Selecting the Best Power Generation Technologies by Using Multi Criteria Decision Making Analysis

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Abstract:

The increasing demand for electric power is prompting engineers to consider sustainable energy production systems in Europe. Challenges include energy supply security, affordability, material efficiency, and environmental protection. Based on a number of variables, this study seeks to determine which sustainable technologies are most effective for producing electricity. Numerous competing criteria are present in the sources of energy production; multi-criteria decision-making methods (MCDM) were applied, and the analysis was conducted using the MULTIMOORA, VIKOR, and TOPSIS methodologies. The results of the MULTI MOORA method revealed the best biomass (CHP) power plants; via VIKOR, the best technology for producing electricity was condensing turbine coal; and for TOPSIS, the best technology was solar photovoltaics. These findings demonstrated that future energy policy should be focused on sustainable energy technologies.

Keywords: *Electricity Production; Best Performance; Electrical Engineering; Sustainability; Multicriteria Decision Making.*

اختيار أفضل تقنيات توليد الطاقة باستخدام تحليل اتخاذ القرار متعدد المعايير

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الخلاصة:

إنّ الطلب المتزايد على الطاقة الكهربائية يدفع المهندسين إلى النظر في أنظمة إنتاج الطاقة المستدامة في أوروبا. وتشمل التحديات أمن إمدادات الطاقة، والقدرة على تحمل التكاليف، وكفاءة المواد، وحماية البيئة. وبناءً على عدد من المتغيرات، تسعى هذه الدراسة إلى تحديد التقنيات المستدامة الأكثر فعالية لإنتاج الكهرباء. وهناك الكثير من المعايير المتنافسة في مصادر إنتاج الطاقة؛ وقد تم تطبيق أساليب صنع القرار متعددة المعايير (MCDM)، وأُجري التحليل باستخدام منهجيات MULTIMOORA وVIKOR وTOPSIS. وقد كشفت نتائج طريقة MULTI MOORA عن أفضل محطات توليد الطاقة بالكتلة الحيوية (CHP)؛ ومن خلال VIKOR، كانت أفضل تقنية لإنتاج الكهرباء هي فحم التوربينات المكثف؛ وبالنسبة لـ TOPSIS، كانت أفضل تقنية هي الطاقة الشمسية الكهروضوئية. وقد أظهرت هذه النتائج أن سياسة الطاقة المستقبلية يجب أن تركز على تقنيات الطاقة المستدامة.

الكلمات المفتاحية: *إنتاج الكهرباء؛ أفضل أداء؛ الهندسة الكهربائية؛ الاستدامة؛ تحليل القرار متعدد المعايير.*

1. Introduction

The energy mix has evolved over time due to factors like resource scarcity, convenience, pollution, and technical innovation. People often transition between different energy sources, and recent developments in economics, technology, society, and politics highlight the need for sustainability and diversification. Early discoveries in electricity include Franklin's kite, Volta's pot, Ampere's differentiation of tension and current, and Ohm's law. These advancements have influenced modern energy, economic growth, and industrial development by promoting sustainability and diversifying energy sources.

In the 19th century, British scientist Faraday created electrical power by placing a metal disc like copper inside a magnetic field. This created an electric field, freeing electrons and negative ions. Electricity is 18% of global energy use and is essential in various fields, including home appliances, industry, and health. It supports economic growth, provides job opportunities, and improves quality of life. Electricity sources include renewable sources like water, solar, geothermal, bioenergy, and nuclear energy, and non-renewable sources like fossil fuels. However, electricity has disadvantages, including permeability of some sources, high costs, environmental pollution, and the risk of skin shrinking due to electrical currents. Renewable energy sources like wind and solar energy are preferred for large areas, while fossil fuels contribute to environmental pollution.

Electricity is generated through various methods, depending on the source, renewable or non-renewable. Three-phase generators convert energy into one form. They consist of a stator, coils, and rotor sections, with excitation coils and a motor or turbine rotating the rotating section. Electricity is typically supplied by a direct current source.

Electric stations are named based on the engine or turbine used, such as steam, gas, or hydropower. They generate electricity through generators at a voltage value, typically near primary sources like water or load centers. The voltage is raised to the transmission voltage through transformers, reducing losses and reducing the cross-section of conductors. Electricity is measured in kilowatt-hours (Kwh), with multiples of this number, such as megawatt/hour (Mwh) and Gigawatt/hour (GWh). Electricity is a minor source of energy, derived from main sources like coal, natural gas, nuclear fission processes, sunlight, wind, and hydropower. With the capacity for renewable energy and the sales of electric cars reaching record highs in 2022, the energy transition has intensified. Low-carbon energy sources have a bright future ahead of them; by 2023, renewable energy capacity is expected to reach 450 GW and grow by at least 18%. Emissions must be cut in half by 2030 and completely eliminated by 2050 to prevent the effects of climate change.

2. Literature Review:

Mandelli el at. (2014) The article discusses Africa's energy situation, emphasizing sustainable development through prudent use of resources, technology, and policies. It presents an innovative structure for integrating EISD indicators and reveals cause-and-effect relationships, requiring ex-ante, itinerant, and ex-post analysis.

Kuzemko et al. (2020) The interdisciplinary study examines the impact of Covid-19 on sustainable energy transition, highlighting the political, economic, and social developments that could influence power control, carbon organization strength, and transformation velocity. The study reaches a tipping point for post-pandemic monetary revival.

Rezaei et al. (2022) This article analyzes the uniqueness of an area as an economic structure for ecologically friendly progress in the energy economy, focusing on smart eco-innovation and elegant technology implementation.

Khan et al. (2021) Climate change raises ecological concerns. Grossman and Krueger's work links NAFTA's economic growth to ecological class. The EKC evaluates green energy accessibility, and sustainable development evaluations of various energy systems are crucial.

Banos et al. (2011) Recent developments in optimization algorithms are being used to design, plan, and organize renewable and sustainable energy issues. Traditional strategies like numeral and linear gap indoctrination are being used, with deductive methods like hereditary algorithms being increasingly studied.

Razmjoo el at. (2019) The study identifies gaps in achieving energy sustainability in 12 countries and suggests that policy makers and professionals must implement policies such as reducing fossil fuel use, replacing them with renewable energy, emphasizing communal transport, efficient resource use, improving energy transportation, providing power access, and using new skills to improve power use and prevent power outages.

Markovska el at. (2009) The power division in Macedonia is analyzed for sustainable energy growth, focusing on the country's SWOTs. The energy sector's success is due to EU regulations and policies. However, issues include lack of local resources, unfavorable energy mix, low power costs, inefficiency, and lack of resources. To address these, a comprehensive long-term energy policy and gradual energy distribution changes are recommended.

Desideri et al. (2012) The research examines a solar power plant in Marciano, Italy, using the Life Cycle Assessment (LCA) methodology to assess its environmental impact and sustainability. The study considers every stage of the process, from soil preparation to final disposal. The analysis uses Semipro software and the Eco Indicator 99 approach. The study compares the environmental effects of photovoltaic solar generators with other power plants, highlighting the increasing use of renewable energy sources.

Welch and Barnum (2009) A study using EIA 906 and FERC 423 calculates cost-carbon ratios for steam plants, revealing a 79% increase in cost and 38% increase in carbon when switching from cost-efficient to carbon-efficient positions. This suggests extensive policy intervention, technology improvement, or market adjustment is needed to bridge the gap between cost-efficient and ecologically sound production. However, the research also shows that older, less efficient plants can produce the same amount of energy and use less fuel than those on the production frontier.

Quaranta and Muntean (2023) The study identifies three types of power resources: exhausted, dwindling, and indefinitely replenishable. Four factors distinguish different energy forms: carbon neutrality, environmental friendliness, accessibility, and contemporary application, which are crucial for long-term energy supply sustainability.

Anand et al. (2017) The AR-CCR model evaluates smart city sustainability indicators' effectiveness in entering and production standards, showing acceptable margin of error and increased heat demand accuracy when weather change is considered.

Prior (1980) Fossil fuels, including coal and natural gas, are dwindling in force, with 50% of their near force decreasing by 2030. They are expected to be carbon neutral by 2060-70. However, their production time is often longer than depletion time, making them insufficient for the planet for over half a century. Despite being inexpensive and producing no carbon emissions, these sources are classified as nonrenewable.

Abas et al. (2015) Depleting energetic resources refer to energy resources that cannot be renewed or conserved while remaining neutral. Coal, natural gas, and petroleum are all considered diminishing resources, but nuclear power presents a paradox due to its potential energy output and potential for biodiversity loss. Transitioning to sustainable energy sources could reduce global warming, improve community health, reduce pollution, and restore biodiversity. These resources are used for transportation, power production, and heating and cooling.

Bani Hani et al. (2022) Energy sources that result from processes are not classified using traditional methods. Energy is lost to the environment as heat, light, wind, and contact, but can be converted into electrical power using electrically powered reapers like thermoelectric, triboelectric, piezoelectric, thermoelastic, and thermomagnetic reapers.

Eryganov et al. (2022) Discharged energy sources, including heat, pressure, and electrons, are used in waste energy capture systems to generate electricity or store for later use. These sources come from mechanical, thermal, optical, chemical, pressure, magnetic, and wind motion. Examples include boiling water, furnace waste heat, and thermal conductive energy storage devices. These systems have shown efficiency and potential for development into novel energy sources, but have not yet gained widespread adoption.

Bundespublikationen (2016) Switzerland's energy consumption exceeds main power demand due to imports, with nuclear waste being the main energy source. Transitioning to a fossil fuel-free economy requires renewable energy sources. Current energy production is 0.24 kWcapita1 from nuclear power, with heat pumps for heating.

Asif (2009) Pakistan faces a 40% electricity deficit by 2008 due to factors like expanding demand-supply gaps, depletion of indigenous oil and gas supplies, rising energy prices, and security concerns. Sustainable energy options include hydropower, solar energy, biomass, and wind power. Pakistan has high solar resource abundance.

Chong (2016) Natural gas, the cleanest fossil fuel, has the potential to replace oil and coal as a major energy source. Its hydrate, containing twice as much carbon as all fossil fuels combined, has been tested in pilot projects, with promising results.

Shafie el at. (2011) Malaysia's energy sources include oil, natural gas, coal, and renewable sources like biomass, solar, and hydro. Despite its natural resources, fossil fuels dominate the nation's production and transport sectors. Malaysia faces energy security concerns, crude oil price volatility, and climate change. Renewable energy is becoming more attractive for Malaysia's long-term energy goals due to its diverse sources, including biomass and solar.

Solomon and Krishna (2011) To combat climate change and diminishing oil equipment, the planet should adopt sustainable energy solutions. Historical transitions between primary energy sources have been influenced by resource shortages, increasing costs, and technical advancements. Examples include Brazil's ethanol-based transportation system, France's nuclear power transition, and the USA's unsuccessful oil-fired power transition.

Evans et al. (2019) The study evaluated the effectiveness of non-combustion renewable power generation systems using sustainability metrics and empirical data. Factors such as power generation costs, greenhouse gas emissions, renewable energy accessibility, energy efficiency conversion, land and water requirements, and societal impacts were considered. Grades were assigned based on each metric.

Maradin el at. (2021) The study analyzed data from 78 wind energy companies in 12 European nations using the input-oriented BCC model. It provides forecasted results for regulators, policymakers, investors, and wind power company management, estimating operating performance.
Tsoutsos and Stamboulis (2005) Renewable power technology offers a unique technical economic system compared to traditional systems. An innovative approach integrates supply and demand,

promoting sustainable growth and diffusion of renewable energy sources, expanding successful applications and industries.

Lund (2007) Sustainable development options involve renewable energy sources like wave, wind, sun, and biomass. Strategies involve reducing energy use, increasing efficiency, and replacing fossil fuels. Denmark's example demonstrates the potential for widespread adoption. Technical developments in the energy sector, including flexible technology deployment and transportation sector conversion, are crucial.

Alizadeh et al. (2019) The study combines BOCR and ANP models to analyze infrastructures, laws, and administrative frameworks for renewable energy growth. Solar power is the most effective option in Iran, and other nations may benefit from this policy framework.

Ali et al. (2019) Bangladesh, a South Asian nation with little access to the electrical grid, uses renewable energy (RET) as an alternative. The research aims to determine the best RET in the South using MCDM and EDAS techniques. The optimum RET is determined using financial, technological, ecological, and political criteria, with a hybrid power system being preferred.

Gao et al. (2017) Research indicates that China's nuclear energy sector is progressing, but no consensus exists on the best transition to a sustainable nuclear petroleum series. A dynamic analytical model was used to compare four options and evaluate economic, ecological, and social viability. China values straight recycling of used petroleum via fast reactors for sustainability, while straight removal of all used petroleum with no recycle is the least desirable.

Lee and Chang (2018) The study evaluates various MCDM strategies for ranking renewable energy sources (RES) for electricity production in Taiwan. The Shannon method calculates the importance of each ranking criterion, and all feasible RES choices are quantitatively evaluated. Efficiency is the most promising RES, followed by employment growth, running costs, and repair and maintenance expenses. Hydro is rated highest, followed by solar, wind, biomass, and geothermal. The findings can inform energy policy and serve as a benchmark for Taiwan's energy future.

Nigim el at. (2004) The integration of Renewable Energy Systems (RES) with conventional fuel sources can improve energy security and reduce environmental and human health impacts. Decision-making tools like AHP and SIMUS can help communities rank their RES options, incorporating stakeholder input and expert opinion. These methods are effective in estimating the sustainability of potential local RES options and easing decision-making strain in large groups.

Wang et al. (2018) Vietnam's increasing energy needs and limited local resources necessitate the development of wind farms to increase energy availability and reduce pollution. Vietnamese scientists are using a (FAHP/TOPSIS) hybrid approach to locate wind power plants in ambiguous environments. After evaluating potential sites, Topsis is used to rank the best ones. The study found the central region as the best place for wind farms.

3. Data and Methodology

Data for this research was obtained from the article titled "Prioritizing Sustainable Electricity Production Technologies: MCDM Approach," which is expected in Europe by 2030. The first two rows describe criteria. MIN stands for non-beneficial criteria, whereas MAX stands for beneficial criteria. Each of the 33 electricity generation technologies under consideration is described in its own row position in Appendix 1.

The methodology used in this study is to compare power generation methods with each other by analyzing the characteristics of each method by using MCDM analysis (Multi-MOORA, CRITIC, VIKOR and TOPSIS methods as described in more detail in the text below.

3.1.Measurement indicators: An index was developed to assess the long-term sustainability of electricity generation technologies. In this study, a number of variables were considered, which can be divided into three categories as follows:

3.1.1. Economic Dimension

1-PR COST: (Private costs, investments, and operation costs (Eurocent/KWh)).

2-AVAILAB: (Average availability (load) factor (%)).

3-SECURE: (Security of supply /Point).

4-GRID COST: (Costs of grid connection/Point).

5-PEAK LOAD: (Peak load response /Point).

3.1.2. Environmental Dimension

1-CO2eq: (GHG emissions /(kg/kWh)).

2-ENV: (Environmental external costs /(EURcnt/kWh)).

3- RADIO: (Radionuclide external costs /(EURcnt/kWh)).

4- HEALTH: (Human health impact /EURcnt/kWh)).

3.1.3. Social Dimension

1-EMPL: (Technology-specific job opportunities /(Person-year/kWh))

2- FOOD: (Food safety risk /Point)

3-ACC PAST: (Fatal accidents from the past experience /(Fatalities/kWh))

4-ACC FUT: (Severe accidents perceived in future /Point)

3.2 Methodology

3.2.1 Multi-MOORA ratio proportion, to normalize data, use:

In situations when there are several standards of measurement and benchmarks, MCDM aims to support and direct the administrator, leader, or management in determining their options. It is a widely recognized rigorous, deliberate, and open process for making decisions. It involves evaluating each choice against a variety of frequently at odds criteria and selecting the best one from a collection of possibilities.

The steps in the process are as follows: establishing the choice problem (in this case, selecting which insurance company to invest in); evaluating the needs; and acquiring the requirements by means of decision scenario analysis and data collecting. establishing objectives and goals, formulating criteria, selecting a model, evaluating alternatives in light of criteria, verifying solutions against the problem statement or statements, and finally implementing the solution.

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^{2}}} \quad \text{……………………………………………………………(1.1)}$$

For normalizing the non-beneficial criteria, below method is used.

$$\text{and } x_{ij}^{*} = 1 - \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^{2}}} \ (j=1,2,……) \quad \text{…………………………..…(1.2)}$$

The decision matrix is shown as the X ij,

Where i is the Electricity technologies chosen for multi-criteria sustainability assessment, j is the Indicator for long-term sustainability assessment of electricity generation technologies, m are the variables, which is 13, n are Electricity and heat generation technologies is 33 obtained by equation 1.

In the equation number 1, I calculated this equation for sum of steps, first fined the best and the worst number of each variable, the second step square the all number in decision matrix, and the next step calculated the sum of each variable , finally applied equation number 1.1 for beneficial criteria, and applied equation 1.2 for non-beneficial criteria. then choose the highest value among:

$$y_{i}^{*} = \sum_{j=1}^{g} x_{ij}^{*} - \sum_{j=g+1}^{n} x_{ij}^{*} \quad \text{…………………………………………(1.3)}$$

The best rank is the biggest value.

where n is the number of goals that need to be maximized and g = 1,...,n.

Depending on whether or not is a helpful or unhelpful variable in the decision matrix, the value of can either be positive or negative. The final preference is shown by the ordinal rank. The best choice therefore has the highest value, whilst the worst alternative has the lowest value.

-Multi-MOORA reference point, The ratio system is the foundation of the reference point. In the case of maximizing, the ratios discovered in the ratio system (such as rj =max xij) are used to find the Maximum Objective Reference Point (vector), By recalculating each element of the matrix of normalized responses and assigning a final rank based on departure from the reference point. Then Tchebychev's Min-Max matrix is obtained from the following formula:

$$min_{i}\{max_{j}(|r_{j}-x^{*}_{ij}|)\} \quad \text{……..……………………………………………(1.4)}$$

After identifying each Electricity generation technologies score, the best performing is categorized as the one with the lowest score.

- The Full Multiplicative Form and MULTIMOORA.

In their proposal, “Brauers & Zavadskas” suggested that MOORA be updated using the Full Multiplicative Form technique, which incorporates both maximum and minimization of solely multiplicative utility functions.

$$U_{j}' = Bi^{A} \quad \text{……………………………………………………………….. (1.5)}$$

where $Aj = \varsigma ixgi$ indicates the result of objectives of the i-th option to be maximized.

where $Bj = \varsigma nxkj$ indicates the result of objectives of the i–th option to be minimized.

The beneficial criterions would be multiplied, and when reaching a non-beneficial criterion, we’d divide by it, the resulting figure is the score. The Electricity generation technologies having the largest score is considered the best performing, and the smallest is the worst performing. And the finally funded final Rankings between (Ratio System & Reference Point & Full Multiplication).

3.2.2 CRITIC method for weight distribution

One of the most important parts of a decision problem are variables, or measurement indicators, thus it's critical to define criteria so that you can judge how well each option achieves the intended results. The relative objective weights. The weight of each criterion was determined using the subsequent procedure: First, each criterion's standard deviation was found:

Step 1: fined the best and the worst number of each variable. Then the best value was established as the lowest value for the relevant criterion and the worst value as the highest value for the relevant criterion since this criterion is one that should be minimized. Then fined Normalized Decision Matrix at equation in the following:

$$x_{\bar{ij}} = \frac{x_{ij} - x_j^{worst}}{x_j^{best} - x_j^{worst}} \quad \ldots\ldots (2.1)$$

Where $x_{\bar{ij}}$ is the normalized score of option i with respect to criterion j, xij is the actual score of option i with respect to criterion j, x best jis the best score of criterion j, and x worst j is the worst score of criterion j.

Step 2: Calculating each criterion's standard deviation. according to equation 2.2.

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m} x_{ij} - x_{\bar{j}}}{m-1}} \quad \ldots\ldots (2.2)$$

(S.T) values for every criterion are calculated over the normalized matrix. Here, m is the total number of choices, and xj is the mean score of criterion j.

Step 3: Calculating Correlation Matrix, the correlation between each criterion in the normalized matrix is calculated in this stage, which is also known as the calculation of the correlation between criteria. Each criterion will naturally produce a result of 1 when compared to itself. The symmetry of the matrix is evident. according to equation

$$pij' = \frac{cov(xi, xjF)}{\sqrt{\sum(xi - \bar{x}i)2 \sum(xj - \bar{x}\bar{y}F)2}} \quad \ldots\ldots (2.3)$$

Where $cov(c_j c_j F)$ is the covariance between $x_i, x_j F$, $\bar{x}$ the mean of the values of the $x_i, \bar{y}$ the mean of the values of the x_i.

Step 4: The formula below takes into account the conflict shaped by criterion j relevant to the choice condition established by the remaining criteria.

$$(1 - pij') \quad \ldots\ldots (2.4)$$

We determine sums for each row by column in the symmetric matrix after computing all values for it equations:

$$\sum_{jf=1}^{n}(1 - pij') \quad \ldots\ldots (2.5)$$

Step 5: Using the following multiplicative aggregation formula to combine the previous two measurements, determine the amount of information.

$$Cj = \sigma j \sum_{jf=1}^{n}(1 - p_{ij}f) \ldots\ldots (2.6)$$

Where, j=1, …… N, It is stated that the criterion with a high figure standard deviation and relatively low correlation coefficient is deemed to have the most information and so holds the highest level of importance.

Step 6: Calculating Obtaining weights.

we find the sums of C' from the previous step.

$$ck = \sum_{k=1}^{n} cj \ldots\ldots (2.7)$$

Step 7: Using the following equation, we obtain the normalized objective weights:

Thus, criterion weights are obtained.

$$wj = \frac{cj}{ck} \quad \ldots\ldots (2.8)$$

$$\sum_{j'=1}^{N}(1-p_{ij'})$$

Step 6: Getting measurements We start by calculating the sums of from the preceding phase.

$$c_k = \sum_{k=1}^{n} c_j$$

Step 7: The normalized objective weights are obtained using the equation that follows.

$w_j = \frac{c_{j1}}{c_k}$

3.2.3 VIKOR Method

Steps in the Vikor procedure:

1- Create the decision matrix.

2- Determine to criteria weight

The decision maker's choices are reflected in the criteria weight assigned at this time, which shows the importance the decision maker places on each criterion.

3- Find the optimal and worst-case scenarios in the decision matrix by evaluating each possible value against the set of criteria.

First, we determine the (best & worst) values for each criterion by determining whether they are advantageous or not.

4-Then we determine the weights of the criteria are then determined. You can either use criteria weighing methods such as Critic or engage professionals to calculate the criteria weights. All criterion weights are assumed to be equal in this case. (The total of all weights equals 1).

5-Then we calculate the utility measures, known as S_i for this equation:

$$s_i = \sum_{i=1}^{n} wi\left[\frac{(f_{iymax}) - (f_{iy})}{(f_{iymax}) - (f_{iymin})}\right] \quad \text{............For beneficial criteria (3.1)}$$

$$s_i = \sum_{i=1}^{n} wi\left[\frac{(f_{iy}) - (f_{iymin})}{(f_{iymax}) - (f_{iymin})}\right] \quad \text{.........For non-beneficial criteria (3.2)}$$

Where wi = weight of criteria.

$(f\_ij)max$=$bestvalueintherelatedcolumn$.

$(f\_ij)min$=$worstvalueintherelatedcolumn$.

(f_ij)=$relatedvalueinthedecisionmatrixthatincluderawdata$.

Then we calculate the regret measures, known as (R_i), R_i values are the maximum values on the each row for each alternative,Then we determine (S_i) max, (S_i) min, (R_i) max, (R_i) $minvalues$.Then we calculate Q_i values. v is the weight for the strategy of maximum group utility, whereas (1-v) is the weight of the individual regret. Normally we take this value as 0,5. But it can take any value from 0 to 1.

$$Q_i = v\left[\frac{S_{i-}(S_{i\,min})}{S_{i\,max-}S_{i\,min}}\right] + (1-V)\left[\frac{R_{i-}R_{i\,min}}{R_{i\,max-}R_{i\,min}}\right] \quad \text{......................................(3.3)}$$

Then we rank the alternatives from the minimum value to maximum value

In order to check if the first alternative in our ranking represents the best alternative or not, two following conditions must be satisfied:

C1 = Acceptable advantages

C2 = Acceptable stability in decision making

3.2.4 TOPSIS method

Hwang and Yoon (1981) established the TOPSIS technique understructure in the early 1980s.

When comparing individual variables with one another, the TOPSIS technique adjusts the n-dimensional distance, Euclidian distance (n - number of variables), between the value vectors expressing particular alternatives and vectors reacting to ideal and negative-ideal variations. The optimal alternative is the one whose value vector is closest to the vector of a negative-ideal solution but farthest from the vector of the ideal answer.

Step 1: The normalized decision matrix creation process

$$r_{ij} = \frac{x_{ij}}{\sqrt{(\sum x_{ij}^2)}}$$

Where i =1, ……., m $x_{ij} and\ r_{ij}$ are original and normalization score of decision matrix, respectively

Step 2: Create the decision matrix for weight normalization.

$$v_{ij} = w_j r_{ij}$$

Where w_j is the weight of j criterion

Step 3: Find the solution to the negative notion and the positive ideal.

$$A^* = \{v_1^*, \dots \dots, v_n^*\}$$

Where $v_i^* = \{\max (v_{ij}) if\ j \in J; \min(v_{ij}) if\ j \in J'\}$

Negative idea.

$$A' = \{v_1', \dots \dots, v_n'\}$$

Where $v_i' = \{\min (v_{ij}) if\ j \in J; \max(v_{ij}) if\ j \in J'\}$

Step 4: Measure the distances between each choice.

The following distinguishes the optimal positive alternative:

$S_i^* = [\sum(v_i^* - v_{ij})^2]^{1/2}$

The following distinguishes the ideal from the ideal alternative:

$S_i' = [\sum(v_i' - v_{ij})^2]^{1/2}$

Step 5: Find the degree to which the answer resembles the ideal one.

$$C_i^* = \frac{S_i'}{(S_i^* + S_i')}$$

$$0 < C_i^* < 1$$

Select the Alternative with C_i^* closer to 1.

4. Results

Table Below are the results of the multi-criteria decision analysis by using three methods Multi-MOORA, VIKOR, TOPSIS, and their Comprehensive:

Table 1: Results

	Multi-MooraRanking	Vikor Ranking	Topsis Ranking
NUC	16	14	28
OIL CL	6	7	7
OIL GT	4	4	4
COA CL	8	5	21
COA IGCC	10	6	19
COA IGCC CCS	12	10	18
LIG CL	19	8	32
LIG IGCC	22	9	31
LIG IGCC CCS	25	13	33
GAS STAG	24	21	16
GAS STAG CCS	3	20	11
GAS GT	18	19	8
HYD S	29	29	13
HYD M	30	30	26
HYD L	31	31	27
HYD DAM	28	25	10
HYD PMP	26	24	9
WIND ON	33	33	23
WIND OFF	32	26	17
PV ROOF	21	28	1
PV OPEN	19	27	2
SOL TH	27	32	3
CHP GAS	23	16	14
CHP GAS CCS	13	18	12
CHP COAL	5	1	22
CHP COAL CCS	14	3	24
CHP GAS STAG	15	15	15
CHP COAL BP	9	2	25
CHP STRAW	1	11	5
CHP WOOD	2	12	6
MCFC	10	22	29
SOFC	16	23	30
MCFC BG	6	17	20

5. Discussion

The Multi-MOORA method and Vikor method showed similar ranking results, with little difference. CHP Straw ranked first in Multi-Moora, followed by CHP Coal in Vikor, and Wind On in both methods.

The overall ranking of power generation technologies, including CHP Coal, OIL GT, CHP Coal BP, CHP Straw, and COA CL, reveals Wind ON as the worst performing technology.
The Topsis method analysis ranks Solar PV in three groups: PV Roof, PV Open, and SOLTH, with the last group being fossil-fired power plants Lignite, LIG IGCC CCS, LIG CL, and LIG IGCC.

6. Conclusion

Renewable energy sources are increasingly being considered in power generation technologies to address pressing issues like global warming, carbon removal, emissions reduction, and sustainability. This study aims to determine the best energy production technologies in European countries using multi-criteria decision-making (MCDM) evaluations. The Multi-Moora analysis found that straw and wood as fuel for CHP biomass was the best technique, but safety practices are essential. The Vikor analysis found that turbine coal condensation was the best source of energy, but this may be irrational due to its non-renewable nature. The Topsis analysis revealed that solar energy was the most logical choice, as it is a renewable, environmentally friendly, and sustainable energy source.

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APPENDIX

Appendix 1: Table of Data Expected in Europe 2030

		NUC	OIL CL	OIL GT	COA CL	COA IGCC	COA IGCC CCS	LIG CL	LIG IGCC	LIG IGCC CCS	GAS STAG	GAS STAG CCS	GAS GT
EMPL	MAX	0.16	0.47	0.74	0.86	0.86	0.86	0.21	0.21	0.21	0.65	1.8	0.65
PEAKLOAD	MAX	0.5	5	5	2.5	2.5	2.5	1	1	1	5	5	5
SECURE	MAX	4	1	3	3	3	3	3	3	0	0	0	0
AVAILAB	MAX	0.9	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
GRID COST	MIN	3	3	3	3	3	3	3	3	3	3	3	3
FOOD	MIN	1	1	1	1	1	1	1	1	1	1	1	1
ACC FUT	MIN	4	4	4	4	4	4	4	4	4	2	2	2
ACC PAST	MIN	0.001	0.132	0.132	0.157	0.157	0.157	0.157	0.157	0.157	0.085	0.085	0.085
RADIO	MIN	0.1452	0.0017	0.0019	0.0012	0.0013	0.0005	0.0005	0.0005	0.0002	0.0002	0.0002	0.0002
ENV	MIN	0.015	0.213	0.174	0.186	0.105	0.118	0.13	0.094	0.106	0.077	0.86	0.124
PR COST	MIN	2.653	7.194	9.681	3.203	3.495	4.15	2.135	2.778	3.351	4.519	5.875	6.563
CO2eq	MIN	0.013	0.208	0.435	0.751	0.694	0.154	0.817	0.786	0.106	0.395	0.11	0.62
HEALTH	MIN	0.19	2.39	1.853	1.548	0.93	1.042	1.134	0.934	1.051	0.563	0.62	0.864

HYD S	HYD M	HYD L	HYD DAM	HYD PMP	WIND ON	WIND OFF	PV ROOF	PV OPEN	SOL TH	CHP GAS	CHP GAS CCS	CHP COAL	CHP COAL CCS	CHP GAS STAG	CHP COAL BP
1.2	1.2	1.2	1.2	1.2	0.36	0.36	6.6	6.6	6.6	0.65	1.8	2.01	2.01	0.86	0.86
1.5	1.5	1.5	1.5	1.5	0	0	0	0	0	5	5	2.5	2.5	5	2.5
5	5	5	5	5	5	5	5	5	5	0	0	3	3	0	3
0.8	0.8	0.8	0.91	0.91	0.29	0.5	0.15	0.15	0.15	0.85	0.85	0.85	0.85	0.85	0.85
3	3	3	3	3	4	5	3	3	3	4	4	4	4	4	4
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	2	2	1	1	1	1	1	2	2	4	4	2	4
0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.085	0.085	0.157	0.157	0.085	0.157
0.0001	0.0001	0.0002	0.0002	0.0005	0.0004	0.0022	0.0028	0.0002	0.0002	0.0002	0.0011	0.001	0.0002	0.0012	0.0004
0.016	0.011	0.01	0.02	0.02	0.007	0.006	0.032	0.064	0.007	0.072	0.079	0.167	0.092	0.083	0.183
7.229	4.519	4.519	7.35	7.35	6.019	6.143	25.14	20.829	11.969	4.225	5.45	0.945	1.468	4.134	0.503
0.013	0.009	0.008	0.015	0.014	0.01	0.007	0.056	0.108	0.008	0.366	0.101	0.674	0.119	0.424	0.741
0.198	0.142	0.127	0.245	0.251	0.142	0.173	0.479	1.082	0.105	0.527	0.574	1.406	0.805	0.612	1.555

CHP STRAW	CHP WOOD	MCFC	SOFC	MCFC BG
4.4	4.4	1.8	1.8	1.8
5	5	0.5	0.5	0.5
5	5	3	3	3
0.95	0.95	0.95	0.95	0.95
4	4	3	3	3
2	2	1	1	1
2	2	2	2	2
0.085	0.085	0.085	0.085	0.085
0.0029	0.0028	0.0018	0.0005	0.0027
0.36	0.078	0.167	0.069	0.241
4.751	3.791	7.3	7.08	7.824
0.069	0.057	0.184	0.127	0.326
1.691	0.639	1.958	0.664	3.196