Risk Mitigation Strategy for the Installation of a WtE Cogeneration Plant in the City of Skopje

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Abstract

1. INTRODUCTION

Waste-to-Energy (WtE) technology has gained attention as a viable solution for waste management while generating renewable energy. The installation of a cogeneration WtE plant presents numerous opportunities for sustainable energy production and waste management. However, its implementation is often challenged by various barriers and risks that must be systematically evaluated and mitigated. Barriers represent obstacles that hinder the adoption or execution of a particular technology or strategy. Overcoming these barriers is essential for the successful deployment of WtE systems. Addressing these challenges through a structured methodology can enhance project feasibility and long-term sustainability.

2. MATERIALS AND METHODS

The study will analyse the challenges faced from installation of WtE cogeneration plant in the city of Skopje, Republic of North Macedonia. The Interpretive Structural Model (ISM) is applied to structure and prioritize challenges affecting WtE plant implementation. Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) analysis is utilized to categorize these challenges into driving and dependent factors. Six primary challenge categories were analysed: Operational challenges (OC1-Inadequate selection and separation of waste at source, OC2-Difficulties in collecting and transporting waste, OC3-Inappropriate waste disposal methods (landfilling and open burning), OC4-Heterogeneous nature of landfill waste, OC5-Management of by-products such as ash and sludge), Technical challenges (TC1-Insufficient advanced and modern technologies, TC2-Lack of trained and aware operational personnel, TC3-Lower gross heating value compared to conventional fuels, TC4-Lack of integrated waste information), Financial challenges (FC1-High capital investment (CAPEX), FC2-Long return on investment period, FC3-Competitive energy prices (from renewable sources)), Regulatory challenges (RC1-The Waste Management Plan for 2021-2031 prioritizes waste reuse and recycling over WtE, RC2-Waste Prevention Plan 2022-2028 prioritizes waste reduction over WtE, RC3-Non-existent regulation for installation and operation of WtE plants), Social challenges (SC1-Insufficient awareness of the population and reluctance to build such plants, SC2-Distrust in the institutions managing the plant due to corruption, SC3-Potential health risks (air pollution, toxic emissions and long-term health effects)), and Environmental challenges (EC1-Air pollution (dioxins, heavy metals and particulate matter), EC2-Combustion residue management (ash and sludge), EC3-Water pollution (from cooling and filtration systems)) [1, 2].

3. RESULTS

ISM analysis structured the risks into hierarchical levels, distinguishing between root causes and their effects. MICMAC analysis further classified the challenges into four clusters: autonomous (Quadrant 1), dependent (Quadrant 2), linked (Quadrant 3), and independent (Quadrant 4) variables. Q1 has low driving and dependence power, Q2 has low driving power, but high dependence power, Q3 has high driving and dependence power, and Q4 has high driving power, but low dependence power [3]. Each figure illustrates the classification of different challenges into quadrants based on ISM analysis, Figure 1 refers to operational challenges, Figure 2 to technical challenges, and Figure 3 the rest of the challenges mentioned above. The prioritization of mitigation strategies is based on the dependency and driving power of each challenge. The highest priority is given to addressing the interconnected factors in Q3. The next focus is on the dependent factors in Q2, followed by the long-term management of autonomous factors in Q1. Finally, continuous monitoring is placed on independent factors in Q4.

In Q3 – 1st Priority, key challenges include OC3, FC2, SC1, SC2, SC3, EC1, EC2, and EC3. To mitigate inappropriate waste disposal (OC3), strict enforcement of bans on open burning, development of sanitary landfills, and promotion of WtE for controlled waste treatment are essential. Addressing the long return on investment (FC2) requires long-term power purchase agreements, preferential tariffs for WtE, and low-interest financing from development banks. Public acceptance of WtE plants (SC1) can be improved through awareness campaigns, transparency on emissions and health impacts, and compensation for affected communities. Strengthening governance (SC2) involves independent oversight, anti-corruption measures, and enabling public monitoring. Air pollution (EC1) is mitigated by modern gas treatment systems, regulatory alignment with EU standards, and regular monitoring. Managing ash disposal (EC2) requires recycling in construction, safe disposal, and stabilization techniques. Water pollution prevention (EC3) involves closed-loop water systems, wastewater treatment, and continuous monitoring. In Q1 – 3rd Priority, challenges TC1, TC2, TC3, and RC3 are addressed. Technological advancement (TC1) is promoted through technology transfer, tax incentives, and pilot projects. Workforce development (TC2) includes capacity-building programs, specialized training centers, and retention incentives. Low waste heat value (TC3) is mitigated by RDF production, biomass co-firing, and adapted WtE designs. Strengthening regulatory frameworks (RC3) involves EU directive alignment, national emission standards, and strict licensing. Challenges OC2, FC1, FC3, RC1, and RC2 lie in the middle of the matrix. Waste collection and transportation (OC2) require modern vehicles, GIS-based route optimization, and public-private partnerships. Financial barriers (FC1, FC3) are tackled through PPPs, green energy funds, subsidies, hybrid WtE-renewable models, market incentives, and flexible pricing. Effective waste management (RC1, RC2) aligns WtE with recycling, circular economy integration, impact assessments, and high-efficiency energy recovery [4].

Fig. 1: Operational challenges

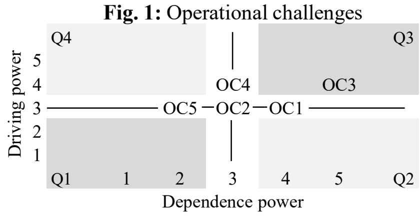


Fig. 2: Technical challenges

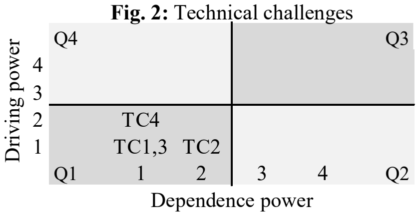
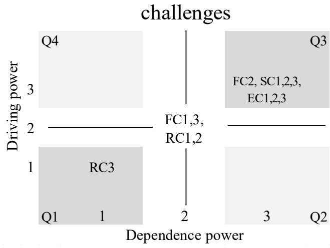


Fig. 3: Financial, regulatory, social and environmental challenges



4. CONCLUSIONS AND RECOMMENDATIONS

Effective risk mitigation in the WtE sector requires a structured approach, prioritizing key challenges based on their dependency and driving power. Immediate focus should be on critical factors such as waste disposal methods, investment security, public acceptance, governance, air pollution, ash management, and water quality. Medium- and long-term efforts should enhance technological advancements, workforce capacity, and regulatory frameworks. Addressing financial and operational challenges is crucial for system efficiency. By implementing these targeted strategies, the WtE sector can achieve sustainability, regulatory compliance, and maximum risk reduction, ensuring the successful implementation and long-term viability of WtE plants.

Biblography

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