For office use only	Team Control Number	For office use only
T1 ________________	**89417**	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**A**	F4 ________________

2018
MCM/ICM
Summary Sheet

Better Energy Structure, Better Life

Summary

Energy is the foundation of all economic development. With the development of the global economy, people are paying more attention to the importance of the use of clean and sustainable energy. Our mission is to create a model for the governments of the four states of AZ, CA, NM and TX in the southwestern United States to assess the overall energy use. At the same time, we will mainly analyzes the utilization of clean and sustainable energy in each state, predict the future energy utilization according to the model, and set goals and concrete measures for the energy co-operation reached by all four states.

For part I: First, we choose a few variables and outline the energy profiles of the four states. Then the dynamic weighted composite index model is used to build a comprehensive energy index (ECI), used to evaluate the reasonableness of the use of the state energy. Analytic Hierarchy Process (AHP) and Sigmoid function are used to determine the dynamic weight, so that the model can develop over time. Besides, Comparing and analyzing the energy cleanliness indicator and renewable energy indicator of each country's ECI, we find that AZ and CA, NM and TX are two groups with more common ground. Then, based on a comparative analysis of the energy cleanliness indicator and the renewable energy indicator, we think CA has the best energy profile. Additionally, we predict the energy status of the states in 2025 and 2050 using the exponential smoothing algorithm based on available data. Based on our projections, we find that CA will maintain its advantage in energy structure in the decades. But AZ which is similar to CA will slow down its pace of the optimization of its energy structure because of its lack of energy renewable capacity.

For Part II: By predicting the development of each state, we find that with the existing policies unchanged, the share of renewable energy in each state will decrease to some extent and the development of nuclear energy will be relatively slow. Therefore, we formulate corresponding goals and opinions on the utilization of renewable energy and nuclear energy so as to help all states to complete their energy restructuring better.

Keywords: energy; evaluation; composite index model

Contents

1 Overview

1.1 Restatement of the Problem

Energy plays a key role in economic development. And a good energy structure can boost economic growth and social development. In the process of optimizing the energy structure, the energy policy plays a leading role, and the premise of formulating a reasonable policy is to have a correct understanding of the current energy situation and to have a more accurate prediction of the future situation. Therefore, we need to establish the corresponding mathematical model to evaluate a state's energy status, due to people's raising attention on energy cleanliness and renewable, so our model should be able to correctly describe a state's energy structure of clean energy and the development of renewable energy. Through the comparison of the final parameters of the model, we should be able to see the changing process of energy status in a region clearly and analyze its main influencing factors. At the same time, the model should also have the ability to forecast and predict the energy status of the state. The results of the model can help policy makers understand the current energy situation clearly and provide a basis for policy adjustment. Besides, based on the results of the model, they can also provide rationalized proposals for improving the energy structure.

1.2 Related Definition

In order to facilitate the narrative of the paper, we make concrete definitions of clean energy and renewable energy.

- Clean renewable energy: biomass, fuel ethanol, geothermal energy, hydropower, solar thermal energy, wind energy.
- Clean non-renewable energy: Liquefied petroleum gas(LPG), natural gas.
- Non-clean renewable energy: Wood and waste.
- Non-clean non-renewable energy: Coal, all petroleum products(excluding fuel ethanol and LPG)

2 Assumptions

- There is no major volatility in the supply and price of energy during the time period described by the model.
- Existing energy will not be depleted during the time period described by the model.

- Ignore the discovery and use of new energy sources not mentioned in the data.
- Not considering the mutation of the consumption of existing energy for a variety of reasons.

3 Energy Profile for Four States

In this section, we show the total energy consumption (TETCB) in each state and its share of fossil fuels, nuclear energy, renewable energy and clean energy [1]. By plotting the line chart, we can characterize the total energy consumption in each state and the change in the trend of energy Structure, the specific content is as follows:

Figure 1: **The change in TETCB of AZ**

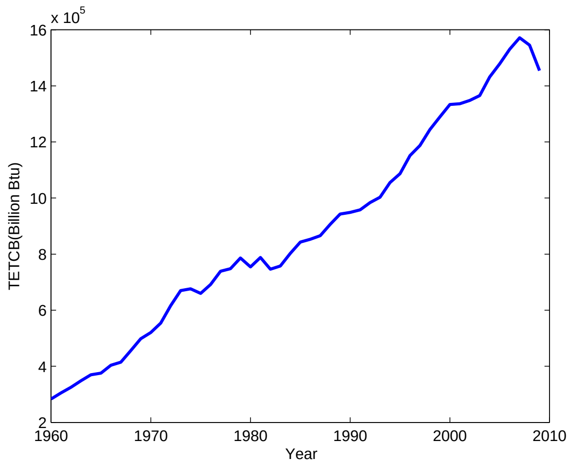
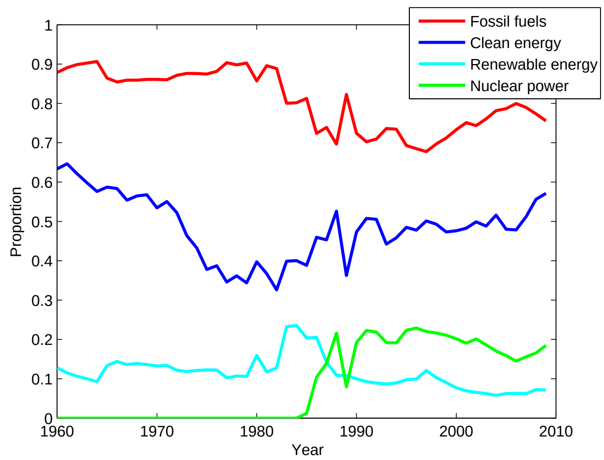


Figure 2: **The change in energy structure of AZ**



First, as we can see from the two figures above, the energy profile of Arizona shows a rapid growth in total consumption. Among them, fossil fuel-based energy, clean energy and nuclear energy are evolving gradually, while the pace of renewable energy development lags behind. What's more, As we can see from Figure 1, the rapid growth of energy consumption in Arizona changed its characteristics in 2007 with a sharp drop. We suspect this is related to the global economic crisis happening then. And the data of the actual GDP given in the attachment also confirm our guess. Finally, from the proportion of the four types of energy sources in Figure 2, we can see that although the proportion of fossil fuels dropped sharply in the 1980s, it started to rise slowly again in the late 90s and keeps at about 80% in recent years. And the proportion of clean energy has been greatly reduced in the 1970s due to a decrease in the use of natural gas, but with the rapid development of biomass, fuel ethanol, photovoltaic solar energy and, most importantly, nuclear energy (After its use in Arizona in 1985, its proportion remained stable at about 20%, becoming an important part of the energy structure), the proportion of clean energy rebounded steadily from 1980 to 2009 and its proportion exceeded 50% in the end. In contrast, the proportion of renewable energy utilization has been slowly declining since the brief growth by leaps in the 1980s and has fallen below 10% since 2000.

Figure 3: **The change in TETCB of CA**

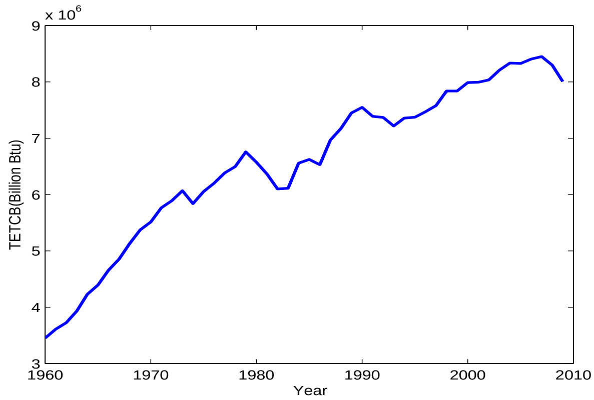
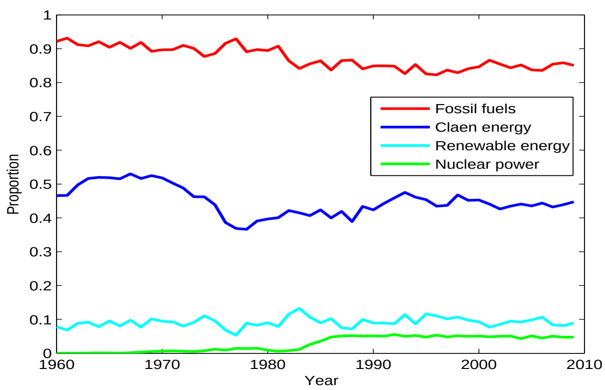


Figure 4: **The change in energy structure of CA**



For California, its total energy consumption keeps growing in general, but the growth rate slows down gradually. And its energy structure remains relatively stable, but the proportion of fossil fuels declines slowly while the proportion of clean energy and renewable energy stay the same. Besides, It is worth noting that the development of nuclear energy undergones a process from non-exist to remaining steady and occupies a certain share of the state's energy structure. Specifically, as shown in Figure 4, the proportion of fossil fuels keeps declining year by year while still maintaining a proportion of more than 80%. At the same time, the proportion of clean energy remains stable above 40% except for a similar decrease as same as that in Arizona in the early 1970s. Similarly, the proportion of renewable energy is also stable at about 10%. Last, as shown in Figure 3 and Figure 4, although the proportions of clean energy, renewable energy and nuclear energy have basically remained stable, the three types of energy sources have indeed developed in the past few decades in view of the growth in total consumption which cannot be ignored.

Figure 5: **The change in TETCB of NM**

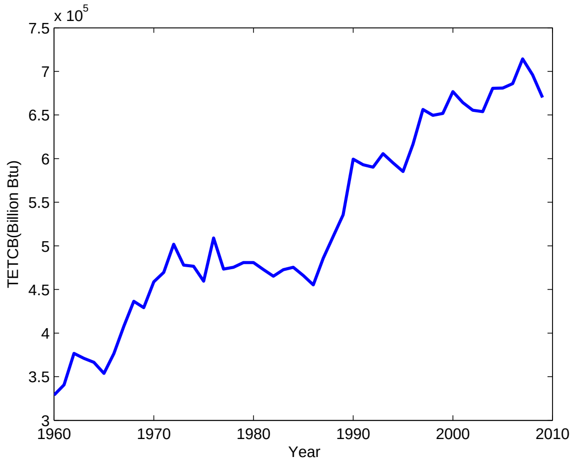
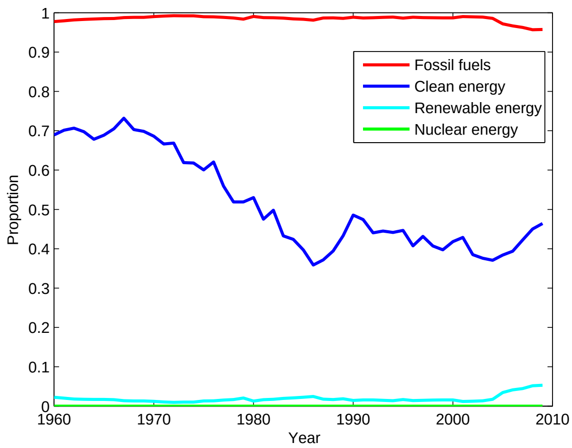


Figure 6: **The change in energy structure of NM**



The total energy consumption in New Mexico has experienced two rapid growth and the groth rate slowed down in the later period. And the state's energy structure is relatively simple, almost all of the energy comes from fossil fuels which absolute dominance the market until know the development of renewable energy started to develop in 2000. Besides, it is noteworthy that the state experienced a period of plateau phase about ten years from the mid-1970s. We speculate that this is due to the fact that the first oil crisis in 1973 caused a large effect on the energy structure in the state. This speculation is also corroborated by real GDP datas and also coincides with the state's energy use. In addition, the state's share of clean energy has shown a significant downward trend, mainly due to the speed of development of clean energy sources such as natural gas and liquefied petroleum gas lags behind the growth rate of total energy consumption.

Figure 7: **The change in TETCB of TX**

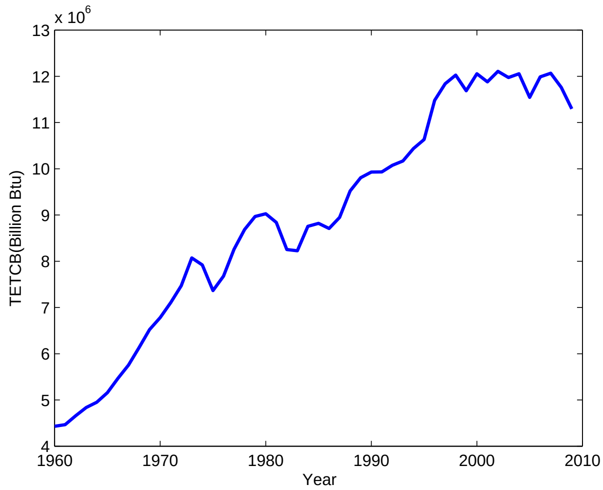
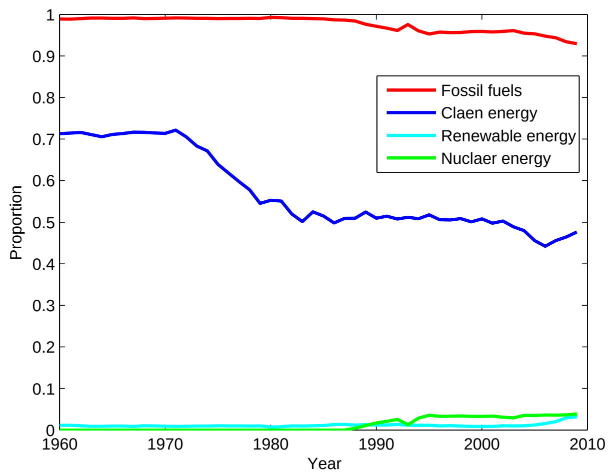


Figure 8: **The change in energy structure of TX**



Texas's total energy consumption increased linearly in the rough before 1995 and reached a plateau in 2000. The state's energy structure is similar to that of New Mexico, where fossil fuels account for almost the entire amount of energy consumed, but the situation has improved gradually with the slow development of renewables and nuclear energy. We noticed the platform period that took place around the year 2000, with reference to the state's real GDP data that we found that the same period of GDP still maintained a steady growth rate as before, so we speculated that the state had a technical revolution in energy efficiency, we will verify this speculation by our future modeling. Besides, the sharp decline in the share of clean energy in the 1970s was broadly in line with the sharp drop in the use of natural gas during the period. And the stabilization subsequently was associated with a rise in the dosage of natural gas and liquefied petroleum gas (LPG).

4 Our Model

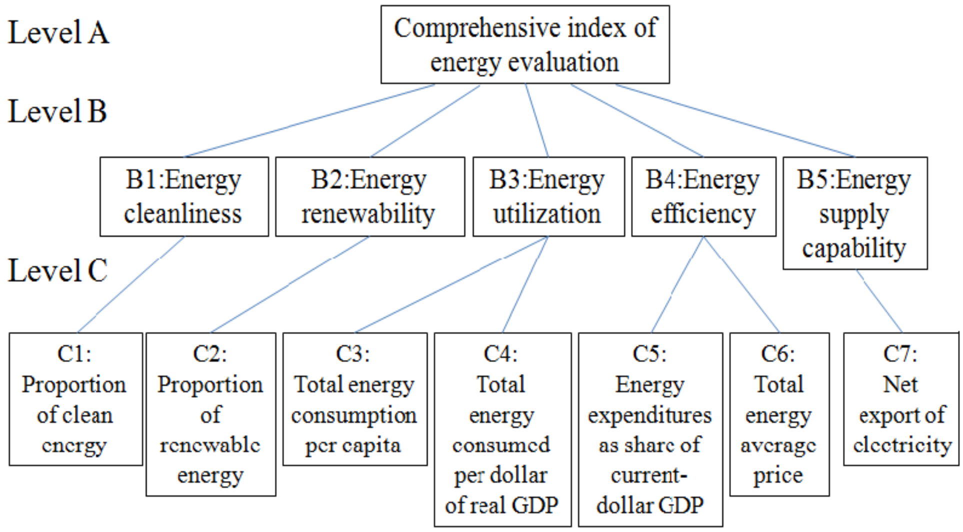
4.1 Dynamic weighted composite index model

4.1.1 The determination and manipulation of Evaluation indicators

By categorizing and filtering the variables contained in the data given in the attachment, we extracted 32 variables from 605 variables that characterize energy production, energy consumption, local economy and population. Finally, after calculating, analyzing and processing the data corresponding to these variables, we come to the following seven indicators for evaluating the energy utilization of each state

- Proportion of clean energy
- Proportion of renewable energy
- Total energy consumption per capita
- Total energy consumed per dollar of real GDP
- Energy expenditures as share of current-dollar GDP
- Total energy average price
- Net export of electricity

In order to facilitate the evaluation, we divided the data into the following three levels:



For the c-level indicators, we divide them into two categories based on their impact on the upper-level indicators, as shown below:

- minimal indicators: C_1, C_2, C_7
- maximal indicators: C_3, C_4, C_5, C_6

In order to unify the impact of these indicators on the upper indicators, we will transform the above four minimal indicators above into maximal indicator, we set the processed indicator to $C_i^{'}$, and the processing formula is as follow:

$$C_i^{'} = \frac{1}{C_i}$$

4.1.2 Standardization of the Indicators

At this point, all seven indicators (C_1-C_7) are maximal indicators, then we use the Range Method to converted C_1-C_7 into values between [0,1], The formula we use is:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}}$$

and the results are shown in 1, we use AZ State as an example.

Table 1: **Standardization of AZ States Indicators**

year	C_1	C_2	C_3	C_4	C_5	C_6	C_7
1964	0.688	0.449	0.121	0.856	0.365	0.125	0.784
1969	0.681	0.684	0.121	0.629	0.365	0.125	0.780
1974	0.371	0.607	0.121	0.566	0.234	0.317	0.776
1979	0.084	0.469	0.174	0.586	0.155	0.068	0.836
1984	0.132	0.992	0.256	0.734	0.209	0.082	0.893
1989	0.112	0.469	0.284	0.740	0.348	0.188	0.857
1994	0.233	0.349	0.366	0.798	0.474	0.368	0.937
1999	0.284	0.364	0.497	0.758	0.689	0.469	0.942
2004	0.342	0.213	0.580	0.797	0.552	0.686	0.991
2009	0.453	0.272	0.661	0.957	0.550	0.659	0.986

4.1.3 Use Sigmoid Function and AHP to Determine Dynamic Weight Function

Since the data of indicators C_5 and C_4 started from 1977, C_6 started from 1970, using the idea of extrapolation, we use the data of C_4 and C_5 in 1977 to supplement the data of which from 1960 to 1976 , similarly, we use the data of C_6 in 1970 to supplement the data of which from 1960 to 1969. There are two indicators that can be described in B3 and B4 separately. So we use the equal-weight method to calculate the relationship between B3 and B4 and their sub-indexes. The formula is as follows:

$$B_3 = \frac{1}{2}C_3 + \frac{1}{2}C_4$$

$$B_4 = \frac{1}{2}C_5 + \frac{1}{2}C_6$$

Because people's understanding of various indicators is subject to the prevailing social environment and cognitive level, we think that a reasonable evaluation criteria should be a time-varying function .Since people's value to B_1-B_5 (five indicators) change with time, so we need to determine the dynamic weight. Since the 1980s, with the people's raising awareness of environmental protection, the demand for cleanliness and renewable energy increase, so, the weight of the cleanliness indicator and the renewable indicator should increase as time passes, but the weight of those two indicators will eventually tend to be a constant. With the innovation of technology and the implementation of the trans-state integrated transmission project, the state's energy supply is ensured. Therefore, the weight of energy supply index should decline over time and also tend to be a constant in the end.

Specifically, with the raising of people's awareness of environmental protection after 1990, a social consensus that requires clean energy has started to take shape. What's more, with the signing of the Kyoto Protocol in 1997, countries gradually increase their demand for energy cleanliness at the political level. Therefore, the growth rates of the weight function w_1 and w_2 should be relatively slow in 1960-1990 and become more and more rapid after 1990 and reach its top in 2000 or so. Over time, the weights should tend to be certain values. At the same time, because the sum of the weight of each factor is 1, so the increase of the weight of one or several factors will inevitably lead to the reduction of the weight of other factors, so the change in the weight of other factors has the opposite trend with w_1 and w_2. So we constructed a Sigmoid-type weighting function to describe it in the following form:

$$S(x) = \frac{1}{1+e^x} \tag{1}$$

In order to determine the constants a and b in the Sigmoid function, we need to know the initial weights and the final weights of the five B-layer indices. Analytic Hierarchy Process (AHP) can be a good solution to this problem. Based on the analysis above, among the positive reciprocal matrixs used to determine the initial weights, the importance of B1 and B2 is less significant, and the importance of B3 , B4 and B5 is more significant, the positive reciprocal matrix is as follows:

$$\begin{bmatrix} 1 & 2 & 1/5 & 1/7 & 1/3 \\ 1/2 & 1 & 1/6 & 1/8 & 1/4 \\ 5 & 6 & 1 & 1/4 & 3 \\ 7 & 8 & 4 & 1 & 5 \\ 3 & 4 & 1/3 & 1/5 & 1 \end{bmatrix}$$

In the positive reciprocal matrix used to determine the termination weight, we increase the importance of B1 and B2. the positive reciprocal matrix is as follows:

$$\begin{bmatrix} 1 & 1 & 1/2 & 1/4 & 3 \\ 1 & 1 & 1/3 & 1/5 & 4 \\ 2 & 3 & 1 & 1/3 & 6 \\ 4 & 5 & 3 & 1 & 8 \\ 1/3 & 1/4 & 1/6 & 1/8 & 1 \end{bmatrix}$$

After checking, the consistency ratio CR of the two matrices is within the allowable range and meets the requirements of AHP. The initial weight and final weight obtained finally are shown in Table 2:

Table 2: **The Initial Weight and Final Weight of B_1-B_5**

	B_1	B_2	B_3	B_4	B_5
Initial Weight	6%	4%	24%	54%	12%
Final Weight	12%	12%	23%	50%	3%

We put the contents of the Table 2 into the formula 1, then we obtain the weight function $w_1(t) - w_5(t)$, as shown below:

$$w_1(t) = 0.06 + \frac{0.06}{1 + e^{t-2000}}$$

$$w_2(t) = 0.04 + \frac{0.08}{1 + e^{t-2000}}$$

$$w_3(t) = 0.24 - \frac{0.01}{1 + e^{t-2000}}$$

$$w_4(t) = 0.54 - \frac{0.04}{1 + e^{t-2000}}$$

$$w_2(t) = 0.12 - \frac{0.09}{1 + e^{t-2000}}$$

Finally, the A-level indicator, the Energy Consolidation Index (ECI), can be expressed as

$$ECI = w_1(t)B_1 + w_2(t)B_2 + w_3(t)B_3 + w_4(t)B_4 + w_5(t)B_5$$

4.1.4 Analysis of Similarities and Differences between States

According to the energy comprehensive index in the previous section, we obtain some more realistic indicators that can evaluate the energy profile of a state in many aspects. In order to analyze the similarities and differences of the energy utilization in each state comprehensively, we give the line charts of the ECI change, the line charts of changes in the energy cleanliness indicator and the line charts of changes in energy renewable indicator separately in each state from 1960 to 2009, then we analysis these three sections comprehensively and compare the energy profile, clean energy and renewable energy usage in each state.

Figure 9: **The change in ECI of four states**

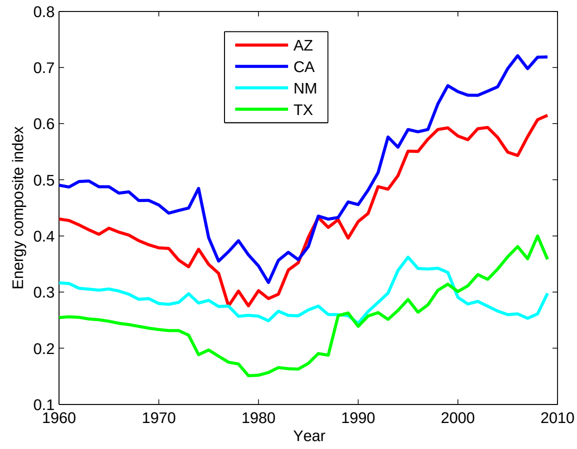


Figure 10: **The change in energy cleanliness indicator of four states**

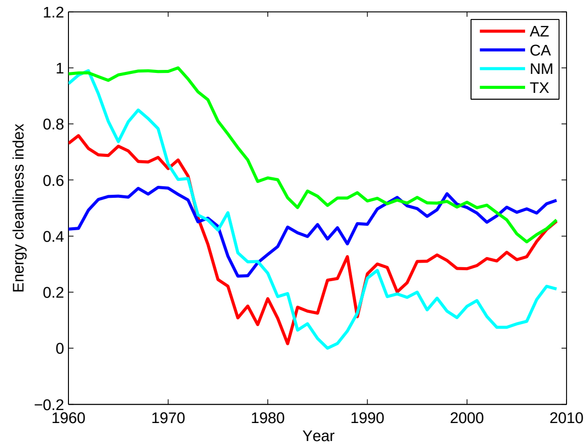
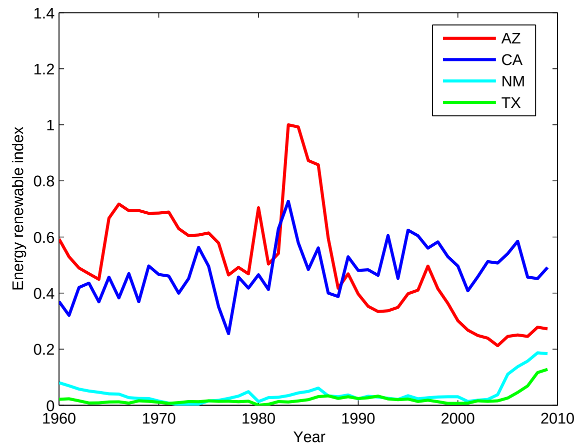


Figure 11: **The change in energy renewable indicator of four states**



As we can see from Figure 9, the ECIs in the AZ and CA states are similar and trend of the changes in the ECLs is very alike, both at a relatively high level for a long period of time and maintained a rapid and steady Growth for 30 years after 1980, which shows that energy utilization in these two states is generally reasonable and improving steadily. WhatâĂŹs more, combining Figure 10 and Figure 11, we can see that the two states also have a strong correlation in the use of clean energy and renewable energy: the energy cleanliness indicator of the two states maintained a steady growth after 1980, the same as the trend of the changes in ECI. So we can see that clean energy in those two states was promoted and developed. Besides, clean energy utilization in the two states has remained at the same high level as ECI.

Figure 12: **The map of AZ and CA**

Much of the common ground between the two states in terms of comprehensive index and the use of clean energy and renewable energy can also be explained in many ways. As can be seen from Figure 12, Arizona is adjacent to California, and because the northern Arizona is the Colorado Plateau with the Rocky Mountains to its east, so the state's road network and major populations are spread to the west which borders California. At the same time, Los Angeles, the port city of California, strengthen the economic relationship between the two states. The economic structure of both states is dominated by high-tech manufacturing. The main energy consumption of high-tech manufacturing industries is electricity. Therefore, the energy structure of the power sector has a greater impact on the energy indicators in these two regions. Besides, by analyzing the energy consumption in the power sector, we can find that the share of oil and coal in the energy consumption of power system in Arizona has been declining for more than 20 years and has dropped below 40% by 2005, while the share of which in California has been steadily Maintained a low figure of 20-30%. And from the GDP data provided, it can be seen that the volume of California's economy is almost eight times that of Arizona, so the driving effect on economic and energy structure due to geographical reasons should not be overlooked.

In addition, according to the model we established, AZ and CA still have some differences. The first is that the ECI of California has been steadily higher than that of AZ and ranks first in the four states, which is in line with the analytical result of the energy cleanliness indicator of the two states in Figure 10. Because our model later magnified the weight of clean energy, so the late fall back of this indicator will have a clear performance in ECI. Second, the ECI growth rate of AZ obviously slowed down after 2000, which is obviously different from that of CA. This is the same trend as that of the changes in the AZ renewable energy indicator in Figure 11, which shows a significant decrease in 2000 or so. This change is also magnified by the dynamic weight in our model.

In contrast, New Mexico and Texas have lower ECIs, meaning less efficient energy use, in connection with the single energy structures in the two states, that is the 90% share of the fossil fuels. As far as clean energy is concerned, we can see from Figure 10 that the trends of the changes in energy cleanliness indicator of the two states have remained highly consistent, that is, they have not recovered since the drastic drop in the oil crisis of the 1970s. We speculate that this is related to the limited source of clean energy: liquefied petroleum gas (LPG). Figure 3 shows that clean energy utilization in the NM and TX states remained at very low levels until 2000. Energy Cleanliness Indicator in those two states began growing rapidly until wind energy started to develop in both states in 2003 and accounted for an ever-increasing share of total energy consumption. Among the two states, the rapid growth of the energy cleanliness indicator of NM also confirmed the upward trend in the changes of ECI in this state in the later period.

The assessment above can also be explained from the economic aspects of the two states. Since New Mexico is located in the transportation hub in the southwestern United States, transportation has always been more developed. And the transport sector consumes about 30% of the total energy consumption, about ten percentage points higher than other state. Petroleum energy is the backbone of the transportation industry and its reliance on petroleum energy limits the rationalization, cleanliness and renewableness of the state's energy structure. Texas is known for its energy and petrochemical industries, which have large coal plants and refineries that consume 20% of their total energy each year and have no clear declining trend according to the data. This economic structure, which is highly dependent on fossil fuels, also explains the reason that the state's energy comprehensive index and the energy renewable indicator are low.

The first difference between NM and TX is that the trend of the changes in the ECI of the two states. After the period of 1990, the ECI of Texas experienced a period of steady growth, while the ECI of NM did not show a significant improvement which is in connection with the trend in the changes of TX energy cleanliness indicator in Figure 10 which has been maintained at a high level in the latter part of the year because natural gas utilization in the TX state is higher than in other states, and the ECI of TX has been stable at 30-40% since the 1980s which has been amplified in our model with the increase in the share of the energy cleanliness indicator.

4.1.5 Determine the Best Profile

Based on the comprehensive evaluation model established, it is clear that the CA state has the best clean energy and renewable energy status among all the states. And this is mainly due to the state's complex energy structure, which includes nuclear, wind, geothermal, hydro and other clean energy sources. Besides, the CA state is the earliest of all four states to start using nuclear energy, indicating that this state attaches great importance to the development of new energy technologies. Our main evaluation criteria are the share of clean energy consumption in the total energy consumption and the share of renewable energy consumption in total energy consumption, that is, the energy cleanliness indicators and energy renewable indicators that we construct. Through these two indicators, we can describe a state's use of renewable and clean energy quantitatively.

4.2 Exponential Smoothing Method

According to the data of the four states known from 1960 to 2009, it can be seen from the theme that no adjustment will be made to the energy policies of the four states. Therefore, no new energy can be considered and the existing energy utilization will be Continue to develop according to the current development. According to the actual situation of each data, we analyze that for the prediction of energy usage-related parameters over time, the closer the data to the predicted time point, the greater the impact on the predicted data, and the data is calculated by year, ignoring the changes in the data that vary from season to season, so it is more suitable to use exponential smoothing method to predict the value of each parameter, the exponential smoothing method increase the impact of the observation of the recent observations on the forecast by increasing the weight of the observation of the recent observations, making the forecast reflect the overall trend of the data quickly. The specific method is to use the FORECAST.EST function in EXClE to achieve the predicted value of the typical data when the confidence interval is 95%. The following is a partial forecast of the data:

Table 3: **Total energy consumption forecast(Billion Btu)**

year	AZ	CA	NM	TX
2010	1491912	8025974	710257.2	11402879
2015	1619222	8124804	740304.8	11930221
2020	1746532	8223634	770352.3	12457563
2025	1873842	8322464	800399.9	12984905
2030	2001152	8421294	830447.4	13512246
2035	2128462	8520123	860495.0	14039588
2040	2255772	8618953	890542.6	14566930
2045	2383082	8717783	920590.1	15094272
2050	2510392	8816673	950637.7	15621614

Table 4: **Fossil fuels consumption forecast(Billion Btu)**

year	AZ	CA	NM	TX
2010	1306178	6000751	805679.4	10449263
2015	1281797	6244195	823794.3	10666848
2020	1257417	6487639	841909.3	10884433
2025	1233036	6731083	860024.3	11103018
2030	1208655	6974527	878139.2	11319603
2035	1184274	7217971	896254.2	11537188
2040	1159893	7461415	914369.2	11754773
2045	1135512	7704859	932484.2	11972358
2050	1111132	7948303	950599.1	12189942

Table 5: **Nuclear power consumption forecast(Billion Btu)**

year	AZ	CA	NM	TX
2010	269872.7	336116.1	0	433608.8
2015	300759.3	348790.3	0	451390.2
2020	331645.8	361464.5	0	469171.7
2025	362532.4	374138.8	0	486953.1
2030	393418.9	386813.0	0	504734.6
2035	424305.5	399487.2	0	522516.0
2040	455192.0	412161.4	0	540297.5
2045	486078.5	424835.7	0	558078.9
2050	516965.1	437509.9	0	575860.3

We use the typical data predicted by exponential smoothing method to adjust the original comprehensive evaluation model. This adjustment is about that during parameter standardization, the maximum value and the minimum value of each parameter need to be considered. And after the prediction, the maximum value and the minimum value of the parameter may change, so the parameters need to be re-standardized. At the same time, sometimes it will appear that the parameter values do not fit the actual situation when using the exponential smoothing method. By setting the upper and lower limits for each parameter, the parameter values will keep within a reasonable range. And for the predicted value which beyond the upper limit or the lower limit, The upper or lower boundary values are used to predict the value of the parameter.

After adjustment, we get a new comprehensive evaluation index. The way of establishing the comprehensive evaluation model is the same as that of solving problems above, so we will not describe it in detail here. The following are the predicted energy composite indices, energy cleanliness indicators and energy renewable indicators in some years:

Table 6: **Energy composite index forecast**

year	AZ	CA	NM	TX
2010	0.361	0.520	0.323	0.193
2015	0.363	0.505	0.328	0.179
2020	0.365	0.512	0.334	0.187
2025	0.368	0.505	0.341	0.200
2030	0.372	0.530	0.349	0.215
2035	0.377	0.517	0.360	0.236
2040	0.384	0.526	0.373	0.268
2045	0.401	0.545	0.393	0.339
2050	0.424	0.567	0.427	0.351

Table 7: **Energy renewable indicators forecast**

year	AZ	CA	NM	TX
2010	0.431	0.511	0.370	0.479
2015	0.467	0.512	0.360	0.469
2020	0.503	0.513	0.350	0.458
2025	0.539	0.514	0.341	0.448
2030	0.575	0.515	0.331	0.438
2035	0.611	0.515	0.321	0.428
2040	0.647	0.516	0.311	0.417
2045	0.683	0.517	0.301	0.407
2050	0.719	0.518	0.292	0.396

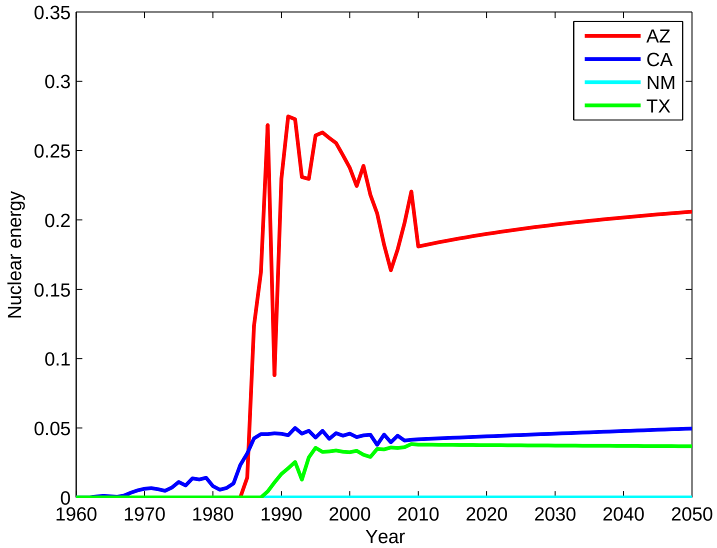
Table 8: **Energy cleanliness indicators forecast**

year	AZ	CA	NM	TX
2010	0.391	0.123	0.043	0.026
2015	0.328	0.105	0.044	0.031
2020	0.265	0.114	0.045	0.036
2025	0.203	0.104	0.046	0.042
2030	0.140	0.131	0.047	0.047
2035	0.077	0.111	0.048	0.053
2040	0.015	0.112	0.049	0.058
2045	0	0.122	0.050	0.064
2050	0	0.121	0.051	0.069

5 Model Application

Based on the predictions above, we can see that the state of CA still maintains its advantage over other states during the period from 2010 to 2050 clearly. Besides, the state's energy structure is continuously optimized and its main growth momentum is the use of the renewable energy. The state's major renewable energy sources are hydropower, biomass and geothermal energy. And the use of these renewable, clean sources of energy plays a key role in the state's energy structure optimization. However, we also notice some problems. According to the forecast, the changes in proportion of nuclear energy in total energy consumption over time from 2009 to 2050 as shown in Figure 13:

Figure 13: **The changes in proportion of nuclear energy**



As we can see from the figure, AZ state's nuclear energy accounts for the highest proportion of total energy consumption, accounting for about 20%, but because of the less total energy consumption in AZ, so the actual use of nuclear energy is not high. The proportion of nuclear energy of total energy in the CA and TX states is around 4%, indicating that nuclear energy utilization in these two states is relatively low, and its growth rate is in line with the growth rate of total energy. In 2009, NM states did not start using nuclear energy, so in the forecast, nuclear energy accounted for 0. Considering that nuclear energy is a clean energy source and nuclear energy can be used by human for a long time due to its characteristics, nuclear energy is evaluated valuable resources from the standpoint of energy sustainability (similar to renewableness) , cleanliness and economy. However, it is not well utilized at present. At the same time, taking the depletion of the fossil fuels into account, so the states should gradually reduce the proportion of fossil fuels in total energy consumption, and nuclear energy is an ideal alternative energy. In the light of the states above, we set the following goals:

- The states should increase the share of their nuclear energy in total energy consumption. By 2025, the proportion of nuclear energy in total energy consumption in the state of AZ should reach 25%; the state of CA, TX reaches 10%; and the state of NM should reach 5%. By 2050, the proportion of nuclear energy should reach 30% of the total energy consumed.
- TX, NM states should change the situation of the single energy structure, and the energy resources of the four pillar industries in the two states should contain 25% of renewable energy in 2025. In 2050, the proportion of which should reach 50%.
- All four states should gradually reduce the proportion of coal used in the power industry. TX state should reduce the proportion of coal in power fuel to 20% by 2025 and reduce it to 0% by 2050, Completely stopping using coal as fuel power. In all other three states, coal-fired power generation should cease by 2030.

6 Strengths and weaknesses

6.1 Strengths

- Comprehensive evaluation model can not only macroscopically describe the overall trend of energy structure in each state, but also can clearly describe the impact of each of these factors on the overall evaluation index.
- The dynamic weight function is applied in constructing the comprehensive index, taking into account the variation of the weights of different factors over time. Because of being in different stages of development, the

understanding of the various characteristics of energy will change. For example, in the early stages of development, more consideration was given to the economics of energy rather than the cleanliness and renewables of energy.

- Exponential smoothing method is used to predict the value of each parameter. Exponential smoothing method increases the influence of the observation value of recent observations on the prediction value by increasing the weight of the observation value in the recent observation period, so that the prediction value can quickly reflect the trend of the change in whole data.

6.2 Weaknesses

- The standardization of indicators uses range method, so the normalized values are related to the maximum and minimum values of the entire set of data. When predicting a parameter, if add a parameter, the maximum and minimum values of the entire data set may be changed, so that the value after parameter normalization is changed. Therefore, it is not very intuitive to compare the values of the composite index obtained before and after the increase of data.
- The smoothness index model is more suitable for short-term prediction. The prediction error accumulates with the increase of the forecasting time, so there may be uncontrollable errors in the long-term prediction.

7 Memo

To: Governor of a state From: Team 89417 Re: Energy Use

Dear Sir/Madam:

Nowadays,people pay more and more attention to the cleanliness and renewability of energy. Therefore, our modeling team studied the energy data of the four states from 1960 to 2009, comprehensively evaluated the energy status of the four states, and predicted the future energy status of the four states, putting forward some suggestions.

Our data analysis shows that from 1960 to 2009, the total energy consumption in all states increased substantially, of which fossil fuels accounted for the largest proportion. With the use of new energy sources , the share of renewable energy of the total energy in both CA and AZ states has increased. Due to the relatively simple energy structure of NM and TX, the main energy sources are fossil fuels, so the level of the cleanliness of energy and the renewable energy are lower. The analysis shows that over time, the state of CA has the best energy profile among four states.

We then forecast the energy status of the four states in the future. The forecast results show that the state of CA still maintains its advantages in energy status, mainly due to the fact that the proportion of renewable energies such as wind energyïijŇ hydropower and electricity in the energy structure in the CA is increasing according to the trend of development, and the other three states' energy profiles are also slowly improving, but overall, the share of total renewable energy in total energy consumption is still small. Nuclear energy as a promising clean energy source is not used by the states except for AZ state.

In response to the analysis and forecasting above, we have formulated phased development goals for the four states. Goals require states to increase their share of nuclear energy use of total energy use. By 2025, the proportion of nuclear energy in total energy consumption in the state of AZ should reach 25%; the state of CA and TX should reach 10%; and the state of NM should reach 5%. By 2050, the proportion of nuclear energy in total energy consumption in all four state should reach 30%.

In order to achieve the goal, we have the following specific suggestions. First, considering the cleanliness, renewability and economy of energy sources, we should develop the nuclear power industry and increase the proportion of nuclear energy in the total energy consumption. Second, develop clean and renewable energy according to local conditions, all four states should vigorously develop clean energy such as wind energy, geothermal energy and hydropower.Finally, I hope our model and advice can help to improve the energy situation in your state.

Respectfully

Team 89417

References

[1] Zhonghua Zhao . Research on evaluation methods of clean energy in Chinese cities [D]. Beijing university of chemical technology,2007.

[2] Jing Qin. Evaluation index and method of rural energy system [D]. Lanzhou university,2011.

[3] Chunyan Wang . Research and application of energy structure optimization index system in Qingdao [D]. Qingdao university,2012.

[4] `https://www.eia.gov/state/seds/sep_use/notes/use_a.pdf`