Introduction

Compared to other manufacturing processes, there are no precise rules to establish a cost and a price for a desalination plant. There are several theories about how cost criteria should be developed and costs should be allocated, but there are no systematic and consolidated approaches to desalination plant budgeting.

Some papers published in international magazines and conferences proposed algorithms to estimate the plant costs according to the unit capacity and performance ratio. However, these algorithms were valid in limited circumstances only and for a certain market and historical situations.

The price of a desalination plant can be affected by several parameters some are purely technical and are related to the specification or performance requirement others are purely commercial and are related to the specific market situation at the time of tendering and contracting.

The most frequently adopted techniques for turnkey cost evaluation are based on:

- Incremental budgeting
- Zero base cost budgeting

These techniques are also adopted for the evaluation of O&M costs or final tariff projection.

The present paper aims at presenting these various techniques and comparing their relative advantages and disadvantages.

General desalination plant pricing issues

The price of a desalination plant can be affected by several parameters some are purely technical and are related to the specification or performance requirement others are purely commercial and are related to the specific market situation at the time of tendering and contracting.

Typical commercial factors influencing the budgeting of a desalination projects are:

1) Type of contract (traditional turn key – build own operate)
2) Contract delivery time
3) Client type and historical project background
4) Market demand
5) Market competition
6) Financial history of recent project
7) Contract conditions
8) Freedom to adopt different technologies
Typical technical aspects having an influence in budgeting a desalination projects are:

9) Technology selection (Thermal-Reverse osmosis)
10) Site characteristics (particularly for Reverse osmosis)
11) Plant lifetime expectancy
12) Plant efficiency i.e.:  
   - Performance ratio  
   - Specific power - chemical consumption
13) Unit size and number
14) Service availability (Degree of redundancy of equipment)
15) Green or brown field project development (availability of infrastructure and plant auxiliaries)

A general price breakdown among materials and manpower shows that desalination plant turnkey costs are also heavily affected by the price of materials. Thermal desalination technology in particular make large use of nickel alloyed components for the heat transfer tubes and are therefore more sensible to metal cost escalations.

However if we look at the structure of a desalination project it is clear that included in the scope of supply there are several auxiliary components which contribute to the cost of the project and may differ from case to case.

A typical Desalination plant package is shown as indicated in the flow schemes below. The presence and the extension of the auxiliary packages becomes an important component affecting the pricing of the project.

**Incremental budgeting**

Incremental budgeting is often used for budgetary proposals or during the project feasibility stage. This technique is based on the cost assessment of a previous “as built” project as a base of developing the budget for a new project. The incremental budgeting technique concentrates on marginal incremental changes from one project to the other. Variations in the capacity and technical specifications between the project to be budgeted and the “as built” project are evaluated as incremental plus or minus cost factors.

![Figure 1: Thermal desalination interface scheme](image-url)
Figure 2: RO desalination interface scheme

This technique tends to be conservative but is often used when for order repetitions in the case desalination plants are similar to the original specification. Furthermore although incremental budgeting is relatively simple and quick to adopt it has the drawback to be backward looking.

In a market like desalination, subject to sharp and rapid technological changes and consequent price adjustment incremental budgeting technique may often lead to over pricing.

One of the first approaches in budgeting turnkey costs for desalination plants is to establish benchmarks based on market statistical data. After these benchmarks are established the expected turnkey costs are evaluated more precisely based on the difference in scope of works from the benchmark projects.

Table 1 below indicates the contracted price and the price per gallon for some of the major installation recently awarded in the Gulf.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Unit capacity</th>
<th>Year</th>
<th>No. of units</th>
<th>Specific cost</th>
<th>Delivery Times</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIGD</td>
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<td>2</td>
<td>6.4</td>
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<td>MED</td>
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<td>2001</td>
<td>4</td>
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</tr>
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<td>1</td>
<td>4.8</td>
<td>14</td>
<td>MSF</td>
</tr>
<tr>
<td>Jebel Ali K1</td>
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<td>1999</td>
<td>2</td>
<td>4.9</td>
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</tr>
<tr>
<td>Jebel Ali K2</td>
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<td>2001</td>
<td>4</td>
<td>4.9</td>
<td>24</td>
<td>MSF</td>
</tr>
<tr>
<td>Umm Al Nar B *</td>
<td>12</td>
<td>2000</td>
<td>5</td>
<td>8</td>
<td>12</td>
<td>MSF</td>
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<tr>
<td>Mirfa B *</td>
<td>7.5</td>
<td>2000</td>
<td>3</td>
<td>7.6</td>
<td>12</td>
<td>MSF</td>
</tr>
<tr>
<td>Shuweiat</td>
<td>16.7</td>
<td>2002</td>
<td>6</td>
<td>5.2</td>
<td>18</td>
<td>MSF</td>
</tr>
<tr>
<td>Layyah (MED)</td>
<td>5</td>
<td>1999</td>
<td>2</td>
<td>4.5</td>
<td>18</td>
<td>MED</td>
</tr>
<tr>
<td>Fujeirah</td>
<td></td>
<td>2002</td>
<td></td>
<td>4 MSF+15 RO</td>
<td></td>
<td>Hybrid</td>
</tr>
<tr>
<td>Umm Al Nar IWPP</td>
<td>12.5</td>
<td>2003</td>
<td>2</td>
<td>4.6</td>
<td>18</td>
<td>MSF</td>
</tr>
<tr>
<td>Taweeelah C</td>
<td></td>
<td>2003</td>
<td>16</td>
<td>4.5</td>
<td>21</td>
<td>RO</td>
</tr>
</tbody>
</table>

* Auxiliary boilers and seawater intake included in the price
However it is quite difficult to work out a precise statistical data from the market sales prices incrementing the contract price from all the additional scope to the evaporator island. Therefore data on statistical market price must be analyzed against the full contract scope of work in order to obtain valid benchmarks.

Typical BOP items, which may be included or excluded from the contract package, are the following:

1. Remineralisation
2. SW intake
3. Outfall channel
4. Potable water tanks
5. Potable water pumping station
6. Auxiliary boiler
7. Heat recovery steam generator
8. Gas reducing. Station
9. Town water tanks
10. Steam reducing station
11. Steam supply system

However despite the market price indication with this type of budgeting approach great consideration should be paid to the operational experience of the plant after installation. In particular sometimes the market benchmarks have shown un-realistic prices for plants that in the real operation have undergone severe operational shortcomings.

In this respect therefore some projects, which have had a poor performance during commissioning, will provide useful information for the planner in the next budgeting stage.

**Zero base budgeting**

The zero base budgeting implies the preparation of a budget from a zero base. This is the purest form of budgeting and is often used after the Tender phase to prepare the working budget of a turnkey contract.

Zero base budgeting implies to define each item included in the scope of work. Subsequently all items and work packages need to be ranked and priced.

In addition to the identification of all materials resources necessary to carry out a project Zero base budgeting impose the evaluation of the labour needed for the construction of a desalination plant and the sequence of procurement, engineering and commissioning.

This technique has the great advantage to be giving a deeper understanding of the cost factors of a desalination plant and the possibility to evaluate alternative.

It is more forward looking than the incremental budgeting technique however requires a detailed understanding of the cost factor for a desalination plant.

According to the zero base budgeting the items that compose a thermal desalination plant can be grouped in the following categories:

- Mechanical equipment and piping
- Electrical equipment
- Instrumentation and control
- Civil items
The works that are necessary to realise a thermal desalination plant can be grouped in the following categories:

- Site erection
- Workshop Prefabrication
- Civil works

Each item is quantified and priced separately.

**Conclusions: Incremental versus Zero base budgeting**

Both incremental budgeting and zero base budgeting techniques can be adopted to forecast turnkey and operating costs in desalination.

Each technique has its own particular advantages and disadvantages. These are schematically indicated in table 2 below:

<table>
<thead>
<tr>
<th>Technique</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incremental budgeting</strong></td>
<td>Fast</td>
<td>Backward looking</td>
</tr>
<tr>
<td></td>
<td>Takes into account</td>
<td>May be not accurate</td>
</tr>
<tr>
<td></td>
<td>operational experience</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Does not require a high</td>
<td>Requires accurate statistical</td>
</tr>
<tr>
<td></td>
<td>engineering input</td>
<td>information</td>
</tr>
<tr>
<td><strong>Zero base budgeting</strong></td>
<td>Forward looking</td>
<td>Slow</td>
</tr>
<tr>
<td></td>
<td>Accurate</td>
<td>Requires accurate pricing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>levels</td>
</tr>
</tbody>
</table>

Incremental budgeting tends to be backward looking and therefore not suitable for a rapidly changing technology like desalination.

Technological changes and innovations can be easily taken into account with the zero base budgeting technique which however in order to be more effective requires a very solid engineering structure and longer time.

**Literature**