Research of four states in the US with energy compact

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Research of four states in the US with energy compact

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Abstract. In Part I, for problem A, when considering the energy compact among states, Nash Equilibrium in game theory is used to determine the targets for renewable energy use in 2025 and 2050. Based on the original forecasting model, the renewable energy target usage data are obtained by re-predicting. For problem B, three policies are proposed based on the model established, from the perspective of energy production technology, rational allocation of resources and government encouragement. In Part II, a one-page memo about all our work is summarized. Finally, the advantages and disadvantages of our model is analysed.

1. The best four-state energy compact

1.1. Problem A analysis
To optimize the allocation of resources among the states and make rational use of resources, taking energy compact is necessary. Energy cooperation includes technical cooperation and energy sharing. According to the historical analysis from 1960 to 2009, it is found that the overall consumption of energy increases with the economic development year by year. Due to the reserve of fossil fuels, the use of fossil fuels tends to be saturated, and the use of clean energy, such as renewable energy and nuclear energy, is growing rapidly.

About 4 states, TX and CA have super economic and technological capabilities, and are rich in natural resources. Then NM and AZ are weaker in these. Game Theory and Nash Equilibrium are used to find the best four-state energy compact.

1.2. Model theory
Through the historical data to predict the situation of energy compact, the growth factor "g" is added to the uncooperative basis. The size of the growth factor is determined by the scarcity factor.

Scarcity factor shows as:

\[ x_i = \frac{ACF(i)}{ACO(i)} \]  \hspace{1cm} (1)

\[ ACF(i) \] is the average i-th resource consumption of four states.

\[ ACO(i) \] the average i-th resource consumption of one states.

Then:

\[ g = \beta \times \log(x_i) \]  \hspace{1cm} (2)

\( \beta \) is the attenuation factor.
A game “G” is constructed. 
\[ G = \{ S_1, S_2, S_3, S_4; \mu_1, \mu_2, \mu_3, \mu_4 \} \] . S1, S2, S3, S4 mean.

Every states “strategic space”, which is the set of all optional strategies for each game player. 
\[ S_{ij} \in S_i \] is the jth strategy of player i. The benefit of the player i is expressed as a multivariate function of the game strategy.

Finding one strategy portfolio \((S^*,..., S^*)\),
\[ \text{st: } \mu(s^*_{1,1}, s^*_{1,2}, s^*_{1,3}, s^*_{1,4}) \geq \mu(s^*_{i,1}, s^*_{i,2}, s^*_{i,3}, s^*_{i,4}) \quad \forall s_{ij} \in S_i \] (3)
The \((S^*,..., S^*)\) is one Nash Equilibrium of G.

1.3. Results and analysis

The original forecast and renewable energy usage targets results of evaluation of the energy situation after 2010 are as shown in fig 10. AZ1, CA1, NM1 and TX1 are the original forecast data. AZ2, CA2, NM2 and TX2 are energy compact forecast data.

![Figure 1. Two forecast results comparison](image)

The fig.1 says that taking renewable energy usage targets is effective, each state's indicators have improved, especially AZ, the improvement of the energy situation is particularly significant. Specific values of 2025 and 2050 are shown to indicate this result in Tab.3.

| Main indicator       | AZ           | CA           | NM           | TX           |
|----------------------|--------------|--------------|--------------|--------------|
| 2025 original forecast| 0.39338      | 0.698205     | 0.298534     | 0.406472     |
| energy compact       | 0.555397     | 0.770386     | 0.312281     | 0.430185     |
| 2050 original forecast| 0.309873     | 0.664013     | 0.334566     | 0.422248     |
| energy compact       | 0.573221     | 0.752292     | 0.359891     | 0.485106     |

1.4. Actions to meet energy compact goals

The goals set out in the above question A indicate that the development of renewable energy between the states is uneven and state’s renewable energy development is poor. In order to accomplish the goal about renewable energy, the following three policies are proposed.

**Policy 1:** States and states cooperate to develop clean energy production technologies to increase clean and renewable energy production. It will also reduce production costs.
Policy 2: The government can subsidize the renewable energy industry to stimulate the production of renewable energy. And the government should increase taxes on non-renewable and polluting energy industries to increase the proportion of renewable energy in total energy.

Policy 3: States should share their own renewable energy resources reasonably to make the use of renewable energy in various states be at a similar level.

Table 2. Renewable energy usage targets for 2025 and 2050

| Main indicator | AZ         | CA         | NM         | TX         |
|---------------|------------|------------|------------|------------|
| 2025          | original forecast | 0.39338    | 0.698205   | 0.298534   | 0.406472   |
|               | energy compact   | 0.555397   | 0.770386   | 0.312281   | 0.430185   |
| 2050          | original forecast | 0.309873   | 0.664013   | 0.334566   | 0.422248   |
|               | energy compact   | 0.573221   | 0.752292   | 0.359891   | 0.485106   |

2. Memo in Part II
I have the honor to inform you about summarizing the state energy profiles as of 2009, our predictions with regard to energy usage, and our recommended goals for the energy compact to adopt.

During the fifty years since 1969, We can conclude that California has the largest best energy system. And all energy indicators are developing in a balanced manner during these years. Arizona has greatly expanded its economy system especially for crude oil and natural gas and coal production since 1970s. New Mexico had a slow growth in all energy indicators before 1970, but then declined until it began to recover significantly in 1990. Texas had an obvious energy indicators development before 1972, but it continued to decline until 2006, and all indicators seem to be poised for growth. And it’s obvious that each state's main source of energy is non-renewable. Only California and Arizona have a slow increase in the proportion of renewable energy in total energy, the other two states are falling.

In the next forty years, we predict that California's and Texas's total energy production will grow steadily to 2030 and then decline, while Total energy production in Arizona and New Mexico level off until 2050. Total energy consumption in Texas and Arizona has steadily increased to 2050, while California's total energy consumption will decline steadily. And New Mexico's total energy consumption has been steady until 2050. Energy sustainability indicators in California and New Mexico and Texas have steadily increased to 2050, while Arizona's energy sustainability indicators have continued to decline. All four states’ energy structure indicators decline to 2050. This represents the development of energy structure diversity in four states is in the wrong direction. As for their energy economic benefits, we predict that only Arizona can guarantee the current status of energy economic benefits will be maintained. Yet energy economic benefits in the other three states will continue to fall.

We can conclude from the above that the most urgent issue for these states is energy structure and sustainable energy development. so we recommend that all states should attach importance to increasing the diversity of energy structures and increase the development and utilization of renewable energy. And we also can see that energy efficiency is in a negative trend. So every state should try your best to improve energy efficiency through various policy methods. Such as increasing GDP without increasing total energy consumption and in the case of constant GDP, energy consumption should be reduced. When it comes to the energy contract between states and states, we think that California should increase its energy supply to Arizona. And each state should send its own advantage energy to energy-deficient states to increase the diversity of their energy structures.

3. Sensitivity Analysis
In topsis decision model, sensitivity analysis is performed to analyze the influence of the choice of the measure, which is analysis of the closeness of the decision-making goals. Here are six methods selected and results are as follows:
Table 3. Different distance in Topsis

|       | Euclidean | Hamming | Cityblock | Minkowski | Jaccard | Chebychev |
|-------|-----------|---------|-----------|-----------|---------|-----------|
| AZ    | 0.43559   | 0.5     | 0.3897    | 0.43559   | 0.52632 | 0.53332   |
| CA    | 0.71461   | 0.76923 | 0.8258    | 0.71461   | 0.76923 | 0.55828   |
| NM    | 0.12187   | 0.16667 | 0.048477  | 0.12187   | 0.5     | 0.27106   |
| TX    | 0.42074   | 0.5     | 0.37509   | 0.42074   | 0.55556 | 0.45496   |

4. Strengths and weaknesses

4.1. Strengths
- When variable screening, using PCA and manual intervention combined approach. Errors can be reduced and the choice of indicators makes more sense.
- In determining the weight of indicators, the way of combination of subjective and objective empowerment is adopted, weight gained is more effective.
- Using of charts is rich, data expresses straight.
- A variety of prediction methods are used, result is more accurate.

4.2. weaknesses
- Due to limiting knowledge, there are places to consider incomplete.
- Effect on state energy is hard to find accurate quantitative data.

5. Conclusion
In this paper, Nash Equilibrium in game theory is used to determine the targets for renewable energy use in 2025 and 2050 in part I. Based on the original forecasting model, the renewable energy target usage data are obtained by re-predicting. For problem B, three policies are proposed based on the model established, from the perspective of energy production technology, rational allocation of resources and government encouragement. In Part II, a one-page memo about all our work is summarized. Finally, the advantages and disadvantages of our model is analysed.

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