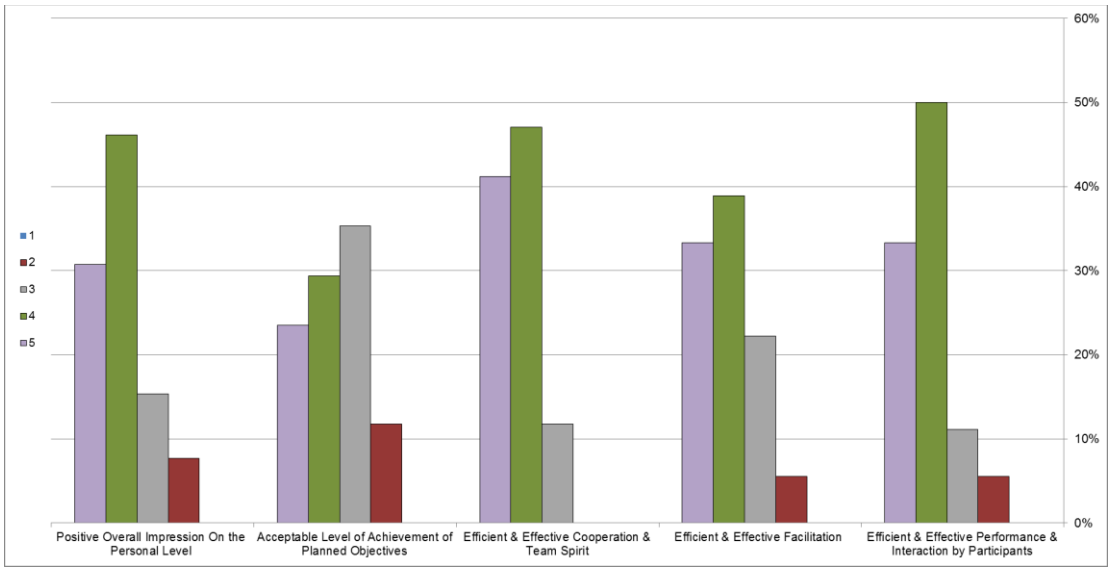
B1	Efficient and Effective Performance and Interaction by Participants
B2	Efficient and Effective Facilitation
B3	Efficient and Effective Cooperation and Team Spirit
B4	Acceptable Level of Achievement of Planned Objectives
B5	Positive Overall Impression On the Personal Level of Participants

Figure 3: Average number of points obtained for the questions on Part B



The participants' feedback was encouraging (an average score of four was recorded), with a large majority giving the highest scores to issues related to B1 (Performance and Interaction by Participants) and B3 (Cooperation and Team Spirit). The intensity of the course, the duration and the heavy agenda, affected the general satisfaction mostly with regards to B3 (the level of achievement of planned objectives); resulting in only 53% of the participants scoring 4 or 5 on this criteria. This could be mostly due to the highly specialized nature of the training, requiring basic knowledge in desalination technologies. It is strongly believed that the different level of competencies among the participants especially due to limited or absence of experience in desalination had a lot to do with this result. Despite that, the general impression on the training remained positive (with an average score of 4 out of 5), suggesting a predominant satisfaction with all aspects of the course.

Figure 4: Results of the evaluation of the execution of the work shop (Percentage by score number)



5.2 Personal impressions and recommendations

Participants were invited to express themselves on the aspects that they have liked the most and their recommendations for improvement in the future. Below is a summary of the findings which were recorded mostlt by the majority of the participants:

Most liked things	Suggestions for improvement
➢ Coordination of the workshop, efficient organisation by SWIM, accommodation and receiving the participants ➢ The venue ➢ The team spirit of the participants and cooperation between them ➢ Course is very useful and rich with information, and knowledge. It offers solid examples and case studies that are linked with actual experience and the real world. It provided good opportunity for learning more and exchanging experience ➢ O&M cost analysis ➢ Research direction to meet cost reductions ➢ The instructor's spirit. Very informative instructor with large knowledge and experience, and keenness to transfer all his experience and knowledge to the participants ➢ Clear material and well prepared presentations ➢ Real world numbers and experience presented which is up to date	➢ Improve the translation ➢ Provide laptops for the exercise ➢ Avoid classroom type of events and lectures for the whole day. End of workshop should not exceed 4pm ➢ Training should be more Interactive ➢ Arrange for technical visit to R/O desalination plant ➢ Include in the training the economic impact of desalination on the countries ➢ Organise Technical workshop about O&M in desalination ➢ Focus on cost estimation and evaluation without going into so much details ➢ Available documents are hints and further details will add value and allow their use as a reference for work. ➢ More details on the cost of desalination are required ➢ Sharing course material and presentations in hard copy before attending the training sessions. ➢ Submission of material before workshop ➢ Redesign the agenda to be proportional to the course duration, otherwise extend the course to five days. ➢ If in the future any other workshop related to desalination is organised, same team should be invited ➢ Follow up the program outcome ➢ Organise the same training in Maghreb ➢ Experience is good but not so much to the point that the main subject becomes part of the story

7. AGENDA

Day 1: Desalination Plant Operation and Performance Monitoring

09:00 – 10:30: ***1.1 Project Cost Estimating – Overview***

Project Cost Definitions
General Methodology for Preparation of Project Cost Estimates
Type and Accuracy of Project Cost Estimates
Cost Models

10:30 – 10:45 Coffee Break

10:45 – 12:00: ***1.2 Project Cost Factors***

Introduction
Factors Impacting Project Costs within the Control of Project Owner

- Project Size
- Capacity Availability Factor
- Source Water Quality
- Target Product Water Quality
- Environmental externalities including concentrate Disposal Method
- Power Supply and Unit Power Costs
- Project Risk Profile
- Public Participation and Other Project Cost Factors

Project Cost Factors Outside of the Control of Project Owner

12:00 – 13:00 Lunch Break

13:00 – 14:30: ***1.3 Construction Costs for Intakes and Pre-treatment Systems***

Plant-site Related Construction Costs
Intake Costs

- Costs for Subsurface Intakes
- Costs for Open Intakes
- Intake Piping and Pump Station Costs
- Intake Screen Costs

Pre-treatment Facility Construction Costs
Chemical Conditioning Costs
Costs of Gravity and Dissolved Air Flotation Clarifiers
Costs of Gravity Media Filters
Costs of UF and MF Membrane Pre-treatment Filters
Cartridge Filtration Costs
Cost Tables and Curves

14:30 – 14:45 Coffee Break

14:45 – 15:45: 1.4 RO System Construction Costs

Key SWRO System Components
High-pressure Pump Costs
Costs of RO Membrane Racks
Energy Recovery System Costs
Cost Tables and Curves

15:45– 16:30: ***1.5 RO Construction Costs for Post-treatment, Concentrate Management and Other Plant Facilities***

Post-treatment Costs
Concentrate Disposal Costs
Waste and Solids Handling Costs
Costs of Electrical and Instrumentation Systems
Costs of Auxiliary and Service Equipment and Utilities

Building Costs
Start-up, Commissioning and Acceptance Testing Costs

16:30 – 17:00 Questions and Discussions

Day 2: Total Capital Costs and Operation and Maintenance Expenditures

09:00 – 10:30: ***2.1 Estimating Indirect and Total Capital Costs***

Costs for Project Engineering Services
- Preliminary Engineering
- Pilot Testing
- Detailed Design
- Construction Management and Oversight

Project Development Costs
- Project Administration, Contracting and Management
- Legal Services
- Environmental Assessment Costs

Costs for Enabling Community Participation
- Costs for Developing Public Relation Documents
- Costs for Public Meetings and Project Reviews

Project Financing Costs
- Government Financing
- Conventional (Bond or Construction Loan) Financing
- Private Project Financing
- Interest During Construction
- Debt Service Reserve
- Other Financing Costs

Contingency
Total Capital Costs

10:30 – 10:45 Coffee Break

10:45 – 12:00: ***2.2 Variable O&M Costs***

Power
Chemicals
Replacement of Membranes and Cartridge Filters
Waste Stream Disposal

12:00 – 13:00 Lunch Break

13:00 – 14:30: ***2.3 Fixed and Total O&M Costs***

Labour
Maintenance
Environmental and Performance Monitoring
Indirect O&M Costs
Total O&M Costs

14:30 – 14:45 Coffee Break

14:45 – 16:30: 2.4 Cost of Water Production

Fixed Cost Components
- Capital Cost Recovery
- Other Fixed Costs

Variable Cost Components
Total Cost of Water Production

16:30 – 17:00 Questions & Discussions

Day 3: Desalination Project Costs – Trends, Examples and Interactive Session

09:00 – 10:30: ***3.1 Desalination Cost Trends***

Overview
Recent SWRO Desalination Projects and Their Cost Breakdown
High-End Cost Projects
- Key Factors Contributing to High Costs

Low-End Cost Projects
- Key Factors Resulting in Low Costs

Impact of Project Delivery
Costing Methods
Project Description
Breakdown of Project Capital Costs
Annual O&M Costs
Cost of Water Estimate
Design-Bid-Build (DBB) Projects
Design-Build-Operate (DBO) Projects
Build-Own-Operate-Transfer (BOOT) Projects

10:15 – 10:30 Coffee Break

10:30 – 12:00: ***3.2 Example of SWRO Project Cost Estimate***

12:00 – 13:00 Lunch Break

13:00 – 13:30: ***3.3 Cost Estimating Session – Team Assignments***

Overview of Interactive Case Study Estimating Session
Definition of Project Case Study
Projects and Deliverables
Division of Project Participants into 5-7 People Work Teams and Assignment of Individual Project Case Study to Each Team

13:00 – 14:00: ***3.4 Development of Project Cost Estimates by the Work Teams***

Work of Seven Individual Teams on their Project Cost Assignments

14:00 – 14:15 Coffee Break

14:15 – 16:00 ***-3.5 Presentations of Cost Estimates Developed by the Work Teams:*** Each of the Five Work Teams Gives 20-minute Presentation of the Cost Estimate of their Project Case Study

16:00 – 17:00 Discussions of Case Study Cost Estimates

8. LIST OF PARTICIPANTS

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