1. INTRODUCTION

The Republic of Cyprus is at a critical stage in the evolution of its energy sector and more specifically in meeting the renewable energy and climate change targets set by the EU. The flexibility and diverseness of renewable energy sources, as well as the rising cost-effectiveness of the electricity market, have driven renewable energy to the forefront of the European agenda for the provision of electricity security. Solid waste represents a potential indigenous fuel for Cyprus that may be harnessed for energy recovery, but this resource has not yet been exploited locally for this purpose.

2. MULTI-CRITERIA ANALYSIS (MCA)

MCA assists in complex-decision-making situations and allows the incorporation of conflicting criteria in incommensurable units (Kylii et al., 2014). Two MCA assessments were carried out using the PROMETHEE method:

1. MCA 1: Identifying the optimum renewable energy technology for electricity generation for deployment, noting the performance from Energy from Waste (EfW) systems
2. MCA 2: Identifying the contribution from the solid waste management sector

3. PROMETHEE METHOD

Step 1: Determination of the deviations according to pair-wise comparisons

\[ d_{ij}(a,b) = g_j(a) - g_j(b) \]  
Where \( d_{ij}(a,b) \) represents the difference between the evaluations of a and b on each criterion

Step 2: Application of the preference function

\[ P_{ij}(a,b) = F_{ij}(d_{ij}(a,b)) = \begin{cases} 1 & \text{if } d_{ij}(a,b) > 0 \\ 0 & \text{if } d_{ij}(a,b) = 0 \\ -1 & \text{if } d_{ij}(a,b) < 0 \end{cases} \]  
Where \( P_{ij}(a,b) \) represents the preference between alternative a in respect of b, as a function of \( d_{ij}(a,b) \)

Step 3: Calculation of a global preference index \( \Pi \) for each pair of alternatives. This expresses the degree to which one action is preferred to another.

\[ \Pi(a,b) = \sum_{i=1}^{n} P_{ij}(a,b)w_i \]  
Where the preference \( P_{ij}(a,b) \) of a over b \( [0,1] \) is defined as the weighted sum \( P_{ij}(a,b) \) for each criterion, \( w_i \) represents the weight associated with the \( i \)th criterion

Step 4: Calculation of outranking flows, PROMETHEE I Partial Ranking system

\[ \phi^+(a) = \frac{1}{n} \sum_{b \neq a} \Pi(a,b) \]  
\[ \phi^-(a) = \frac{1}{n} \sum_{b \neq a} \Pi(b,a) \]  
Where \( \phi^+(a) \) and \( \phi^-(a) \) are the positive and negative outranking flows of alternative a

Step 5: Calculation of the net outranking flow, PROMETHEE II Complete Ranking system

\[ \phi(a) = \phi^+(a) - \phi^-(a) \]  
Where \( \phi(a) \) denotes the net outranking flow for each alternative

4. OPTIONS

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Figure 2: Flow chart of different options assessed

5. CRITERIA BREAKDOWN

Table 1: Criteria breakdown – Renewable Energy Options

6. RESULTS

The results from MCA 1 yield Solar PV in 1st place with \( \phi = 0.234 \). MCA 2 results are not illustrated here.

Solar PV
- **PROS**: High irradiation potential, high social acceptance & gross positive net flow contribution from environmental criteria
- **CONS**: Variable source, thus low reliability

Energy from Waste
- **PROS**: Minimises the diversion of biodegradable waste from landfills and high reliability of supply
- **CONS**: Greenhouse gas emissions & high visual impacts

RDF co-combustion in cement kiln
- **PROS**: Low capital costs and land requirements due to the presence of the Vassiliko Cement kiln. High local marketability and export potential of cement
- **CONS**: High specificity of processed waste for co-combustion, relatively high transport demand which will be required to take the RDF to the facility, and inexist potential for energy generation

7. REMOVAL OF UNCERTAINTY

The methods used to remove uncertainty from the MCA assessment were:

- Facilitating stake-holder participation and collaborative decision-making by conducting personal interviews in Cyprus
- Using generalised criterion functions in PROMETHEE to describe pairwise evaluation differences
- Using a sensitivity analysis to assess the uncertainty in the weighting of criteria

8. SENSITIVITY ANALYSIS

A sensitivity analysis was carried out to test the robustness of the results. The sensitivity analysis was performed by modifying the weight distribution of criteria and providing weight stability intervals. The analysis showed:

- Solar PV was consistently identified as the optimum renewable technology, except when raising the reliability criterion weight coefficient
- RDF co-combustion in cement kilns was consistently identified as the optimum solid waste management method when fine-tuning the weight coefficients

9. CONCLUSIONS & RECOMMENDATIONS

- Solar energy is the favoured renewable energy source and CSP systems could become attractive for deployment with future reductions in costs
- RDF co-combustion in cement kilns is the favoured solid waste management option, but there are technical challenges imposed on the production of a co-fuel product to a specification
- The study could be repeated using a stochastic method by defining the uncertainty in the input data with probability distributions

REFERENCES


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