COST-EFFECTIVENESS ANALYSIS FOR WATER MANAGEMENT IN THE ISLAND OF PAROS, GREECE

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EXTENDED ABSTRACT

The present work addresses the question of developing a more efficient and least cost water resources management in arid or semiarid regions. Decision making processes in these circumstances is subject to tight budgetary constraints that reduce the number of the available solutions.

A methodology is developed and is implemented in a structured procedure of well defined steps in the island of Paros, Greece. Supply side management options proposed by local stakeholders and published studies are evaluated, and the incremental cost effective curve is derived. The results indicate that new drills and a new desalination plant can meet the current and near future water demand.

Keywords: Cost-Effectiveness Analysis, Incremental Cost Curve, Water resources management.

1 INTRODUCTION

In arid and semiarid regions the limited water resources, the drastic increase in water demand and the lack of planned and controlled use and distribution create deficiency problems that affect water supply. Water resources planning activities have been established in response to the serious problems that have arisen, yet the failures of meeting the planning objectives show that there is a need to go beyond the usual techniques which are based upon the costs and benefits of the proposed actions.

Decision makers in these regions, who are faced with the issue of satisfying demand under limited supply, are familiar with the range of the available solutions. However, what so far has not been available to them is a method for determining the optimal interventions within a complex range, and solutions that are not only effective in meeting demand but are also economically efficient. Optimization models might provide such answers; yet the main approach types, hydrology – inferred or economic optimization [1], due to their complexity and data requirements are impractical to decision makers. Modeling and consideration of criteria, such as equity, environmental quality and social value of water use is not always straightforward and most of the times adaptation to the particular case study is a prerequisite.

The scope of the present work is to determine a systematic, easy to use methodology that can provide guidance to water resources decision makers in selecting the most economically efficient measures for addressing current and future water needs. Towards this end, two methods are broadly used for investment evaluation: Cost Benefit Analysis (CBA) and Cost Effectiveness Analysis (CEA).

Many researchers [2, 3] consider CBA inappropriate for the evaluation of investments that generate social or environmental externalities. The main difficulties and objections lie in the assignment of monetary values to benefits, a procedure which is usually biased and time-consuming and the fact that the method reduces the multiplicity of criteria and objectives underlying decision making to a single monetary criterion, namely the net present value of the investment.

On the other hand CEA is a method that can provide value added information to aid decision-makers [4]. The outcome is a set of solutions achieving the stated objectives at the minimum cost through a relatively easy standard procedure, which determines whether the additional cost for a more effective solution corresponds to the gain in effectiveness. The method is appropriate in cases where the monetary value of the benefits provided by the alternative solutions is insufficient or impractical [5]. The output of alternative solutions is usually a single, quantified physical measure [6]. Outputs can also be environmental or social indicators; the term “output” does not indicate “impact”, but the desired and intended effects of solutions.

The use of CEA, as a means for selecting measures to achieve the Directive environmental objectives, is suggested by the Working Group on Economic Issues of the EU Water Framework Directive in their Guidance Document [4]. In particular it is suggested that CEA should be used for:

- Making judgments about the most cost effective program of measures that could be implemented to bridge a potential gap in water status between a baseline scenario and the objectives set by the water authorities.
- Assessing the cost-effectiveness of alternative measures in order to estimate whether those programs of measures are disproportionately costly or expensive.

The Guidance Document does not clearly identify the specific output to be used in the analysis or provide specific guidance on using CEA in the assessment of measures in the water sector. The present work introduces a methodology on the basis of the recommendations of the Working Group, and testing its applicability in a Case Study.

The selected output was the percentage of shortage coverage that can be achieved through the implementation of a series of measures. The approach takes into account the parameter that indicated solutions should be supplementary. The incremental cost of each successive solution is being determined and can be used the formulation of a long-term water management plan.

The method is applied to the current situation in the Greek island of Paros. Using data and a selection of supply enhancement measures provided by the Water Utility of Paros, the analysis identifies a set of cost effective solutions that can cover the current and forecasted shortage in a ten years horizon.

2 METHODOLOGY

In the present work the output of the cost effectiveness analysis is defined as the ratio of additional water production versus the current deficit. The effectiveness of the various water management interventions is estimated on the basis of nine standard steps, grouped in four tasks, and which are presented in Figure 1, [8].

The 1st Task concerns the formulation of alternative combinations between the actions proposed. This consists of the examination of the compatibility of actions, the formulation of the exhaustive set of alternative combinations, and the estimation of the annual water production and annualized cost for each measure and combination.

As a 2nd Task the cost-effectiveness analysis is performed. This procedure includes the identification and elimination of combinations that are economically inefficient or ineffective. Inefficient are solutions that for the same water production have greater cost than others, while ineffective are those that for less water production present same or higher costs.

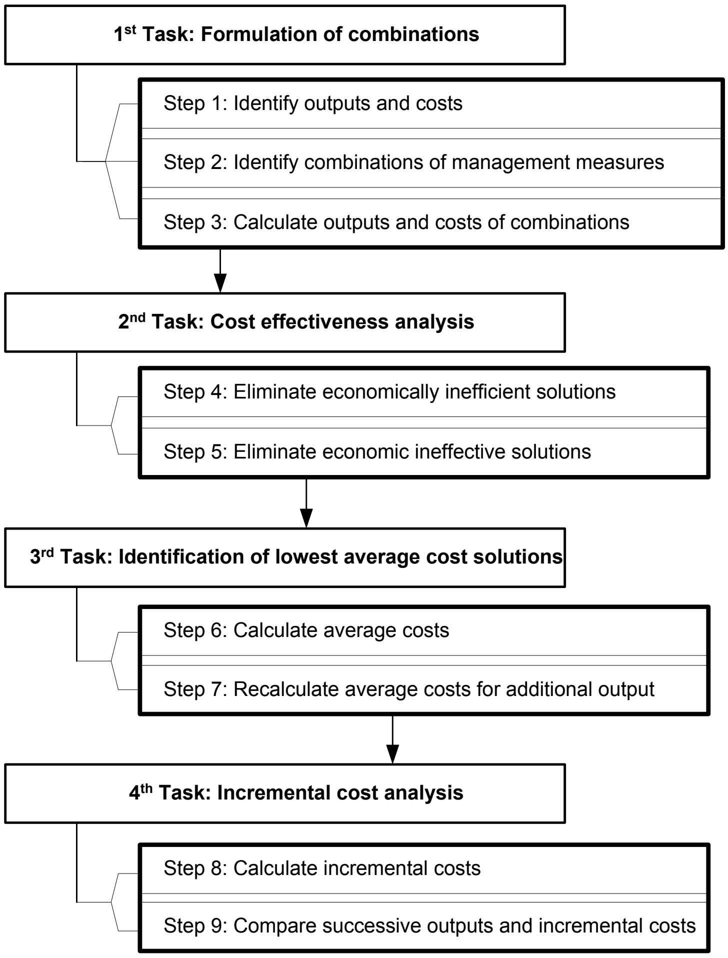

Figure 1: Steps of cost effectiveness analysis

The 3rd Task involves the calculation of the average costs of the cost effective combinations, identifying the lowest average cost combination. The average cost of the remaining combinations of measures is calculated by dividing the cost by the output of each combination (Step 6). For Step 7, the previous step's lowest average cost level of water production becomes the first level for calculation. The calculation uses the additional costs and additional outputs of the remaining combinations to identify the average costs for additional output. The combination with the lowest average cost is selected and the recalculation continues with the remaining levels of output. Subsequently, by answering the question: "Of the remaining levels of output, which level has the lowest average cost for additional output?" the solutions with output less than that of the lowest average cost level are eliminated and the recalculation continues with solutions with output greater than the lowest average cost solution. Recalculations are made until the final level of output, namely the solution with the greatest production, is identified as the lowest average cost solution.

The 4th Task is the development of the Incremental Cost Curve; incremental cost is the difference in cost between two solutions divided by the difference in output between the same two solutions. The final step of the method is the comparison of the successive solutions and their incremental costs, in order to depict whether the next level of economically effective water production is worth the additional monetary cost.

3 CASE STUDY

The island of Paros is a typical case where the water shortage occurs mainly during summer months. Tourism and irrigation demand reach their peak during this time creating conflicts between uses. Existing infrastructure is not adequate and therefore new water management responses to cover the shortage are necessary.

The current water budget is formulated as follows:

- Water demand for the island in 2001 was estimated at 1,790,000 m^3.
- Water production is equal to 1,265,000 m^3/yr.
- There is a water deficit of 525,000 m^3/yr.
- Irrigation and animal breeding activities rely mostly on groundwater through several private wells and boreholes. There are no records on the water consumption, but assuming that approximately 200 m^3/yr are needed for a 1000 m^2 area, it is estimated that annual demand is equal to 1,000,000 m^3.
- Almost 40% of the annual water production is consumed during July and August, the peak tourist season.
- 58 drills are in use, which cover 95% of the island needs in drinking water, with average daily withdrawals of 4,000 m^3 in the winter and 12,000 m^3 in the summer, reaching 14,500 m^3 during the peak period in mid August.
- One desalination plant with capacity 1,450 m^3/day is in trial operation, using brackish water from a spring with a relatively stable and substantial supply of 2,000 m^3/day throughout the year.
- One small interception and storage dam has been constructed, but is not yet operational.
- Seven interception walls have been constructed along a torrential current in order to decelerate run-off and to enhance the aquifer.
- Finally, there are some private initiatives for the purchase of small tanks (from 2 m^3 to 50 m^3), mainly by the owners of lodgings in order to ensure adequate supply during the peak season.

Demand projections are based on the trend of the population increase during the last two decades. Permanent population growth rate is estimated at 1.5% annually. Assuming a tourism growth of 3% up to 2010 and of 1.5% thereafter, it is estimated that water demand in the island in 2010 will escalate at 2,175,000 m^3 and at 2,340,000 m^3 in 2015 [9].

Table 1 presents the set of water supply measures that are feasible and acceptable after consultation with the island's stakeholders, the administrative authorities (Municipality, Water Utility) and the end users (farmers, lodging owners). Meetings with representatives of these stakeholders took place in situ and discussions were carried out regarding their professional and personal opinion on the available water management options.

The technical details of these measures, such as water supply and capacity of the new drills, capacity and operation of new desalination plants and storage capacity the reservoirs are based upon information from the records of the Water Utility of Paros [10] or proposed management plans from previous studies [11, 12]. The cost of the proposed measures is equal to the annual cost, namely the sum of annual depreciation of capital cost and the annual operation and maintenance costs.

Table 1: Proposed water management interventions

Intervention	Technical details	Annual water production (m^3)	Annual cost (€)
Drills	2 Drills (20 m^3/h, 14 h/d all year operation)	200,000	52,000
	4 Drills (20 m^3/h, 14 h/d all year operation)	400,000	104,000
	6 Drills (20 m^3/h, 14 h/d all year operation)	600,000	156,000
Desalination	Desalination Plant (1,200 m^3/d, 170 d/yr operation)	205,000	107,000
	Desalination Plant (1,400 m^3/d, 170 d/yr operation)	238,000	119,000
	Desalination Plant (1,600 m^3/d, 170 d/yr operation)	272,000	131,000
Small Dams / Reservoirs	Reservoir (150,000 m^3, 80% exploitation)	120,000	112,000
	Reservoir (180,000 m^3, 80% exploitation)	150,000	124,000
Water Hauling	Use of tankers	9,000	63,000
Network Improvement	Loss Reduction by 10%	347,000	145,000
	Loss Reduction by 15%	424,000	285,000

Starting the analysis, the formulated possible and acceptable combinations are equal to 288. The outputs and costs of all the solutions are presented in Figure 2.

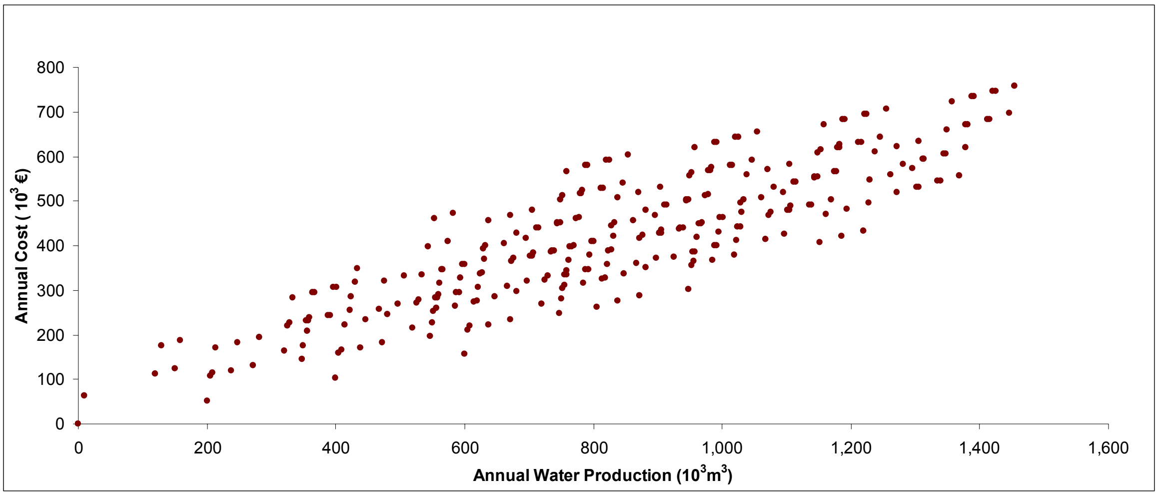

Figure 2: Estimated outputs and costs of all solutions

Eliminating the solutions that are economically inefficient or ineffective, 30 solutions emerged, presented in Figure 3.

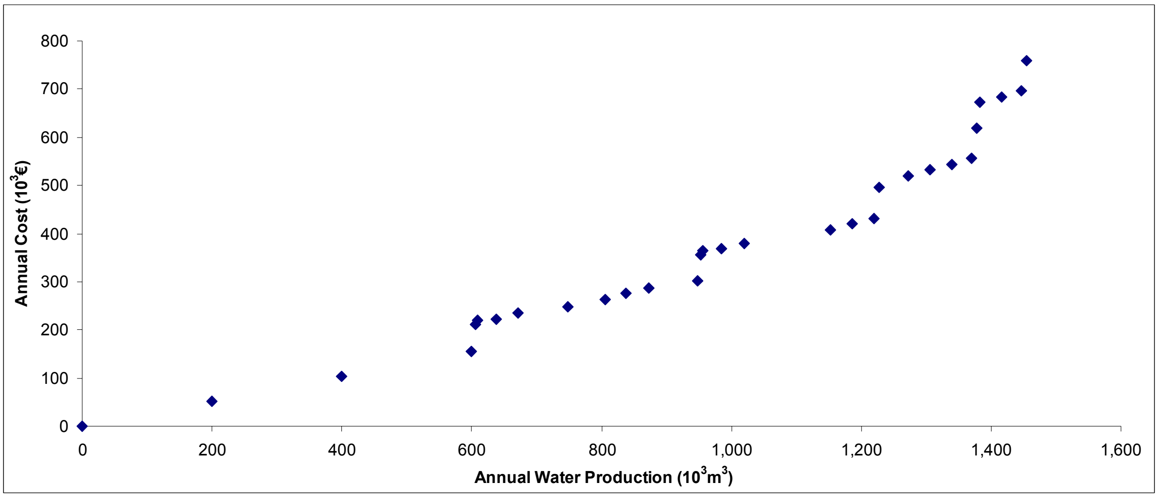

Figure 3: Cost effective and least cost solutions

The average costs of the remaining solutions were estimated and the solutions with lowest average cost for additional output were identified. The combinations of water management measures that are identified as cost effective are presented in Table 2.

Table 2: Cost effective solutions

Solution	Description
1	6 Drills (20 m^3/h, 14 h/d all year operation)
2	6 Drills (20 m^3/h, 14 h/d all year operation) Loss Reduction by 10%
3	6 Drills (20 m^3/h, 14 h/d all year operation) Loss Reduction by 10% Desalination Plant (1,600 m^3/d, 170 d/yr operation)
4	6 Drills (20 m^3/h, 14 h/d all year operation) Loss Reduction by 10% Desalination Plant (1,600 m^3/d, 170 d/yr operation) Reservoir (180,000 m^3, 80% exploitation)
5	6 Drills (20 m^3/h, 14 h/d all year operation) Loss Reduction by 10% Desalination Plant (1,600 m^3/d, 170 d/yr operation) Reservoir (180,000 m^3, 80% exploitation) Further Loss Reduction by 5%

Figure 4 presents the solutions identified in the context of all solutions that have been examined.

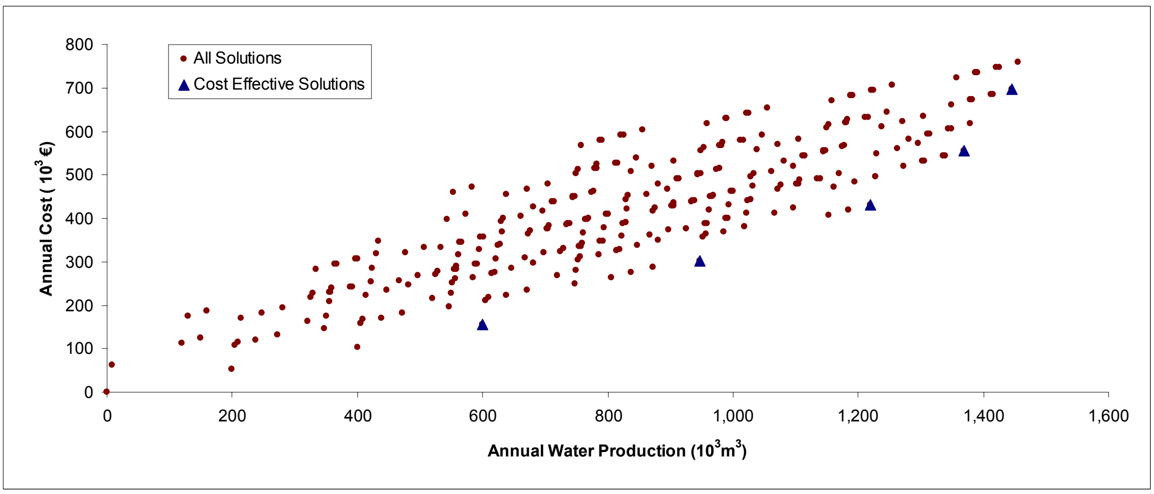

Figure 4: All solutions and cost effective solutions

The Incremental Cost Curve for the cost effective solutions is depicted in Figure 5. For meeting current water needs, interventions that focus on existing infrastructure (external network leakage control) and the commonly used practice of groundwater exploitation are preferred. Higher production levels require the construction of a desalination plant, which is preferable to the construction of a reservoir. For meeting demand requirements in the year 2010 significant structural interventions should be made, such as surface storage reservoir construction and major network improvements. It should be noted that water hauling is not included in any of the cost effective solutions as its cost is relatively high for the amount of water that it can provide.

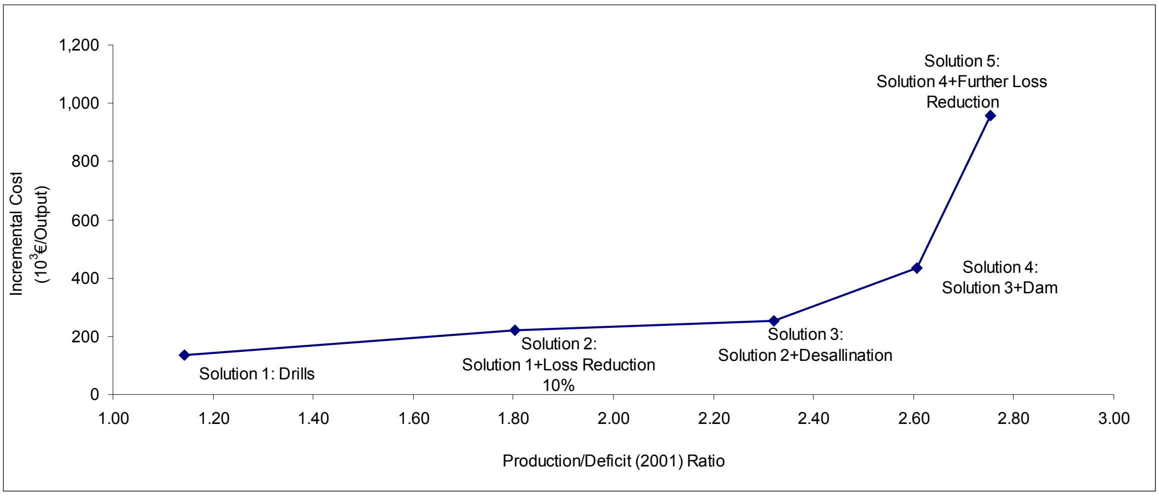

Figure 5: Incremental cost curve

Regarding anticipated demand for the next years, the proposed solutions can be implemented successively to meet the estimated increase. Figure 6 presents the annual water production that can be achieved if a water management plan which follows the suggested solutions is applied. The appropriate year for the implementation of each measure takes into account the annual water requirements and seasonal variation, ensuring that peak water demand is adequately met.

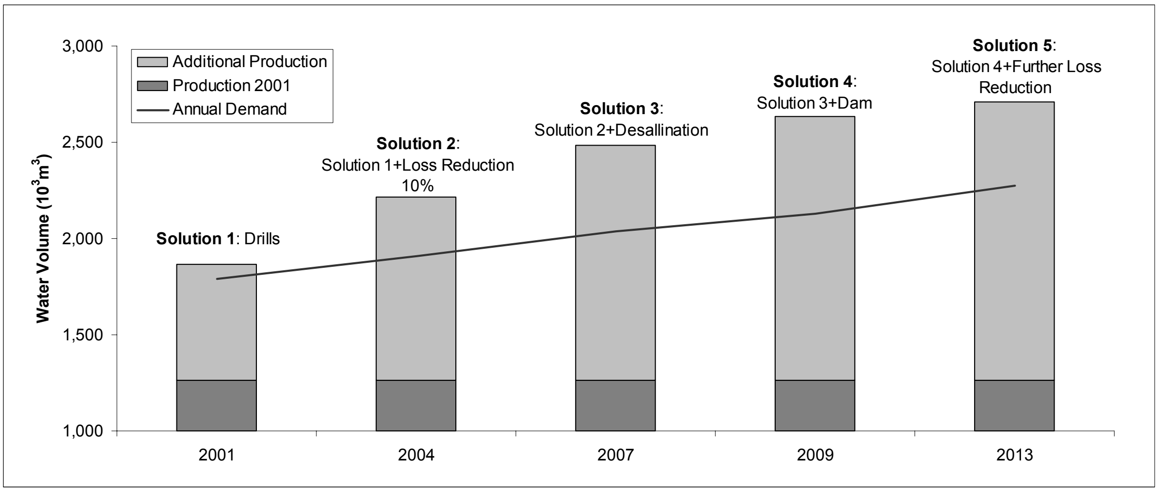

Figure 6: Demand increase and time scheduling of proposed solutions

Figure 7 presents the additional annual cost of the system after the implementation of the management action plan. Assuming a discount rate of 4%, the average water cost for the period 2001-2013 is estimated at € 400,000.

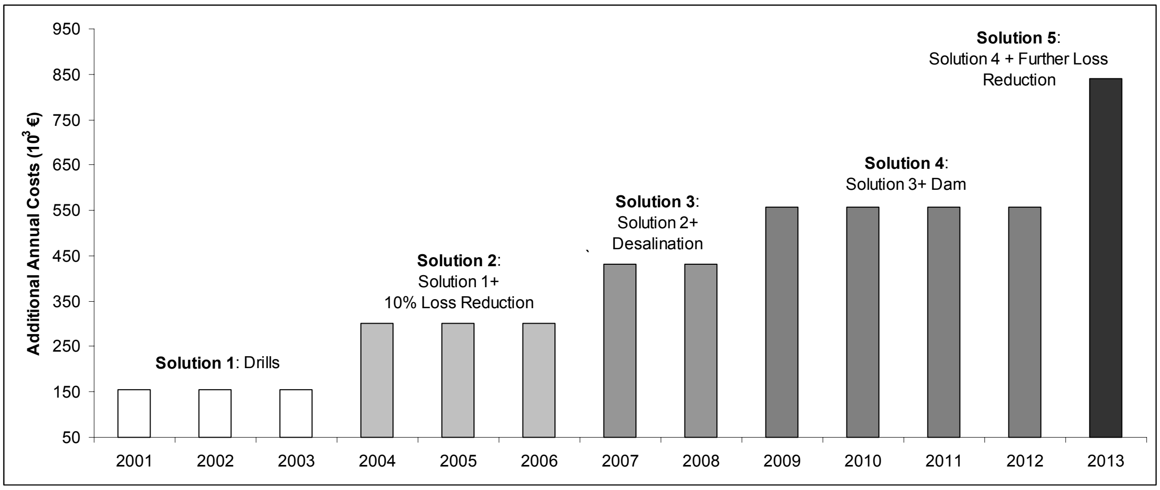

Figure 7: Additional water cost after measure implementation

4 CONCLUSIONS

The cost-effectiveness analysis shows that current and future water deficit in the island of Paros can be covered efficiently through supply side interventions, taking also into consideration the size of necessary investments in the sector. The evaluation of alternative management plans and the scheduling of their implementation can be considered as a first step towards the formulation of an economically efficient and effective water management plan.

Finally, the presented approach provides a coherent and easy-to-use methodology for assessing the efficiency of water management interventions. The selected indicator is one that can address the main water management problems in the island of Paros. However the approach can readily be adapted according to the objectives of the actions considered; ecological, economic or social indicators can be included either as single units or as the aggregated result of a multi-criteria analysis.

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