EVALUATION OF ALTERNATIVE SETS OF DOMESTIC WATER SAVING TECHNOLOGIES USING A COMBINATION OF COST BENEFIT ANALYSIS AND MULTI CRITERIA ANALYSIS

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ABSTRACT

This paper presents a composite evaluation approach for alternative sets of domestic water saving technologies that can be installed in a new residence or retrofitted in an existing one. The results of the application of this evaluation approach for various scenarios are also presented and discussed with regards to their financial and sustainability performance.

The evaluation is performed by combining Financial Cost – Benefit Analysis (FCBA) with Multi - Criteria Analysis (MCA). In this respect, we integrate within the evaluation framework the financial household-centric approach of FCBA with the sustainability – related insights of MCA. The latter are the result of non-monetary environmental, public health, technological and social assessments which “add to” the financial assessment provided by FCBA, without altering or interfering with its results. As such, we broaden the scope of analysis, acknowledging the complexity of an appraisal for which the FCBA result is not sufficient to inform the actual decision. This makes the evaluation approach suitable for a wider range of decision-makers and stakeholders in a policy-making process that can identify variable sets of objectives (beyond the financial feasibility for the homeowner) against which the various investment options are evaluated.

The unit of evaluation is the set of water-saving Fixtures, Appliances and Systems (FAS) installed in a single household. Water-saving fixtures include efficient bath and kitchen faucets, showers and toilet cisterns while systems include decentralized technologies for the exploitation of grey-water, wastewater and rainwater. The decentralized systems evaluated, are greywater treatment systems using membrane bioreactor technology (MBR). The scenarios constructed involved the installation of different sets of water-saving fixtures, appliances and systems for varying residence types.

Assessment of the results revealed significant financial gains deriving from the investment in simple water saving fixtures and major environmental benefits associated with the re-use of a valuable natural resource like water. The application of advanced decentralized technologies treating grey and/or wastewater, although it appears to be not viable financially, apart from some special scenarios in residences with many members, is linked with expanded re-use options and hidden benefits are revealed like increased social acceptance for advanced and robust technologies.

Keywords: Water Savings, Financial Cost – Benefit Analysis, Multi - Criteria Analysis

1. Introduction

Management of water demand on the household level through the use of water-efficient fixtures/appliances and water re-use/recycle technologies, like greywater recycling and rainwater harvesting systems, can play a crucial role in tackling the sustainability challenge in the water sector. Enhancing the limited deployment of such equipment and technologies in the Mediterranean and Greek urban centres is of major importance, given also the additional risk of decreased availability and quality of fresh water due to flooding and droughts. In this paper, we primarily evaluate the financial attractiveness of the investment in various sets of fixtures, appliances and systems (FAS) by modeling the financial life-cycle cost (FCBA) of those sets. This facilitates the homeowner's decision –making by estimating the payback period, the present value of the entire investment and its cost-benefit ratio. We add to this evaluation an estimated indication of the sustainability performance of the various sets of installed FATs in the household, according to four key criteria (MCA). As such, we provide a comprehensive composite evaluation on the household level with an increased added value to decision-making. The description of the FCBA and MCA elements of the evaluation are described in the following parts of the paper. Then, the evaluation results of three indicative scenarios are illustrated and shortly discussed. In the final part of the paper a number of general concluding remarks are presented.

2. Financial cost – benefit analysis

The model for the FCBA is grounded in the financial evaluation of the Life Cycle Cost (LCC) of the FAS, taking into account all relevant financial costs over their life-cycle (from supply to disposal) and the financial costs and gains arising from changes in water and energy consumption on the household level. The estimation of the relative costs and gains, arising either directly from the assets themselves (such as supply, operation, maintenance etc) or from changes in water and energy bills, is based on the comparison in financial terms between a "Project Scenario" and a "Do Nothing Scenario". In the "Project Scenario" the user/homeowner invests in a set of water-saving FAS and installs them in a new or existing house while in the "Do Nothing Scenario" the user/homeowner does not install any new water-efficient fixtures and appliances nor any recovery technologies. Cash flows (outflows / inflows) for the user / homeowner are expressed on an annual basis for up to 30 years and the main model results derive from calculations on the yearly cash-flows and their present values.

3. Sustainability assessment

The sustainability assessment is based on four key criteria, namely the environmental, public health, social and technological. Each of those criteria is based on a number of indicators and more precisely on the change of the quantitative or qualitative values of those selected indicators when comparing the "Project Scenario" with the "Do Nothing Scenario". The indicators selected to capture the environmental dimension of the sustainability assessment include potential for restricted reuse of treated grey water, percentage of nutrients and organic load that can be recycled through irrigation, energy and chemicals consumption, sludge production and water savings achieved. Public health indicators relate to the quality of the final effluent and the relevant risks while technological indicators relate to the adaptability in different hydraulic and pollution fluctuations, lifetime of the equipment, maintenance requirements and their market penetration/availability. The social dimension is appraised mainly by indicators of the public acceptance / familiarity with the FAS but also with the levels of nuisance.

4. Application of the composite evaluation

The following three indicative scenarios have been evaluated using the described composite evaluation. For each one of them we present the basic evaluation results and a number of "Break – Even" versions, in terms of financial attractiveness.

Scenario 1

This first application of the evaluation concerns replacement, in the middle of their service-life, in a household of 4 members, of conventional water-saving fixtures and appliances with water-efficient ones (the bathroom faucet, the showerhead, the kitchen tap, the toilet cistern, the washing machine and the dish washer). The house is connected to the sewage network, leading to a central wastewater treatment plant (WWTPs)[1] incorporating secondary biological treatment followed by disinfection. The house is a permanent residence and the appraisal period is ten years.

This is a very attractive scenario in financial terms with a payback period for the homeowner of less than 2 years and a Net Present Value (NPV) of the investment of more than 4.000 euro. Moreover, the MCA has revealed a substantial improvement in all sustainability metrics. The investment can also be regarded as marginally attractive even in the case of a household of 1 person. In the version of Scenario 1 where the conventional washing machine and dish washer are not replaced, the investment is much more attractive having a payback period of almost 6 months. In this version of Scenario 1, the investment is marginally attractive if the four occupants of the household live in the house only 36 days on average per year.

Scenario 2

This application of the composite evaluation concerns the installation, in a new permanent residence of 4 members, of water-efficient fixtures and appliances (bathroom faucet, showerhead, kitchen tap, toilet cistern, washing machine and dish washer) instead of conventional ones and an MBR (Membrane Biological Reactors) greywater treatment system which collects greywater from the bathroom faucet sink and the shower. The processed greywater can be used for the irrigation of a 50 m^2 garden and the toilet. The house is connected to the sewage network. Treatment of the remaining 'black water' is conducted in a central WWTP incorporating secondary biological treatment followed by disinfection.

This is also an attractive scenario in financial terms with a payback period for the homeowner of about 7 years and an NPV of the investment of more than 1.300 euro. All sustainability metrics present a great improvement of more than 70 points except the technological one which is around 50 points. The investment is much more attractive in the case of a household of 6 persons. In this version of scenario 2, the homeowner's discounted payback period is at the level of three years and the NPV for ten years is more than 9.000 euro. If a household has 2 members, a garden of 172 square meters or more is needed for the investment to have a positive NPV while in central case of a 4 members' household, the garden need to be 27 square meters of more. All versions of Scenario 2, present equally high scores in their sustainability metrics besides the case in which the household members are 2. In this case the environmental score is about 7% lower than the central case of 4 members.

Scenario 3

The third application of the evaluation concerns the installation, in a new permanent residence of 4 members, of conventional water use fixtures and appliances (bathroom faucet, showerhead, kitchen tap, toilet cistern, washing machine and dish washer) and an MBR (Membrane Biological Reactors) greywater treatment system which collects greywater from the bathroom faucet sink and the shower. The processed greywater can be used for the irrigation of a 50 m2 garden and the toilet. The house is connected to the sewage network and the treatment of the remaining 'black water' is conducted in a central WWTP incorporating secondary biological treatment followed by disinfection.

Even though it is not a financially attractive scenario, the sustainability metrics present very high scores especially in the technological aspects. Remarkably, the investment becomes very attractive even in the case in which there are no irrigation needs (no garden) if the household has 6 instead of 4 members and a water- efficient showerhead takes the place of the conventional one. Also, the investment is marginally attractive (NPV equal to 0 in a ten years' period) with a 4 members' household, a garden of 57 square meters (instead of 50 square meters) and a water- efficient showerhead taking the place of the conventional one.

[1] According to common practice in central WWTPs in Greece, it is assumed that a small fraction of treated wastewater (in the order of 10%) is considered to be re-used for process water and irrigation purposes.

Scenario	Water Saved (%)	Yearly Water Savings (m3)	Yearly water Savings due to GW system (m3)	Processed Greywater use in the Toilet	Processed Greywater use for Irrigation	Yearly Energy Savings (Kwh)	Total Acquisition Cost (€)	Discounted Payback Period (years)	Net Present Value (€)	Internal Rate of Return (IRR)	Environmental Rating	Public Health Rating	Social Rating	Technology Rating
1	50,3	151				2.965	1.496	1,84	4.377	>100%	46,2	42,9	58,3	58,3
2	58,4	229	78	43	35	2.809	7.070	7,08	1.344	17,2%	76,6	78,6	87,5	54,2
3	19,8	78	78	43	35	-156	5.574	>>	-3.626	-17,8%	56,8	78,6	66,7	91,7

Table 1: Results of the composite evaluation of the 3 scenarios

5. Concluding remarks

The FCBA of water-saving FAS on the household level has revealed that an investment in advanced domestic greywater treatment system can be financial attractive for the homeowner if combined with an investment in water-saving fixtures. The replacement of the conventional showerhead with water saving one is in many cases enough. Also, investing in an advanced domestic greywater treatment system can have financial benefits if the household has many members or large gardens requiring watering. The great financial benefits of investing just in water – saving fixtures and appliances is also an additional finding.

All scenarios exhibit significantly improved environmental performance compared to the “Do Nothing Scenario”. The scenarios of adopting a recovery technology (scenario 3) or a set of water saving fixtures and appliances (scenario 1) have almost equal environmental scores. As such, It can be said that the environmental advantage of water saving is balanced by the benefits of re-use of grey water. The second scenario has the highest environmental score since it combines the benefits of using a recovery system with the application of water-efficient fixtures and appliances. The use of an advanced treatment technology incorporating membranes allows for the treated grey water to be recycled in the house with minimum use of chemicals and low sludge production. The version of the second scenario with less household members has a slightly lower environmental score. This is because higher grey water production leads to higher reuse of treated wastewater and nutrient and organic matter recycling. The main downside of this recovery technology is the relatively high energy consumption, which, however, in the second scenario is greatly outweighed by the energy saving that derive from the use of less hot water due to the water efficient fixtures.

Public health scores justify the use of an advanced treatment system (scenario 2 and 3) mainly due to the production of high quality effluent which minimizes any risk for public health impacts of onsite wastewater systems. On the other hand, conventional water use fixtures outweigh the water-saving fixtures present in terms of market penetration and availability and this is a reason why scenario 3 has a higher technological score. The application of small private greywater treatment systems is typically followed by reduced noise and odor emissions which enhances social acceptance of such systems. Also, the use of an advanced technology, such as a membrane system, provides a sense of security and robustness. Furthermore, the application of water saving fixtures provides very little perception of change in the flow of the water supply, making the products easier acceptable by the public.

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