1st Iberian Conference on Multi-Criteria Decision Making/Analysis (IMCDM/MCDA 2025)

Prioritising Municipal Photovoltaic Initiatives Using Multi-Criteria Decision Analysis

A case study concerning photovoltaics in Rajadell, Spain.

MUHAMMAD TANVEER UL ISLAM

CEGIST, Instituto Superior Técnico, Universidade de Lisboa

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1 Introduction

1.1 Motivation

Municipalities as Major CO_2 Emitters

Cities significantly contribute to greenhouse gas emissions; local actions are crucial to meet climate targets.

☀ Solar PV: A Pillar of Sustainable Energy Transition

Photovoltaic initiatives offer scalable, clean energy solutions essential for sustainable development.

MCDA for Transparent Decision-Making

Employing Multi-Criteria Decision Analysis ensures fair and transparent prioritization of municipal projects.

1.2 Context

Global warming

GHG emissions

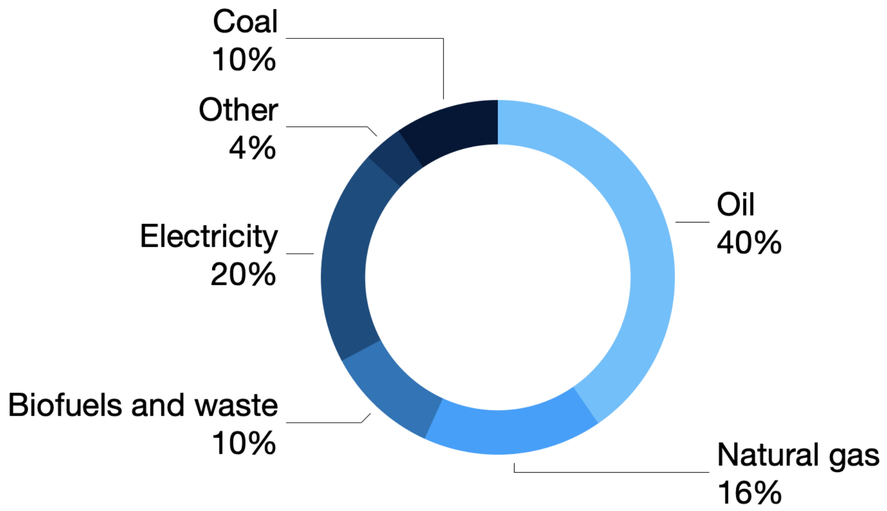
Agricultural and industrial practices
Deforestation
Fossil fuel use

Energy sector

73% of GHG emissions
Electricity: 20% of the energy consumed

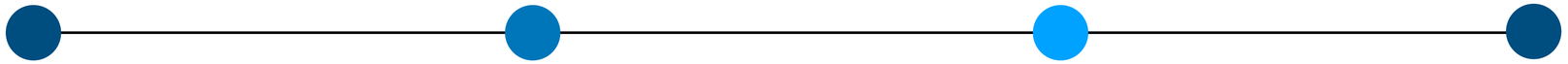
Climate agreements

Paris Agreement
REPowerEU
EU Covenant of Mayors for Climate & Energy



Share of world final consumption by source (2024).

1.3 Problem statement

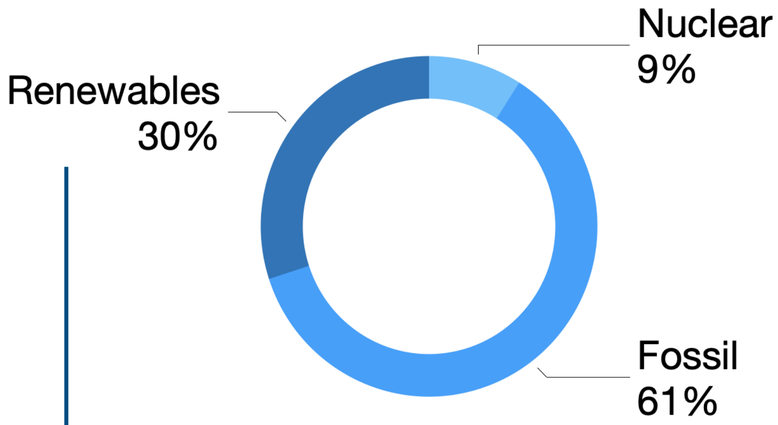


MCDA model

Photovoltaic projects
Reduction of local emissions
Urgency of implementation
Case study in Rajadell

2 Literature review

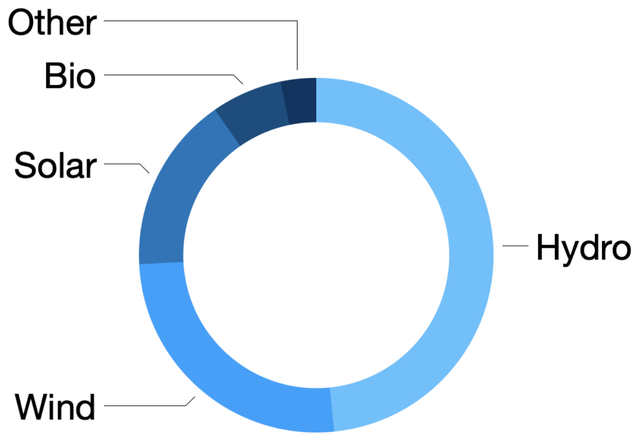
2.1 Renewable energies



Global share of electricity production by source (2024).

Solar PV

- Mature technology
- Cost reduction
- Modularity
- Self-consumption
- Great relevance in Spain



Global share of renewable electricity production by source (2024).

2.2 Knowledge gap

Research areas

Power plant site selection
Evaluation of energy sources
Technology assessment
Sustainability and policy assessment

MCDA techniques

TOPSIS
AHP
ELECTRE
ANP
PROMETHEE

Ranking (II, III)
Choice (IS)
Sorting (Tri)

Highlighted studies

(Thebault et al., 2022)
(Neves et al., 2018)

3 Background

3.1 Spanish framework

Spanish electricity mix

- 40% Renewables
- 11% Solar energy

PV systems

- Stand-alone system
- PV power plant
- Self-consumption system
  - Individual
  - Collective

Regulations

- RD 244/2019
- RD 15/2018
- REBT

4 Methodology

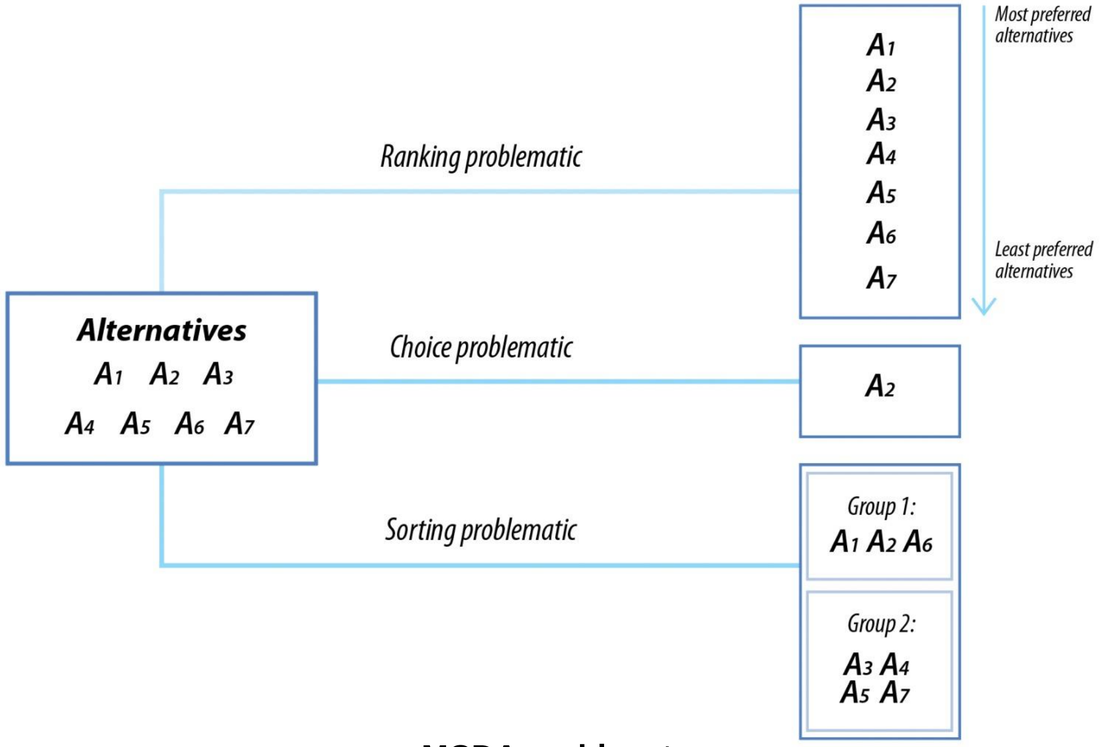
4.1 MCDA

MCDA

- Multiple criteria
- Problem types
  - Ranking
  - Choice
  - Sorting

ELECTRE Tri-nC

- Qualitative evaluations
- Heterogeneity
- Arbitrariness and uncertainty



MCDA problem types

4.2 The ELECTRE Tri-nC approach

Pairwise comparison

Alternatives $A = \{ a_1, a_2, \ldots, a_i \}$ $\longleftrightarrow$ Reference actions $B = \{ B_1, B_2, \ldots, B_q \}$

Performance $g_j(a_i)$

Criteria

$F = \{ g_1, g_2, \ldots, g_n \}$ $n \geq 3$

$w_j > 0, j = 1, \ldots, n$

Assignment

Categories

$C = \{ C_1, C_2, \ldots, C_q \}$ $q \geq 2$

Preference relations

Indifference	$g_j(a) - g_j(a') \leq q_j$
Weak preference	$q_j < g_j(a) - g_j(a') \leq p_j$
Strict preference	$g_j(a) - g_j(a') > p_j$

Parameters

Credibility level λ

Veto, preference, and indifference thresholds

$v_j \geq p_j \geq q_j \geq 0$

5 Case study

5.1 Overview

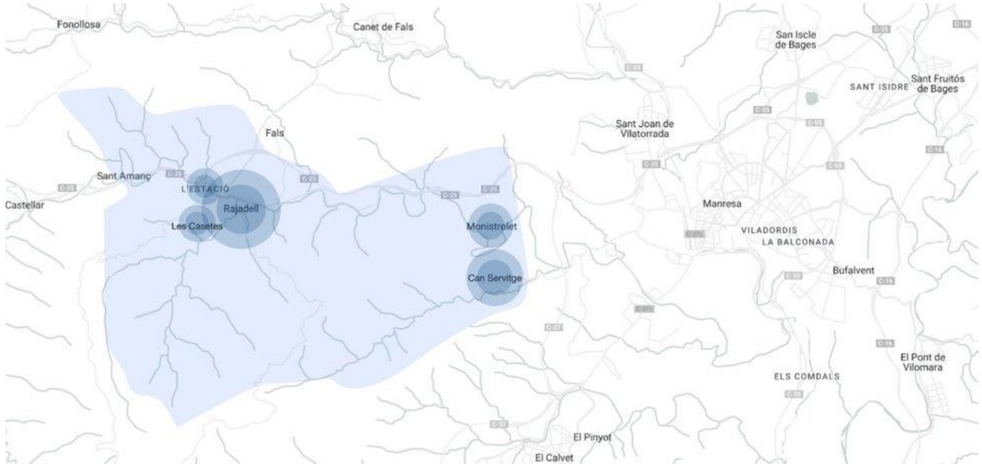
Rajadell

1000 inhabitants
Energy consumed | 6000 MWh
Emissions | 1800 tonnes

Goals

2030 | Emissions reduction by 55%
2050 | Climate neutrality

Global irradiation for horizontally mounted PV modules.



Map of Rajadell with its respective population centres.

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5.2 Actions

Investors

- Public
  - Local council
  - Catalan Water Agency
- Private
  - Homeowners
  - Local businesses
  - Companies

Sectors

- Residential
- Agricultural
- Catering and tourism
- Electric transport
- Power generation

Structures

- Fixed
  - Roof-added
  - Free-standing
- Mobile
  - Solar tracking

Systems

- Grid-connected
- Self-consumption
- Commercial applications
- Energy community

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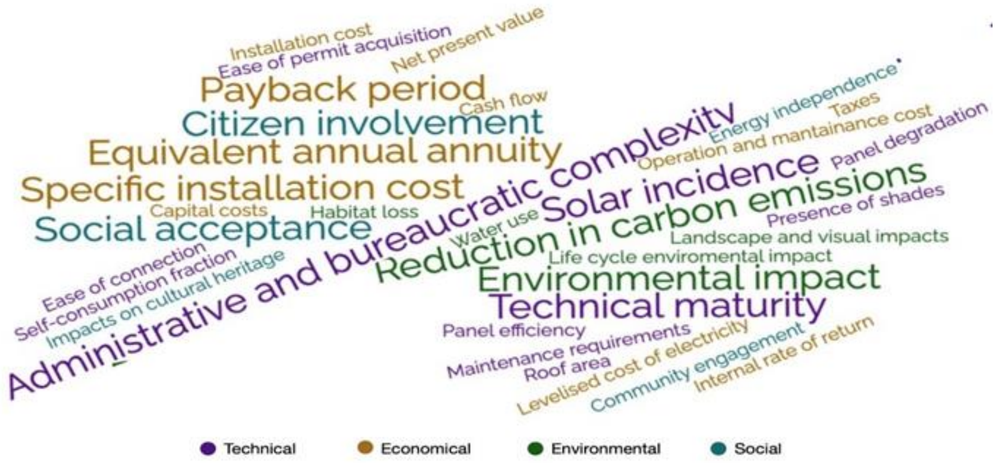
5.3 Criteria



Different criteria used in MCDA research applied to photovoltaics.

Technical

- Technical maturity **10.65%** ↑
- Administrative and bureaucratic complexity **14.53%** ↓
- Solar incidence **14.53%** ↑

Economic

- Financial impact **8.06%** ↑
- Payback period **15.83%** ↓
- Specific installation cost **10.65%** ↓

Environmental

- Environmental impact **8.06%** ↓
- Annual avoidance of emissions **10.65%** ↑

Social

- Social acceptance **5.46%** ↑
- Citizen involvement **1.58%** ↑

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5.4 Categories and parameters

Category	Urgency of action	Implementation by
C_1	Low	2050
C_2	Medium	2030
C_3	High	2026

Categories of the model.

Reference actions
- Two for each category

Performance table
- 10 actions
- 10 criteria
- Matrix 10x10

Criterion parameters
- Preference threshold
- Indifference threshold
- Veto threshold

Method parameter
- Credibility level

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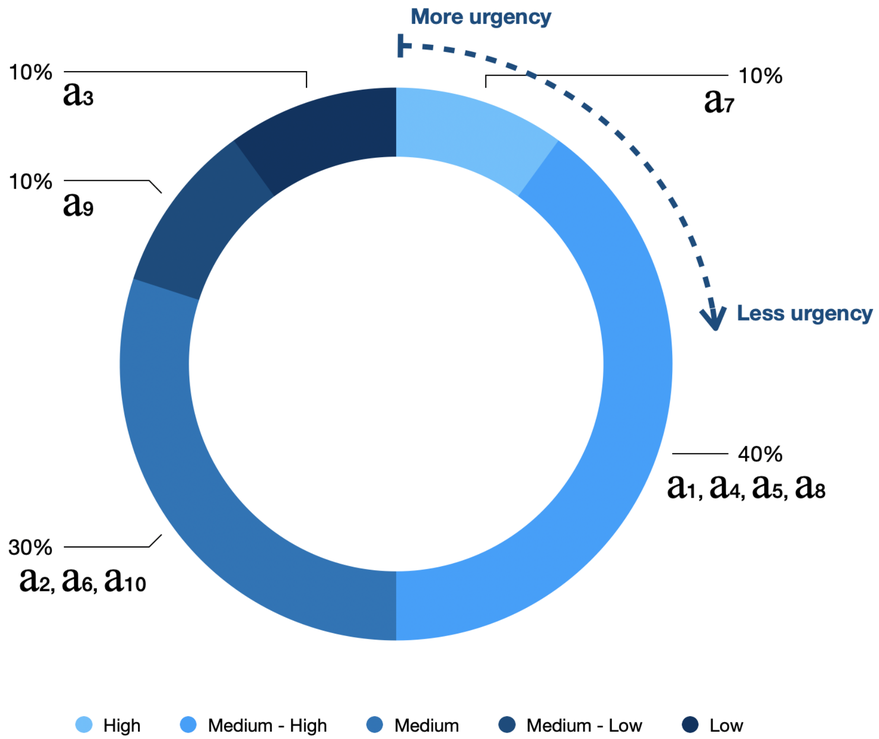
6 Results

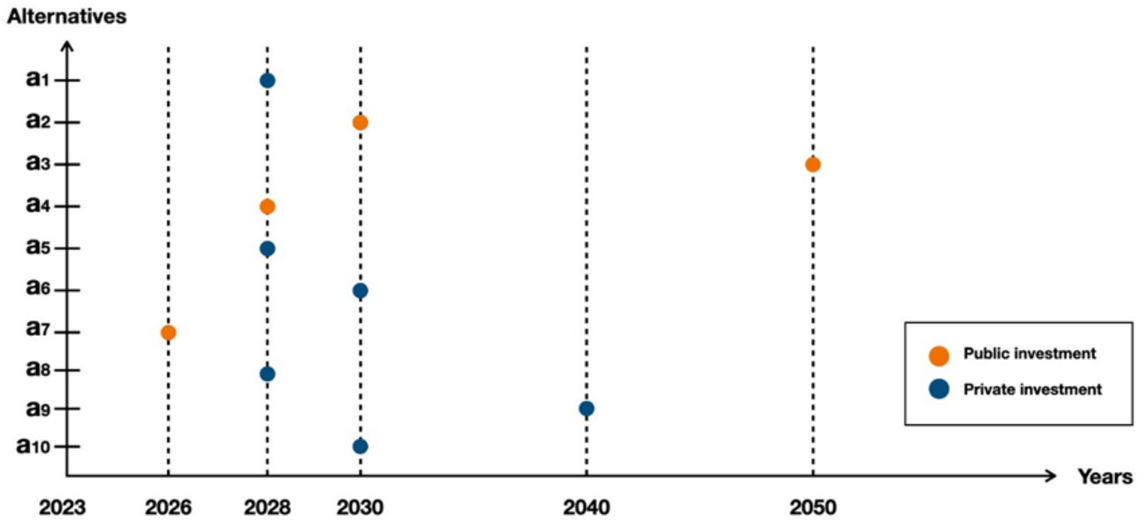
6.1 Actions Priority

Action	PV Initiative	Urgency Category	Key Strengths	Key Weaknesses
a1	PV self-consumption in residences	C2–C3	High CO_2 reduction (273 tons/year), citizen involvement	Long payback (7.58 years)
a2	PV self-consumption in local buildings	C2	Low cost (€1,296/year)	Low emissions reduction (15.6 tons CO_2)
a3	Solar street lighting	C1	Improves public infrastructure	High cost (€25,466 loss), low impact
a4	Self-consumption at sewage plant	C2–C3	Efficient (1.73 €/Wp), moderate CO_2 savings (12.5 tons)	Limited citizen engagement
a5	PV self-consumption in livestock farms	C2–C3	Supports agriculture, moderate cost (€7,615/year)	Niche applicability
a6	Solar-powered water pumping system	C2	High energy efficiency (1,984 kWh/kWp)	Technical complexity (tracking system)
a7	Local community solar farm	C3	Highest urgency: 37 tons CO_2 reduction, 6.7-yr payback	Administrative hurdles
a8	Self-consumption in local businesses	C2–C3	Balanced cost/benefit (€8,660/year, 27 tons CO_2)	Requires business buy-in
a9	Solar-powered vehicle charging station	C1–C2	Future-proof technology	High cost (€2,407 loss), immature market
a10	Utility-scale solar farm (1.5 MW)	C2	Massive CO_2 reduction (732 tons/year)	Vetoed: Low social acceptance

6.2 Analysis and timeline proposal



Classification of alternatives according to their urgency of implementation.



Timeframe of the implementation proposal.

6.3 Implications

Goals

2030 | Emissions reduction by 55%
2050 | Climate neutrality

Achievements by 2030

Without solar farm - 21.43%
With solar farm - 61.37%

Local policy recommendations

Tax benefits
PV adoption in municipal buildings

Policy improvements

Rural localities
Energy communities
Large-scale solar PV

7 Conclusions

7.1 Findings and limitations

Main findings	Relevance of PV technology Potential for improving PV performance Involvement of many stakeholders
Main limitations	Potential bias Knowledge of data
Future research	Multiple Decision-makers Adaptation to other contexts

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THANK YOU

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