NATIONAL TECHNICAL UNIVERSITY OF ATHENS
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«Infrastructure and Construction Project Management»

Postgraduate Diploma Thesis

Repowering of Onshore Wind Farms: Comparative Analysis of European Frontrunners Using Multi-Criteria Decision Analysis

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Abstract

The increasing number of onshore wind turbines in Europe reaching the end of their operational lifetime creates a major challenge for maintaining renewable energy capacity and achieving the European Union's 2030 climate objectives. As first-generation wind farms become technically outdated and economically inefficient, selecting the most appropriate end-of-life strategy becomes a strategic priority. Among the available options, decommissioning, lifetime extension, and repowering, the latter has gained increasing attention as a technically feasible and policy-aligned pathway to sustain and expand wind generation capacity within existing sites.

This thesis investigates the level of maturity of onshore wind repowering across seven European countries: Denmark, France, Germany, Greece, Italy, Spain, and Sweden. The objective is to identify which countries demonstrate the most advanced and supportive environments for repowering and to extract lessons and best practices that can guide the improvement of repowering frameworks in countries that currently underperform.

To achieve this, a structured Multi-Criteria Decision Analysis (MCDA) framework was developed, integrating twelve indicators grouped under five pillars—financial, legal, technical, environmental, and social. Quantitative and qualitative data were compiled from peer-reviewed literature, national reports, and European databases. The Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method was employed to rank countries based on their overall readiness and performance regarding repowering.

The analysis reveals that Denmark, Germany, and Spain constitute the frontrunners, supported by consistent support schemes, clear permitting processes, mature recycling solutions, and strong public awareness. France and Italy show moderate progress, whereas Sweden and Greece remain in early stages due to administrative complexity, low repowering activity, and insufficient legal incentives. The findings emphasize that robust policy frameworks, grid readiness, and circular economy integration are decisive for accelerating repowering deployment.

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This study provides a transparent and replicable benchmarking tool for policymakers, investors, and stakeholders aiming to evaluate and enhance repowering potential at national and European levels. Its results contribute to a clearer understanding of how Greece can integrate successful European practices to unlock its ageing wind capacity and contribute more effectively to EU energy and sustainability targets.

Keywords: Wind energy, Repowering, Multi-Criteria Decision Analysis (MCDA), TOPSIS, Renewable Energy Directive (RED III), Onshore wind, Policy benchmarking, European Union.