X SICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

XSICEL 2021
Transición energética en la 4ta revolución industrial

Using a Multi-criteria analysis to study the inclusion of ocean sources in the energy matrix of Colombia

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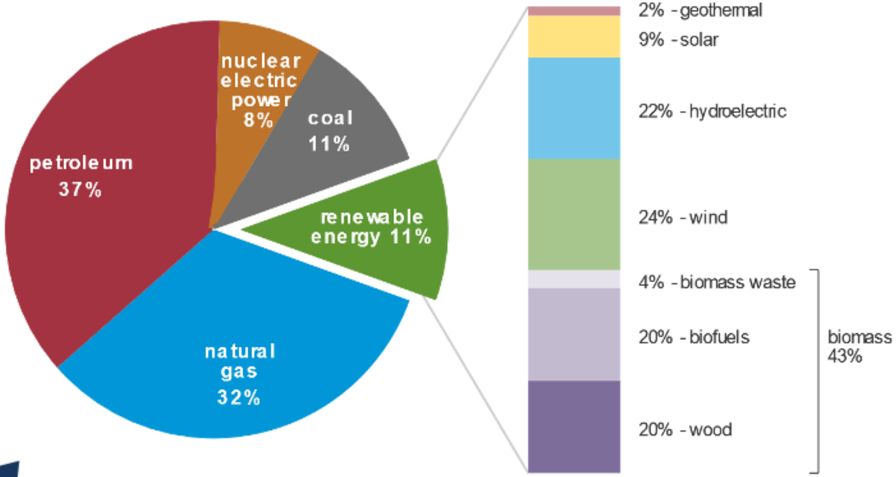
I. Introduction

- Primary Energy Sources (OCDE countries)
- Scientific researching

Review

Example: EE UU



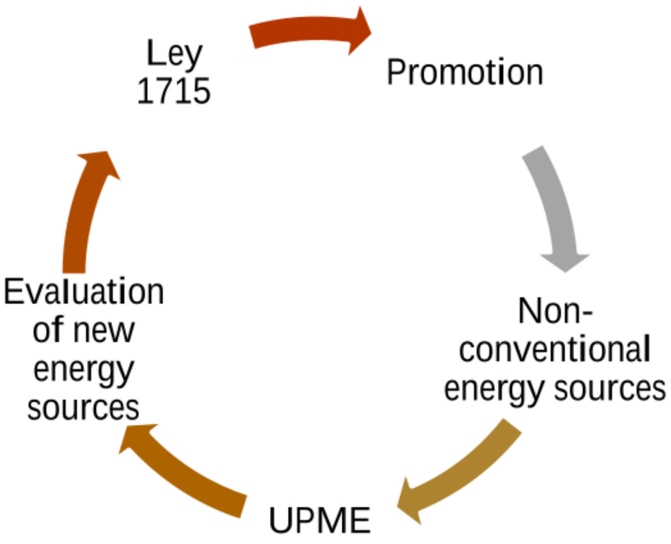
Note: Sum of components may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2020, preliminary data

- List of energy source in the world
- How is it used?

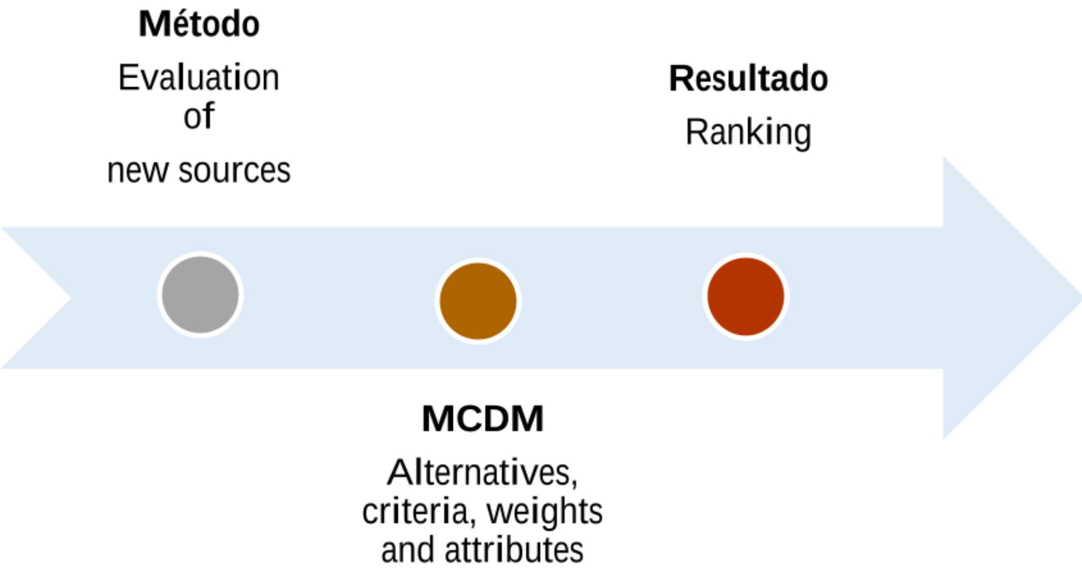
Analysis

I. Introduction

Regulations – UPME

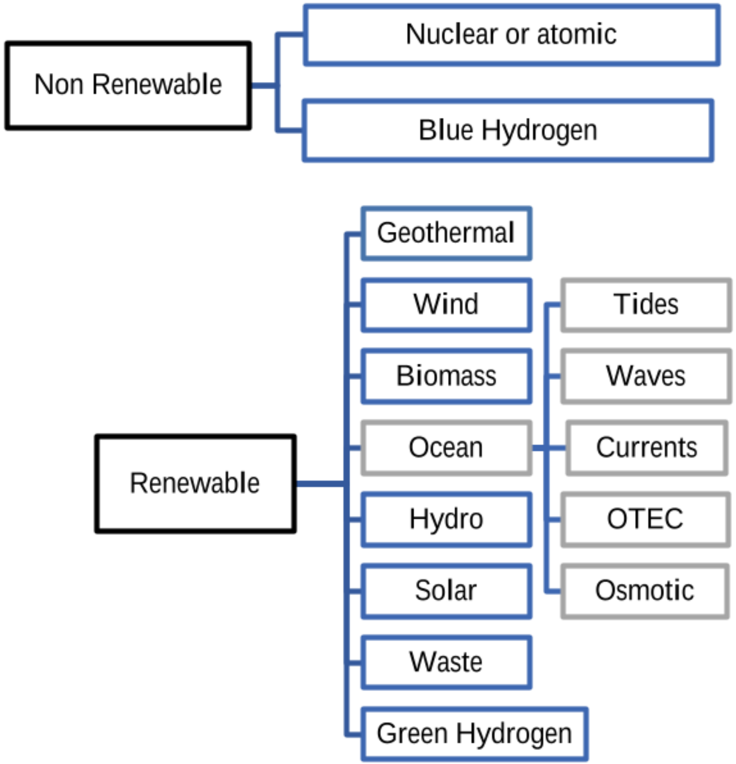


UTP – Minciencias – UPME

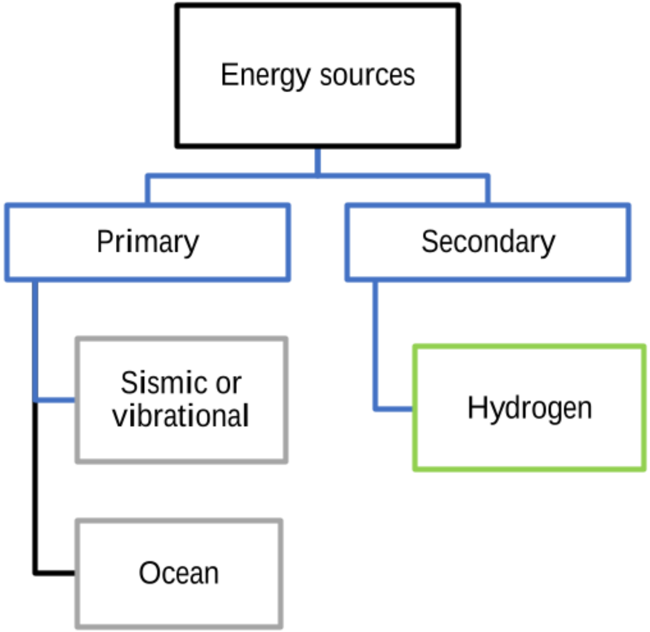


I. National Review

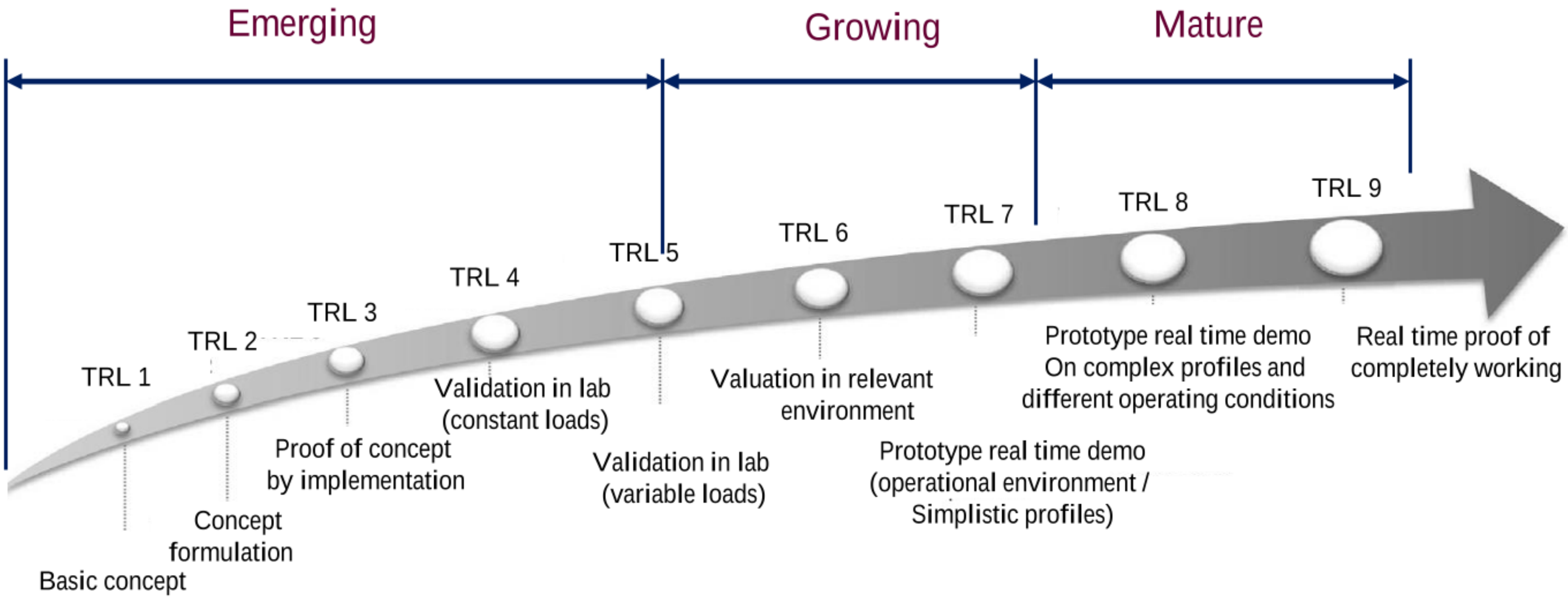
Sources named in Law 1715



Sources unused



I. Technological Readiness Level - TRL



Sources:
State of the art and taxonomy of prognostics approaches, trends of prognostics applications and open issues towards maturity at different technology readiness levels - 2017

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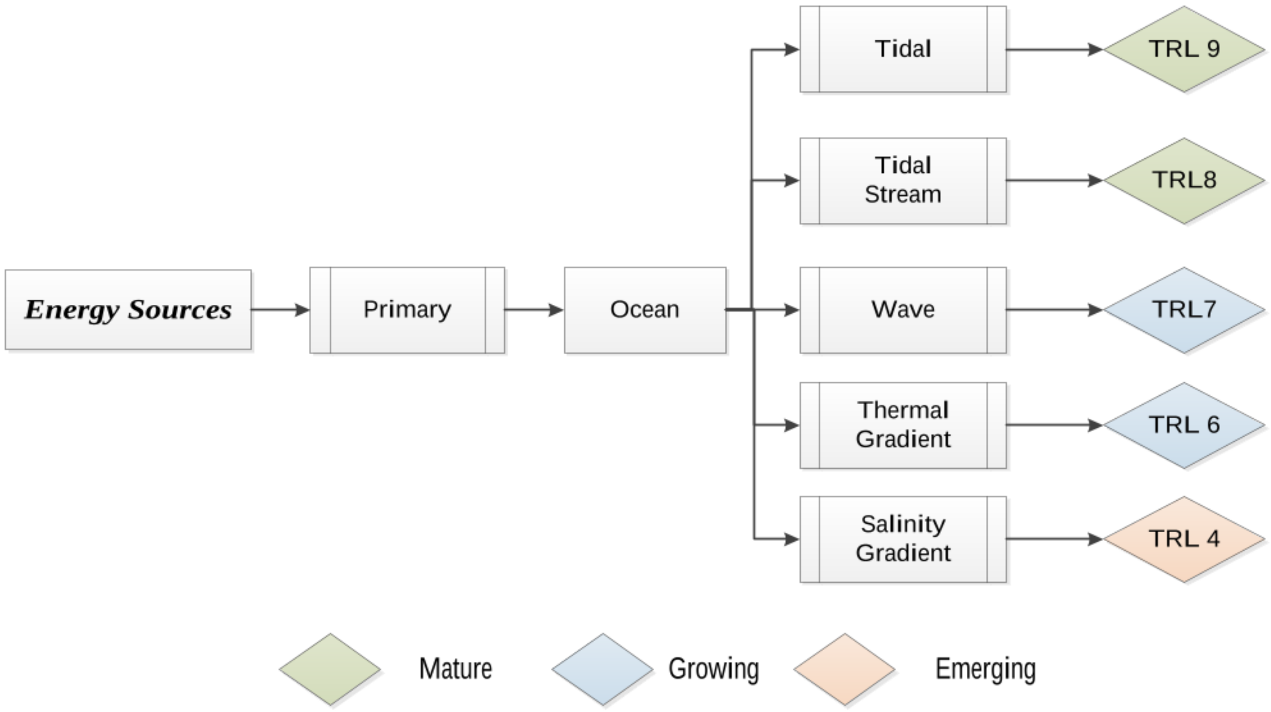
II. Methodology

Phase I Technological Maturity Review



II. Methodology

Phase I **Scenario to be evaluated and List of criteria for the assessment based on MCDM.**

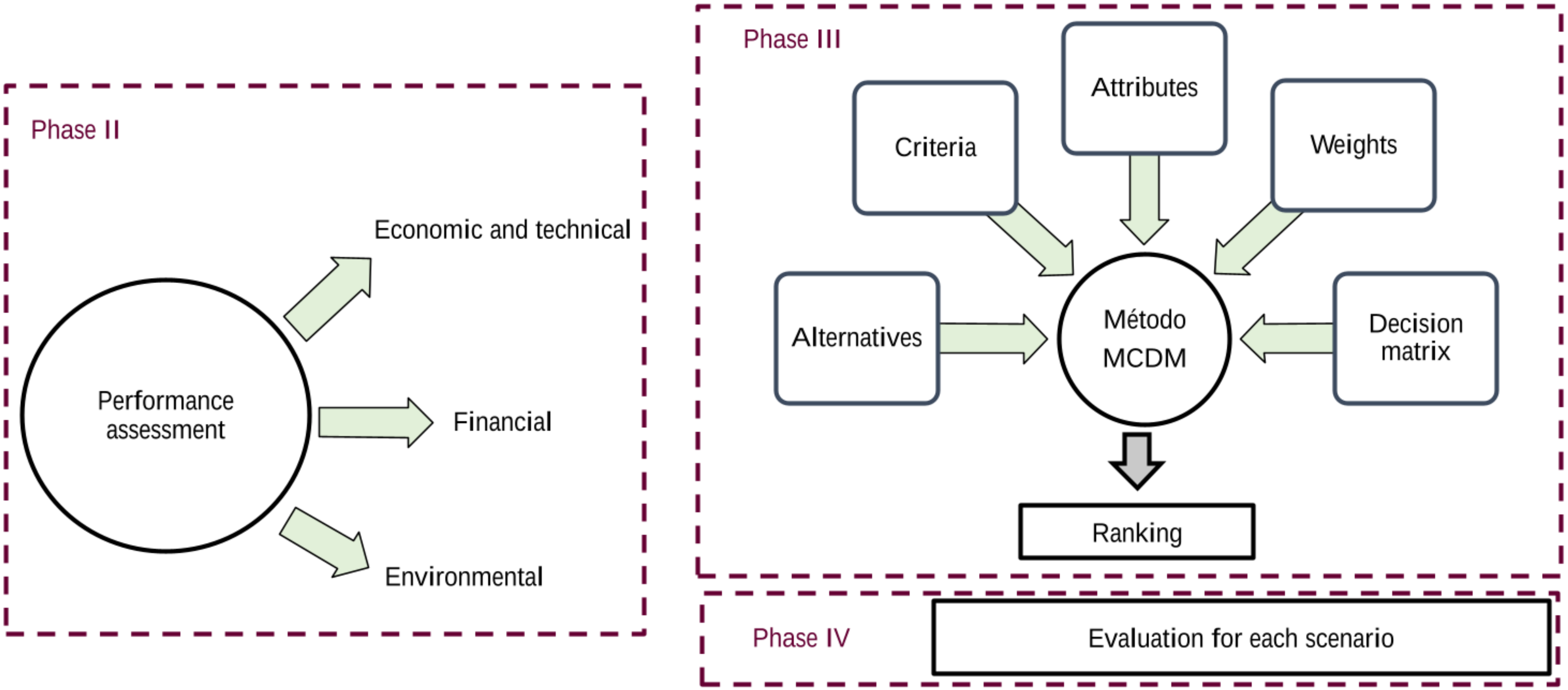
Scenario 1
- Evaluation:
  Solar - Wind - Currents

Scenario 2
- Evaluation:
  Solar - Wind - Tidal

Scenario 3
- Evaluation:
  Solar - Wind - Wave

Symbol	Criterion	Scenario	Atributo	Unit
PC	Power capacity	Technical	Beneficial	MW
FC	Capacity factor		Beneficial	%
CAPEX	Costos de inversión	Financial	Cost	$/kW
LCOE	LCOE		Cost	$/MWh
CO_2e	Emission reduction	Environmental	Beneficial	tCO_2/year

II. Multicriteria decision making methods – MCDM



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III. Result

Decision matrix

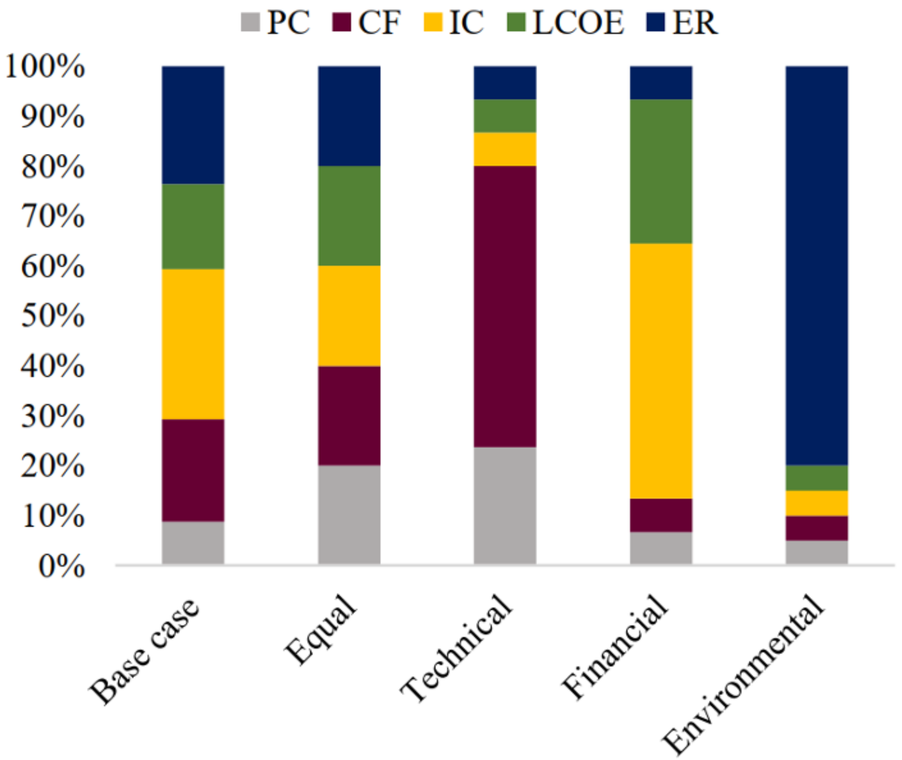
Alternativa	Technological Maturity [TRL]	Power Capacity [MW]	CAPEX [USD/kW]	LCOE [USD/MWh]	Emissions Reduction [t/year]	Capacity Factor [%]
Waves	7	2	4900	306	2.736	30
Tidal	9	250	3412	196	342000	30
Current	8	4	11466	594	6384	35
Solar	9	86	995	46	67080	23
Wind	9	19	1800	71	26144	38

III. Result

Weights of criteria for each case

Analytical Hierarchy Process (AHP)

Aplied to technical experts in renewable energies



III. Result

Performance assessment

Economic and technical

Alternative	E_{xg} [MWh/year]	E_{xr} [$/year]	D_b[$]	E_q[$]
Solar	176.043	17.604.315	49.024.500	21.010.500
Wind	65.026	6.502.636	19.464.900	8.342.100
Waves	5256	1.576.800	6.860.000	2.940.000
Tidal range	657.000	131.400	597.100.000	255.900.000
Ocean current	12.264	7.358	9.553.600	4.094.400

Financial

Alternative	Rate annual [$/kWh]	EPP [years]	NPV [$]	BCR	ALCS [$/year]	LCOE [$/MWh]
Solar	100	1,8	114.872.774	6.5	12.583.907	46
Wind	100	2,8	27.356.694	4,3	2.996.829	71
Waves	300	7,6	2.181.380	1,7	238.962	306
Tidal range	200	6,9	230.636.658	1,9	25.265.433	196
Ocean current	600	6,9	12.322.432	1,9	1.349.879	594

III. Result

Multicriteria decisión making methods – MCDM

Scenario 1: Solar - Wind - Currents

Base	Homogeneous	Technical	Economic	Environmental
Solar	Solar	Wind	Solar	Solar
Wind	Wind	Currents	Wind	Wind
Currents	Currents	Solar	Currents	Currents

Scenario 2: Solar - Wind - Tidal

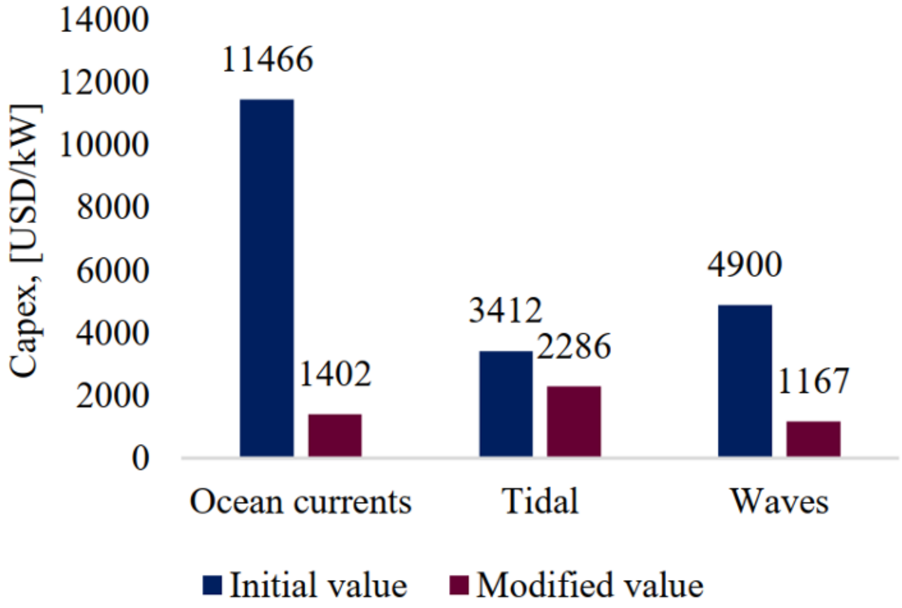
Base	Homogeneous	Technical	Economic	Environmental
Wind	Wind	Wind	Solar	Tidal
Solar	Tidal	Tidal	Wind	Solar
Tidal	Solar	Solar	Tidal	Wind

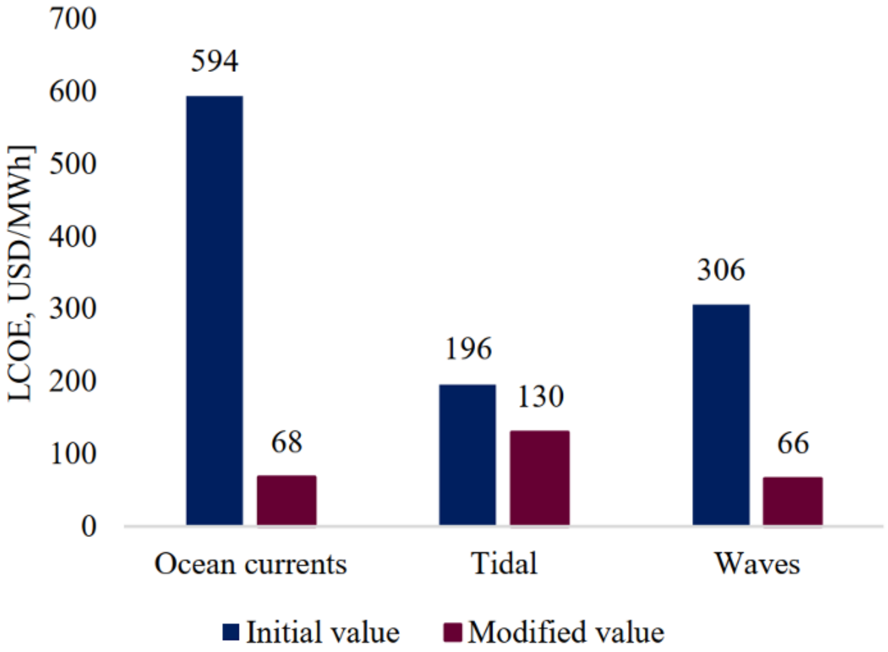
Scenario 3: Solar - Wind - Wave

Base	Homogeneous	Technical	Economic	Environmental
Solar	Solar	Wind	Solar	Solar
Wind	Wind	Solar	Wind	Wind
Wave	Wave	Wave	Wave	Wave

III. Result

Multicriteria decisión making methods – MCDM





III. Result

Sensitivity analysis

- The wave energy would eventually be competitive in the Colombian energy market if CAPEX were 1.167 USD/kW, LCOE were 66 USD/MWh, and energy were sold at 62 USD/MWh.

- The energy of ocean currents would be competitive in the Colombian energy market if CAPEX were 1.402 USD/kW, LCOE were 68 USD/MWh, and energy were sold at 62 USD/MWh.

- Tidal energy eventually reached a CAPEX of 2.286 USD/kW and a LCOE of 130 USD/MWh, they would not be competitive in the market because of to achieve financial viability implies on a sale energy price of 118 USD/MWh, a value 1,9 times higher than the energy sale price at which the auction closes.

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III. Conclusion

1. The assessment of renewable energy technologies can be conducted by Multicriteria Decision Making Methods considering technical, financial, and environmental criteria as a tool to reduce financial risks and guarantee the objective goals of renewable energy projects.

2. The results of the financial and the environmental performance assessment were used to grant the numerical values of criteria such as the LCOE and the gross annual GHG emission reduction. It found that the gross annual GHG emission reduction percentage is the same for all the alternatives, but tidal range exhibits increased gross annual emission reduction due to its high-power capacity. Likewise, tidal range exhibits the best financial performance among the alternatives. Unlike tidal range, ocean energy exhibits the worst environmental and financial performance.

III. Conclusion

3. Tidal range is the best alternative and ocean current the worst for all the scenarios. This could be explained considering the difference in the power capacity, being higher for tidal range. Since higher power capacities eventually imply higher electricity exported to grid for similar capacity factors, and higher electricity exported to grid leads to higher gross annual GHG emission reduction for similar GHG emission factors and lower Levelized Cost of Energy for similar investment cost values.

4. For similar power capacities, solar energy would be a better alternative than tidal range considering that solar's financial performance was better than tidal range, even though the power capacity of solar was approximately 65% lower.

5. The LCOE and capex evaluation is not enough to determine the feasibility of the project. The sale of energy is a fundamental parameter to assess financially within an energy market.

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¡Thanks!

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