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T4 ________________	**C**	F4 ________________

2018
MCM/ICM
Summary Sheet

A Four-State Energy Compact

Summary

Energy is an important support of modern economy. In our paper, we construct a model defining the four-state energy compact integrating variables to process data, and succeed in characterizing the engergy profile by proportion and growth rate.
First, we integrate variables and make engergy profile shown as an area chart. We develop Energy Profile Model composed of Energy Proportion Model and Growth Rate Model.To obtain the proportion of energy in each state over time, we further simplify variables to fossil fuels energy, renewable energy and nuclear energy. After using sinusoidal model to fit cures, we get the function expressions between prportion and time. We use Moving Average in Time Series to get 1963-2007 energy consumption. We establish Growth Rate Model in similar way.
Next, we choose sector (industry，commerce and residential industries) and population to discuss influential factors of the similarities and differences about the four states’ usage of cleaner, renewable energy sources. Thus we define the impact factor.The similarity is that the ratio of impact factors of AZ, NM, TX is 3.412 : 1 : 1. We use the IPAT formula and the revised ” Laspeyres” exponential decomposition method to analyze the impact of population growth.
Then, we select the average price, import expenditure size and size of productivity of power as the evaluation criteria. And use analytical hierarchy process (AHP) to determine their weights. In 2009, Texas had the ”best” have the “best” profile for use of cleaner, renewable energy whose total sort weight is 0.4043. We give two kinds of predictive values of the energy profile of each state for 2025 and 2050 based on two models.
Finally, we state that the average price of electricity should be set at about 28.26 dollars in 2025 and 34.97 dollars in 2050 as the goal for this new four-state energy compact. We discuss three actions the four states might take to meet their energy compact goals.

Keywords: Renewable Energy, IPAT, AHP, Time Series, Electricity

Contents

1 Memo

To: The group of Governors From: Team # 89307 Date: 12 February
Subject: A Four-State Energy Compact
Our team has summarized the state profiles as of 2009. Mathematical models are built to illustrate it.
In each state, the growth of energy consumption keeps the energy structure from small to large scale, with the proportion of cleaner, renewable energy sources increasing.
In New Mexico(the smallest energy consumption), oil and petroleum products, coal and natural gas are the main component.
In Texas(the largest energy consumption), oil and petroleum products and natural gas have always dominated. The proportion of biomass and wind energy is very low.
We predict the energy consumption of four states by Energy Proportion Model and Growth Rate Model. By Energy Proportion Model, the total energy consumption of AZ in 2025 is 2320000, of which 9.4% is Renewable energy. The most states' proportion of renewable energy is 8% in 2025. By Growth Rate Model, the most states' proportion of renewable energy is 9%. When it is 2050, the former is 12%(excluding the data of AZ) while the latter is 11%.
So the results of our models can be referred. And we find the average price of electricity of the four states in 2025 and 2050 are 35.32732299 and 43.71283002 based on our models. Therefore, the average price of the four states in 2025 should be set at about 28.26(80% of the predictive values absent any policy changes) dollars.
In 2050 the average price should be set at about 34.97(80% of the predictive values absent any policy changes) dollars. We state it as the goal for this new four-state energy compact.

2 Introduction

2.1 Restatement of the Problem

Energy is an important support of modern economy. It turns to be the material basis for the survival of human society, and it plays an indispensable role in promoting the economic and social development.[4] With the economic development and fast population growth，the demand for energy grows larger and larger，energy consumption increases substantially，and the traditional energy resources decline day by day，which can not meet the needs of economic development. So the United States in need of new energy to satisfy the increasingly growing demands for energy consumption，in addition，it can construct environmentally friendly country.
There are four states –California (CA), Arizona(AZ), New Mexico (NM), and Texas (TX) –that wish to form a realistic new energy compact focused on increased usage of cleaner, renewable energy sources.
We need to provide an energy profile for each of the four states using the data given and develop a model to describe how the energy profile. Then we are required to address the results of our model to provide a concise description for the similarities and differences between the four states.We also should select the credible criteria to determine the 'best' profile for usage of cleaner, renewable energy in 2009 and predict the energy profile of each state for 2025 and 2050 in the absence of policy based on the historical development and our understanding of the profile.
Then we are supposed to determine renewable energy usage for 2025 and 2050 and necessary actions to meet the goals for new renewable energy compact. Finally, we should prepare a memo to the group of Governors summarizing the state profiles.

2.2 Overview of Our Work

The flow chart of the whole model is presented below in Figure 1:

3 Assumptions and Notions

3.1 General Assumptions

- We mainly consider the consumption of fossil fuels, renewable energy and nuclear ernergy. At the same time, we consider the proportion of fossil fuels, renewable energy and nuclear energy.
- We do not consider energy loss such as the loss of electricity system and co-product fuel ethanol when calculating renewable energy costs because of lack of price data.
- We assume that the electricity is often consumed in time, and the electricity stored in the battery will be consumed by the commercial sectoer.

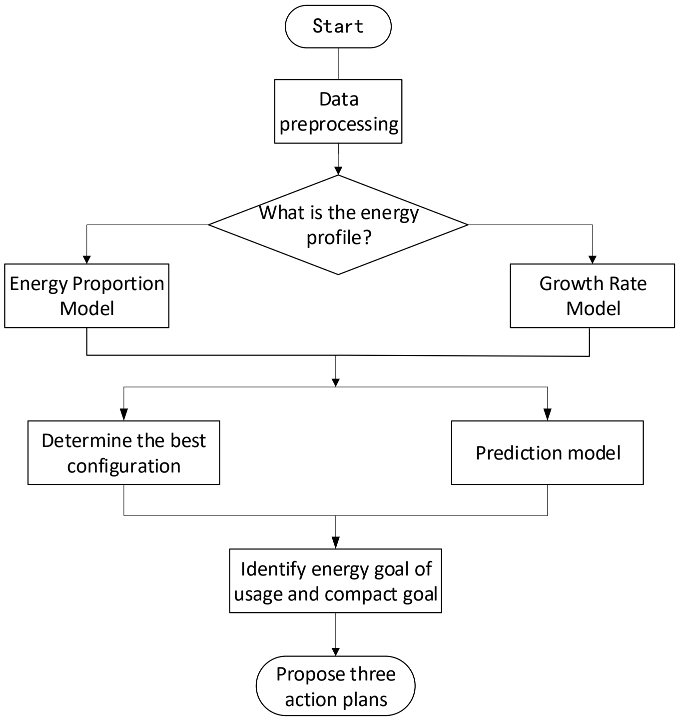


Figure 1: Flow Chart Demonstration of the Model

- We do not take the electricity producted from fossil fuels into consideration because we do not know the efficiency of the conversion of various of fossil fuels into electricity.
- We consider various types of renewable energy, nuclear energy will be converted into electricity.
- We approximate the sum of renewable energy production，electricity produced from nuclear energy，net imports of electricity into the United States and net interstate sales of electricity and associated losses (negative and positive values) as electricity total consumption.
- When considering the proportion of various of energy, we mainly focus on fossil fuel energy, renewable energy and nuclear energy because there is an overlap between electricity consumption and the energy described above.
- We ignore the impact of the world energy reserves and trade patterns.

Abbreviation	Description
A	Per capita GDP, is defined as the quotient of GDPRX over TPOPP
$P(t)$	The proportion of certain types of energy at the end of year t
$Q(t)$	The impact factor of certain types of sector at the end of year t
$c(t)$	The fitting consumption of certain types of energy at the end of year t
$v(t)$	The growth rate of certain types of energy at the end of year t
$rc(t)$	The real consumption of certain types of energy at the end of year t
$TC(t)$	The consumption of total energy at the end of period t

3.2 Notations

4 Energy Profile Model

In this section, we derive a model to characterize how the energy profile of each of the four states has evolved from 1960 -2009, called the energy profile model. Specially, we state total energy consumption as the sum of fossil fuels energy, renewable energy and nuclear energy.

4.1 Integrat variables

First, we address the data according to the integrity and redundancy of the information. We divide energy into 4 major categories and 11 minor categories like what displayed in Table 1. Then, we analyze the 50 years of data in 11 variables on each of these four states' energy production and consumption. Since all forms of energy tend to eventually be converted into electricity, we temporarily ignore the effects of electricity imports and exports. To simplify the problem, we ignore trade between each state in the United States too. Fuel ethanol, wood and waste are partially coincidental with biomass.So we choose biomass as a representative.

Note: $PMTCB$ represents all petroleum products total consumption excluding fuel ethanol.
Note: we only use data from the provided excel table and that mentioned in the pdf file.

$$FFTCB = CLTCB + NNTCB + PMTCB \tag{1}$$

$$PMTCB = PATCB - EMTCB \tag{2}$$

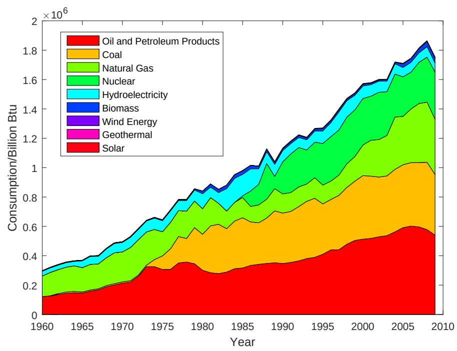
However, after screening the data, we found that, judging from the order of magnitude difference, fuel ethanol(excluding denaturant) accounts for a very small percentage of fossil fuels.The maximum was produced in California in 2009, but not more than 1.5%.(AZ:1.48%,CA: 1.37%,NM: 0.51%,TX: 0.64%)At the same time, we found loss of the cost of all petroleum products total consumption excluding fuel ethanol. Therefore, we use $PATCB$ rather than $PMTCB$ in Equation 3.

$$FFTCB \approx CLTCB + NNTCB + PATCB \tag{3}$$

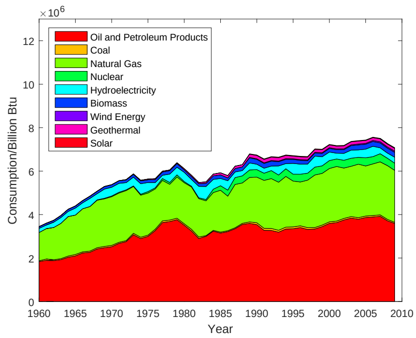
minor categories	MSN	major categories(MSN)
Oil and Petroleum Products	PMTCB	
Coal	CLTCB	Fossil Fuels(FFTCB)
Natural Gas	NNTCB	
Nuclear Energy	NUTCB	Nuclear Energy(NUTCB)
Hydroelectricity	HYTCB	
Biomass	EMLCB+EMTCB	
Wind Energy	WYTCB	Renewable Energy(RETCB)
Geothermal Energy	GETCB	
Solar Energy	SOTCB	
Electricity	ESTCB	Electricity(ESTCB)

Table 1: Energy Categories

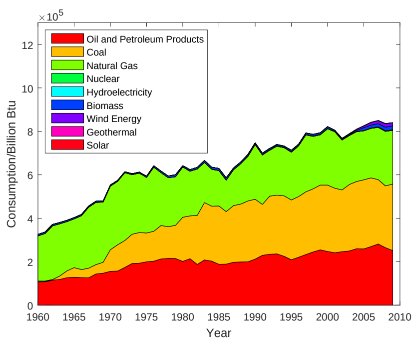
We analyze the data and use energy consumption as an indicator of energy profile in four states.
Then the energy configuration analysis we established is shown in Figure 2 as an area chart. (code seen in Appendix 1)
The four states has been ranked from low to high according to the total energy consump-



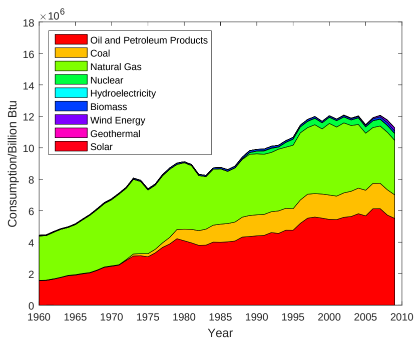
(a) Energy Structure of AZ



(b) Energy Structure of CA



(c) Energy Structure of NM



(d) Energy Structure of TX

Figure 2: Four-State energy profile

tion.

- In New Mexico, oil and petroleum products, coal and natural gas are the main component.New Mexico's total energy consumption is the least in the four states.
- In Arizona, fossil fuels have always dominated, still accounting for well over half in 2009.Although there are fluctuations, hydroelectricity and biomass have been to maintain a certain amount of consumption.
- In California, oil and petroleum products and natural gas also are the main component. California's energy is diverse, whose energy consumption structure include hydroelectricity, biomass, wind energy, and geothermal.
- In Texas, oil and petroleum products and natural gas have always dominated.The proportion of biomass and wind energy is very low.

4.2 Analysis Model

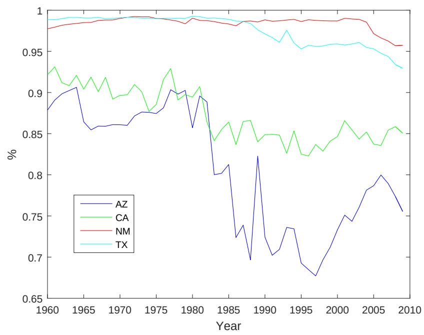
4.2.1 Energy Proportion Model

Because electricity is often consumed in time, the electricity stored in the batteries will be consumed by the business. And fossil fuels energy, various types of renewable energy (except biomass, mainly fuel ethanol) and nuclear energy will be converted into electricity, we choose fossil fuels energy, renewable energy and nuclear energy to address data.
Through the analysis and integration of the data, we get the proportion of fossil fuels energy, renewable energy and nuclear energy in each state over time as shown in Figure 3.

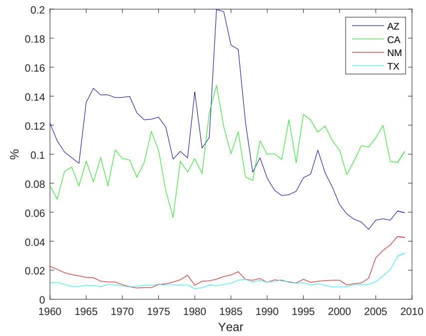
Let the proportion of energy be $P(t)$. We set the proportion of fossil fuels energy, renewable energy and nuclear energy as $P_{FF}(t)$, $P_{RE}(t)$ and $P_{NE}(t)$.
Based on Equation 3, we give the conditions as follows:

$$\begin{cases} P_{FF}(t) + P_{RE}(t) + P_{NE}(t) = 1, \\ P_{FF}(t) \geqslant 0, \\ P_{RE}(t) \geqslant 0, \\ P_{NE}(t) \geqslant 0. \end{cases} \tag{4}$$

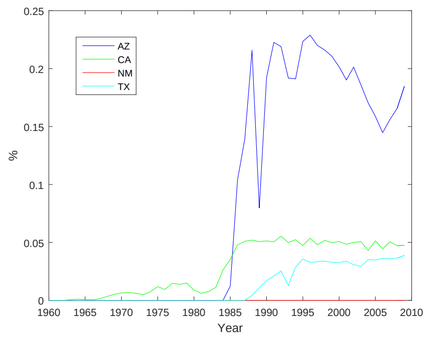
Thus, we can figure out $P(t)$. By using sinusoidal model to fit, we get the function expressions between prportion and time. R-square List = [0.855, 0.8152, 0.8767, 0.9611, 0.8417, 0.2596, 0.8203, 0.6865, 0.7012, 0.9439, 0.8733] (code seen in Appendix 2)Most of R-squares are more than 0.8152, so the fuction $P(t)$ determined by sinusoidal model is very reasonable.
According to the proportion model, the proportion of fossil fuels in CA,NM and TX is stable over time, while AZ' s has a large fluctuation and instability.
When considering renewable energy, the volatility of renewable energy in AZ is large while CA' s is stable. In nearly six years, the proportion of renewable energy in NM and TX is gradually increasing, which show steady increasement of the renewable energy development momentum.
Nuclear energy accounted for basic stability over time, and has showed a trend of growth.
The followings are the fitting formulas for the three types of energy proportion under the influence of policy, economic cycle and other factors.



(a) The proportion of fossil fuels energy



(b) The proportion of renewable energy



(c) The proportion of nuclear energy

Figure 3: The proportion of energy in each state over time

- Fossil Fuels Energy

$$AZ : P_{FF}(t) = 5.017\sin(0.0009969t + 126.7) + 0.05704\sin(0.2216t - 185.5) \quad (5)$$
$$CA : P_{FF}(t) = 0.9382\sin(0.003223 + 121.2) + 0.02213\sin(0.1233t + 10.23) \quad (6)$$
$$NM : P_{FF}(t) = 1.177\sin(0.02632t + 75.04) + 0.1912\sin(0.06945t + 118.3) \quad (7)$$
$$TX : P_{FF}(t) = 0.9915\sin(0.009547t + 108.4) - 0.005761\sin(0.2997t - 344.7) \quad (8)$$

- Renewable Energy

$$AZ : P_{RE}(t) = 0.1324\sin(0.04229t + 43.67) + 0.0211\sin(0.3172t - 376.8) + 0.02394\sin(0.4863t + 54.64) \quad (9)$$

$$CA : P_{RE}(t) = 0.1392\sin(0.05312t + 21.74) + 0.03919\sin(0.115t + 27.81) + 0.006153\sin(0.2602t6.156) \quad (10)$$

$$NM : P_{RE}(t) = 0.03235\sin(0.07386t - 19.74) + 0.03528\sin(0.1421t - 26.3) + 0.0202\sin(0.198t + 117.2) \quad (11)$$

$$TX : P_{RE}(t) = 0.02556\sin(0.04159t + 43.83) + 0.01253\sin(0.08998t + 76.51) + 0.003882\sin(0.2536t + 6.431) \quad (12)$$

- Nuclear Energy

$$AZ: P_{NE}(t) = 0.728\sin(0.02875t + 200.4) + 0.2046\sin(0.1376t + 249.5) \tag{13}$$
$$CA: P_{NE}(t) = 0.0606\sin(0.03157t + 63.55) + 0.01022\sin(0.2172t - 173.5) \tag{14}$$
$$TX: P_{NE}(t) = 0.0377\sin(0.07327t + 149.9) + 0.004349\sin(0.3589t - 123.7) \tag{15}$$

Note:Because there is no nuclear power plant in NM, we think its nuclear energy proportion is always zero.

4.2.2 Growth Rate Model

For a given state, we describe the state's energy development by defining variables for growth rates.
Now define the concept of growth rate, set the growth rate v as a function of year(time).

$$v(t) = \frac{c(t) - c(t-1)}{c(t-1)} \tag{16}$$

We use Moving Average in Time Series to get 1963-2007 energy consumption called $c(t)$[5], whose goal is to eliminate stochastic disturbances and year-to-year interactions. And we take the real consumption called rc from the excel table.

$$c(t) = \frac{\sum_{i=t-2}^{t+2} rc(t)}{N}(N = 5), \qquad i \geq 3 \tag{17}$$

Thus, we can figure out $v(t)$. By using sinusoidal model to fit, we get the function expressions between growth rate and time. Most of R-squares are more than 0.653, so the fuction $v(t)$ determined by sinusoidal model vis very reasonable.(code seen in appendices 3)

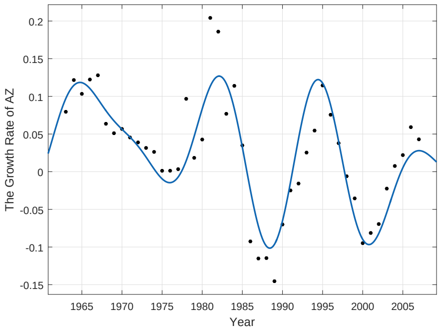
- The Growth Rate of Renewable Energy

$$\begin{aligned} AZ: v(t) = 0.1324\sin(0.04229t + 43.67) + 0.0211\sin(0.3172t - 376.8) \\ + 0.02394\sin(0.4863t + 54.64) \end{aligned} \tag{18}$$

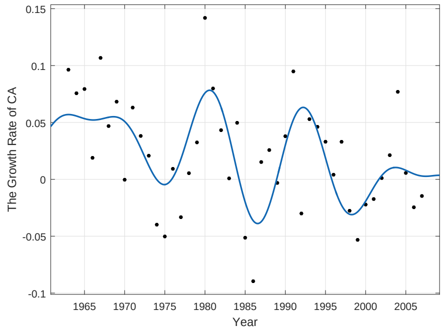
$$\begin{aligned} CA: v(t) = 0.1392\sin(0.05312t + 21.74) + 0.03919\sin(0.115t + 27.81) \\ + 0.006153\sin(0.2602t6.156) \end{aligned} \tag{19}$$

$$\begin{aligned} NM: v(t) = 0.03235\sin(0.07386t - 19.74) + 0.03528\sin(0.1421t - 26.3) \\ + 0.0202\sin(0.198t + 117.2) \end{aligned} \tag{20}$$

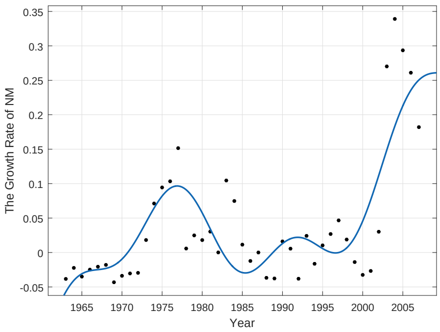
$$TX : v(t) = 0.02556\sin(0.04159t + 43.83) + 0.01253\sin(0.08998t + 76.51) + 0.003882\sin(0.2536t + 6.431) \quad (21)$$



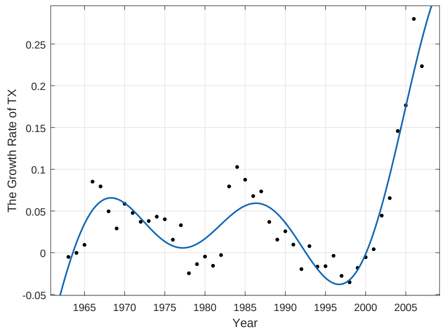
(a) Growth rate of energy consumption of AZ



(b) Growth rate of energy consumption of CA



(c) Growth rate of energy consumption of NM



(d) Growth rate of energy consumption of TX

Figure 4: Four-State growth rate of energy consumption

- The Growth Rate of Fossil Fuel Energy

$$AZ : v(t) = 0.03936\sin(0.04589t + 49.21) + 0.0287\sin(0.2133t - 142.3) + 0.009263\sin(0.431t - 289.9) \quad (22)$$

$$CA : v(t) = 0.03393\sin(0.0602t + 21.27) + 0.02562\sin(0.1332t + 17.44) + 0.01385\sin(0.5719t - 4.184) \quad (23)$$

$$NM : v(t) = 0.05732\sin(0.02103t + 99.33) + 0.0175\sin(0.189t - 93.12) + 0.01297\sin(0.6878t + 53.84) \quad (24)$$

$$TX : v(t) = 0.03289\sin(0.0466t + 48.2) + 0.01849\sin(0.2133t - 141.5) + 0.01206\sin(0.6927t + 45.17) \quad (25)$$

- The Growth Rate of Nuclear Energy

$$AZ: v(t) = 0.03289\sin(0.0466t + 48.2) + 0.01849\sin(0.2133t - 141.5) + 0.01206\sin(0.6927t + 45.17) \tag{26}$$

$$CA: v(t) = 2.219\sin(0.1487t - 154.8) + 0.2715\sin(0.2861t - 0.7948) + 2.218\sin(0.1615t - 38.96) \tag{27}$$

$$TX: v(t) = 0.1818\sin(0.2526t - 113.4) + 0.1604\sin(0.3707t + 42.78) + 0.0297\sin(1.902t + 120.8) \tag{28}$$

It can be seen from the figure above that the consumption of renewable energy has a cyclical change over time, but it has shown a significant upward in the past 10 years in NM and TX.

4.2.3 Influential Factors of the similarities and differences

According to our energy profile model and the data provided, we select industry and population as influential factors to analyze the similarities and differences about usage of cleaner, renewable energy sources between the four states.

- Sector
  The similarities and differences between the four states can be seen from the degree of demand for energy consumption in various industries.
  To determine the industrial factors over time, we chose the industry, commerce and residential industries. For the transportation industry, after analyzing the data, the impact on renewable energy is negligible. The largest proportion in CA is 1.34%, considering the contribution rate, we ignore it.
  We give the definition of the impact factor. Since the energy consumption of each year is known, and we assume that the impact factor is a function of time $Q_1(t)$, $Q_2(t)$, $Q_3(t)$ are defined as the impact factor.

$$c_1 \cdot Q_1(t) + c_2 \cdot Q_2(t) + c_3 \cdot Q_3(t) = rc(t) \tag{29}$$

  The similarity is that the ratio of impact factors of AZ, NM, TX called as $Q_1(t)$, $Q_2(t)$, $Q_3(t)$ is 3.412 : 1 : 1.
  The difference is that the ratio of impact factors of CA states changes over time, with the attached illustrations of CA shown in Figure 5.(code seen in Appendices 6)

- Population
  We assume that the value of dollar is stable remain unchanged for several years(2000-2005).

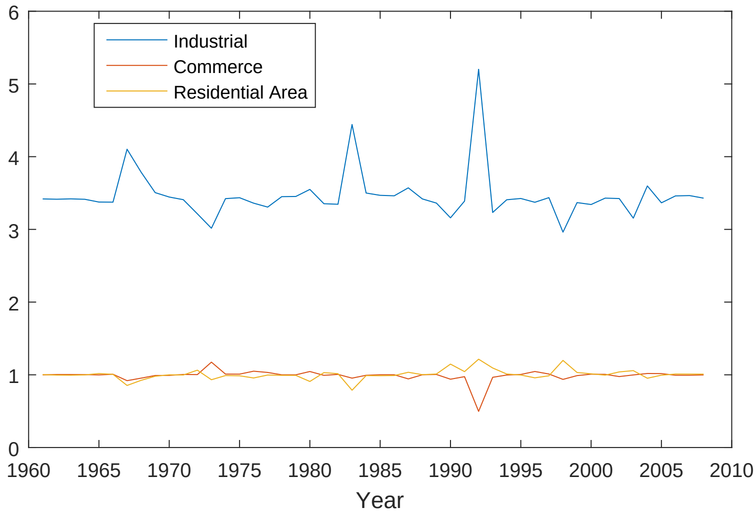


Figure 5: The impact factors of CA changes over time

We use the IPAT formula and the revised "Laspeyres" exponential decomposition method to analyze the impact of population growth on total energy consumprtion gowth.[6]
We take Δ as the change from the end of the year to the beginning.
In the model, $\Delta TPOPP$ can represent the impact of population size on energy consumption.
The population of these four states increases approximately linearly over time, and the rate of increase is positively correlated with their population base.

$$\begin{aligned}\Delta TETCB &= TETCB_t - TETCB_0 \\ &= \Delta TPOPP^{effects} + \Delta A^{effects} + \Delta TETGR^{effects}\end{aligned} \tag{30}$$

$$\begin{aligned}\Delta TPOPP^{effects} = \Delta TPOPP \cdot A_0 \cdot TETGR_0 \\ + \frac{1}{2}(\Delta TPOPP \cdot \Delta A \cdot TETGR_0) \\ + \frac{1}{2}(\Delta TPOPP \cdot A_0 \cdot \Delta TETGR) \\ + \frac{1}{3}(\Delta TPOPP \cdot \Delta A \cdot \Delta TETGR)\end{aligned} \tag{31}$$

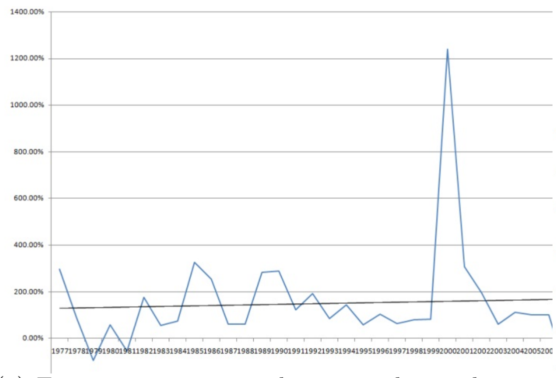
$$\begin{aligned}\Delta A^{effects} = TPOPP_0 \cdot \Delta A \cdot TETGR_0 \\ + \frac{1}{2}(\Delta TPOPP \cdot \Delta A \cdot TETGR_0) \\ + \frac{1}{2}(TPOPP_0 \cdot \Delta A \cdot \Delta TETGR) \\ + \frac{1}{3}(\Delta TPOPP \cdot \Delta A \cdot \Delta TETGR)\end{aligned} \tag{32}$$

$$
\begin{aligned}
\Delta TETGR^{effects} &= TPOPP_0 \cdot A_0 \cdot \Delta TETGR \\
&+ \frac{1}{2}\left(TPOPP_0 \cdot \Delta A \cdot \Delta TETGR\right) \\
&+ \frac{1}{2}\left(\Delta TPOPP \cdot A_0 \cdot \Delta TETGR\right) \\
&+ \frac{1}{3}\left(\Delta TPOPP \cdot \Delta A \cdot \Delta TETGR\right)
\end{aligned} \tag{33}
$$

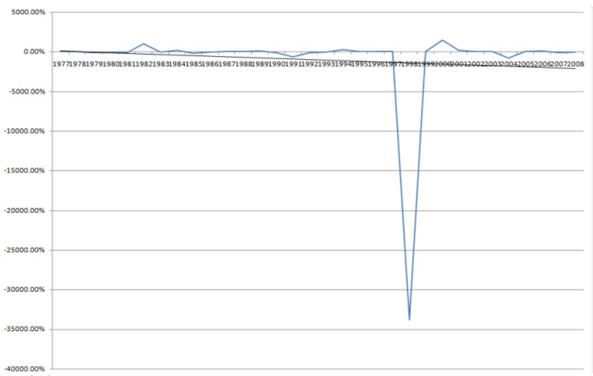
However, the disaggregation analysis structure based on the population scale model shows that the energy consumption growth in each state has great volatility in growth of population size.

Positive effect shows that Americans have a lot of differences in energy usage. The peak $\Delta TETCB$ far above 100% between 1978 and 2009 can also reflect the wealth distribution of Americans. The energy consumption characteristics of high-income groups play a significant role in the overall energy consumption structure.

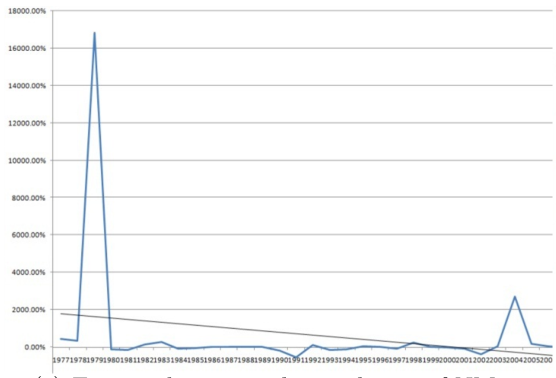
After excluding the largest peak, we find that the increase in population size in AZ and CA has a negative effect on the increase in energy consumption while the increase in population size in NM and TX has a positive effect on the increase in energy consumption.



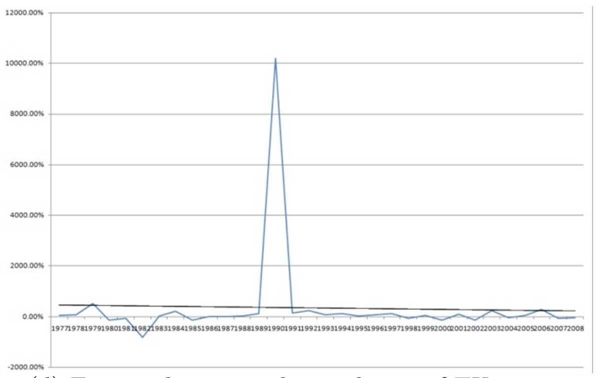
(a) Energy consumption changes with population of AZ



(b) Energy changes with population of CA



(c) Energy changes with population of NM



(d) Energy changes with population of TX

Figure 6: Energy changes with population of four states

4.2.4 Evaluation Criteria for the best Profile

We select the appropriate indicators, establish an credible evaluation criteria to determine which of the four states appeared to have the "best" profile for use of cleaner, renewable energy in 2009.
Through the analysis of the data, we have integrated distribution in cleaner and renewable energy. Various types of renewable energy (except biomass, mainly fuel ethanol) and nuclear energy will be converted into electricity. From the perspective of distribution, the share of electricity in the four states is the largest and more representative, so we choose the energy source of electricity as the basis for analysis.
Then we select the average price, import expenditure size, size of productivity as the evaluation criteria (they are highly correlated with energy efficiency) according to literature we view.[7] In order to get the weight vector, we need to compute the weight of the three factors. Thus, we can figure out that the weight vector $B = \begin{bmatrix} 0.259 & 0.0653 & 0.6757 \end{bmatrix}$. Finally, in consistency check, the consistency index CI $= 0.0098 < 0.10$, which means that the weight determined by AHP is very reasonable.[8](code seen in Appendix 7) Therefore, we established the three criteria of paired comparison judgment matrix.

The average price of electricity paired comparison judgment matrix

$$W_1 = \begin{bmatrix} 1 & 0.719854804 & 1.168808758 & 0.958872523 \\ 1.389169031 & 1 & 1.62367293 & 1.332036014 \\ 0.85557196 & 0.615887585 & 1 & 0.820384444 \\ 1.042891496 & 0.750730453 & 1.218940714 & 1 \end{bmatrix}$$

The import expenditure size of electricity paired comparison judgment matrix

$$W_2 = \begin{bmatrix} 1 & 0.040360221 & 4.525931207 & 0.27494136 \\ 24.77687143 & 1 & 112.1384156 & 6.812186739 \\ 0.220949006 & 0.008917551 & 1 & 0.06074802 \\ 3.637139201 & 0.146795741 & 16.46144181 & 1 \end{bmatrix}$$

The size of productivity paired comparison judgment matrix

$$W_3 = \begin{bmatrix} 1 & 0.282887 & 3.39227 & 0.212667 \\ 3.534976 & 1 & 11.99159 & 0.751772 \\ 0.294788 & 0.083392 & 1 & 0.062692 \\ 4.70219 & 1.33019 & 15.9511 & 1 \end{bmatrix}$$

The four-state weights matrix

$$A = \begin{bmatrix} 0.2332 & 0.0337 & 0.1049 \\ 0.324 & 0.8361 & 0.3709 \\ 0.1995 & 0.0075 & 0.03.9 \\ 0.2432 & 0.1227 & 0.4933 \end{bmatrix}$$

$$C = A * B^T \tag{34}$$

The largest total sort weight is in **TX** whose total sort weight is 0.4043. Therefore, TX has the "best" profile in 2009.

Table 2: The Total Hierarchy

Standard		Average price	Import expenditures	Productivity	Total sort weight
Standard layer weights		0.259	0.0653	0.6757	
four-state weights	AZ	0.2332	0.0337	0.1049	0.1335
	CA	0.324	0.8361	0.3709	0.3891
	NM	0.1995	0.0075	0.0309	0.073
	TX	0.2432	0.1227	0.4933	0.4043

4.2.5 Predict the energy profile of each state for 2025 and 2050

$$v^-(t) \leq v(t) \leq v^+(t) \tag{35}$$

We address that $v(t)$ cannot be in the range of 80% to 100% of the boundary value for many years based on the absence of policy.
Predictive Result by Energy Proportion Model and Growth Rate Model to predict the energy profile of each state, for 2025 and 2050 in the absence of any policy changes by each governor's office.
After comparing the predictions of the two models, we find that the results based on Growth Rate Model are basically smaller than that based on Energy Proportion Model, and the difference will be greater when the prediction is further away.
This is because Growth Rate Model considers the cyclicality and volatility of the growth rate, and the cyclicality and volatility can lead to negative value of growth rate in some years while the total consumption used in Energy Proportion Model is approximately linear linearly proportional to time. This inevitably leads to differences, and the longer the forecast year, the greater the difference.
We also find that the proportion of renewable energy in AZ was up to 33%, and we believe that the proportion is obviously large, which may not be consistent with the actual situation. Various numerical value for unity (Billion Btu)

Table 3: The energy consumption predicted by Energy Proportion Model

Consumption	Year	Total	Fossil	Renewable	Nuclear
AZ	2025	2320000	1621957.268	219190.8396	478851.8922
	2050	3130000	1730704.623	1038752.306	360543.0705
CA	2025	8827500	7444779.641	893501.5493	489218.81
	2050	10555000	8140122.189	1663263.361	751614.4503
NM	2025	1034925	947674.8402	87250.15979	0
	2050	1275850	1138215.545	137634.4553	0
TX	2025	15502500	13591078.48	962591.0042	948830.5125
	2050	19505000	14375512.95	1915932.14	3213554.907

Table 4: The energy consumption predicted by Growth Rate Model

Consumption	Year	Total	Fossil	Renewable	Nuclear
AZ	2025	2248319.93	1591602.402	214609.231	442108.2977
	2050	2974605.804	2487110.463	289309.8205	198185.5211
CA	2025	8221835.779	6843119.367	958467.7855	420248.6265
	2050	9307875.255	7532637.203	1607317.613	167920.4387
NM	2025	920543.7673	834833.1874	85710.5799	0
	2050	924918.767	831442.2678	93476.49919	0
TX	2025	13271821.75	11558362.78	883172.252	830286.712
	2050	14799231.47	11794310.35	1123835.433	1881085.688

5 Energy Compact Model

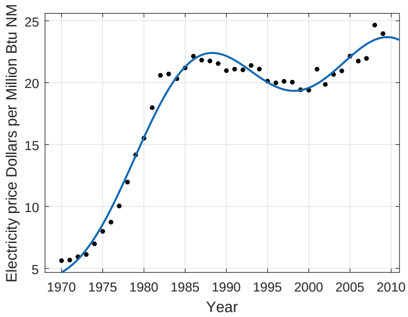
5.1 Renewable Energy Usage Targets

Based on our discussion in Evaluation Criteria for the best Profile and above models, the average price of electricity in 2025 and 2050 respectively.
Table 5 presents the predictive values of average price in 2025 and 2050. Find the average price of the four states in 2025 and 2050 are 35.32732299 and 43.71283002 based on the fit curves as shown in Figure 7

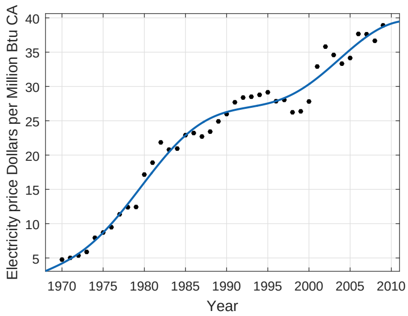
Therefore, the average price of the four states in 2025 should be set at about 28.26(80% of the predictive values absent any policy changes) dollars.
In 2050 the average price should be set at about 34.97(80% of the predictive values absent any policy changes) dollars. We state it as the goal for this new four-state energy compact.
In order to establish Interstate Energy Price Contract for 2025 and 2050, we obtain the table by using the above two models, that is, Growth Rate Model and Energy Proportion Model. We predict the total consumption and the proportion of renewable energy in 2025 and 2050 from two kinds of ideas. It can be seen in Table 6 that the two models have small error of the simulation. The fact indicates that the two models are successful.

Table 5: The predictive Values of average Price in 2025 and 2050

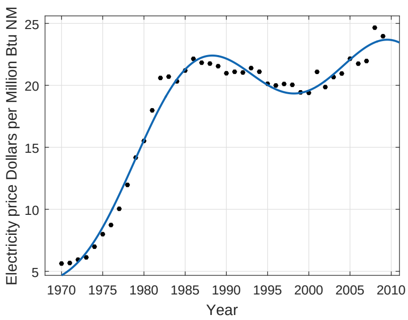
	AZ	CA	NM	TX
2025	39.62902025	36.22521619	34.23589234	31.21916318
2050	43.44450209	42.34353690	45.45793568	43.60534539



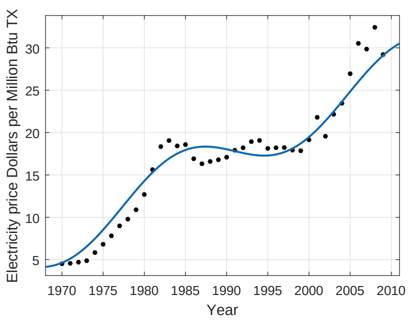
(a) Average Price of AZ



(b) Average Price of CA



(c) Average Price of NM



(d) Average Price of TX

Figure 7: Four-State Average Price of Recreatable Energy over time

5.2 Actions to meet the Energy Compact Goal

- Support clean coal technology.
  According to our prediction model, the future fossil energy consumption of the United States is still very large, and the proportion of the total energy consumption is also large. Therefore, in order to achieve the goal of the Western Interstate Energy Compact, namely to increase amount of usage of renewable energy and utilization ratio, states have to reduce the proportion of fossil fuel and increase the efficiency of usage of fossil fuels. Supporting clean coal technology can improve coal utilization and heat conversion efficiency. Such measures could effectively reduce fossil fuel's consumption.

- Support photovoltaic solar cell semiconductor materials research.
  Since the U.S. will adopt a new energy plan, it will inevitably slow the development of renewable energy, which will have a negative impact on global climate change. Most of renewable energy production will not have a larger effect on the environment (except hydroelectricity industry), so continue to support the development of renewable energy is indispensable. However, most renewable energy depends on the natural conditions. Increasing the energy conversion rate of photovoltaic solar

Table 6: The error between the two model predictive values

	Predictive value	AZ	CA	NM	TX
2025	Proportion predicted by the proportion	9.45%	10.12%	8.43%	6.21%
	Proportion predicted by growth rate	9.55%	12%	9.31%	6.65%
	error	-0.10%	-1.54%	-0.88%	-0.45%
2050	Proportion predicted by the proportion	33.19%	15.76%	10.79%	9.82%
	Proportion predicted by growth rate	9.73%	17.27%	10.11%	8%
	Error	23.46%	-1.51%	0.68%	5.00%

energy and reducing the cost of photovoltaic solar energy generation can make the production of this renewable energy source as environmentally-friendly as possible.

- Apply preferential policies to energy transactions between the states.
  Lower the threshold of energy trade across the states, and strengthen the interstate commerce energy flow. In order to realize the Western Interstate Energy Contract and promote the cooperation among the states, states should reach an agreement on the interstate commerce of energy. States also should adopt preferential policies to deal with the interstate energy trade, especially the electricity trade generated from renewable energy production. And states should gradually coordinate their distributionof the renewable energy industry with other states according to their own geographical conditions and industrial needs. So that state's renewable energy efficiency ratio will be as low as possible.

6 Strengths and weaknesses

6.1 Strength

- We use two models to predict the consumption of various energy sources in 2025 and 2050 from both the proportion and the growth rate of energy consumption. It make up for the errors caused by some uncertain factors. We take the industrial development over time into account. At the same time, we consider that the consumption of various forms of energy will have a certain periodicity and volatility due to the influence of industry, environment, population, technology and other factors.
- The growth rate model adopts the method of moving average to define $c(t)$, which eliminates some uncontrollable factors such as random errors of data records and the influence of the previous year on the following year.
- The population size decomposition model called IPAT quantifies the impact of population on clean energy.

6.2 Weakness

- Since the predictive value of Proportion Model depends on the total energy consumption, the linear fit of the total energy consumption less prime in the consideration of factors. It will make all kinds of energy consumption too large.
- The two models in CA predict a larger error in the share of renewable energy in 2050.
- No sensitivity analysis was done in the evaluation Evaluation Criteria
- Incomplete assumptions. There are claims that natural gas reserves in 2040 depletion.Our model does not consider the limited reserves.
- In this paper, the solution of the model is limited to the capacity of the computer, and it can't achieve higher accuracy.
- Our model cannot resolve the existence of information cascade (the most influential one is not always the best one) phenomena.

7 Conclusions

The energy configuration analysis we established is shown in Figure 2 as an area chart after integrat variables. The energy structure of each state has its own characteristics.In Arizona, fossil fuels have always dominated, still accounting for well over half in 2009. In Texas, the proportion of biomass and wind energy is very low.
Through Energy Proportion Model, we get the proportion of fossil fuels energy, renewable energy and nuclear energy in each state over time as shown in Figure 3. We define the proportion of energy $P(t)$. Similarly we obtain Growth Rate Model defining the proportion of energy $v(t)$.
We choose industry and population to discuss influential Factors of the similarities and differences about usage of cleaner, renewable energy sources between the four states. The similarity is that the ratio of impact factors of AZ, NM, TX called as $Q_1(t)$, $Q_2(t)$, $Q_3(t)$ is 3.412 : 1 : 1. The difference is that the ratio of impact factors of CA states changes over time, with the attached illustrations of CA shown in Figure 5.
The population of four states increases approximately linearly over time. However, the disaggregation analysis structure based on the population scale model shows that the energy consumption growth in each state has great volatility in growth of population size.
We use analytical hierarchy process, abbreviated to AHP. Determine three indexes we choose-average price, import expenditure size, size of productivity of electricity as the evaluation criteria weights.The largest total sort weight is in TX whose total sort weight is 0.4043. In 2009, Texas had the "best" have the “best” profile for use of cleaner, renewable energy.
According to $P(t)$ and $v(t)$ based on our models, we get the predictive value of the energy profile of each state for 2025 and 2050 as shown in Table 3 and Table 4.
The average price of the four states in 2025 should be set at about 28.26(80% of the predictive values absent any policy changes) dollars.
In 2050 the average price should be set at about 34.97(80% of the predictive values absent

any policy changes) dollars. We state it as the goal for this new four-state energy compact. We discuss three actions the four states might take to meet their energy compact goals.

- Support clean coal technology.
- Support photovoltaic solar cell semiconductor materials research.
- Apply preferential policies to energy transactions between the states.

References

[1] S. Sathyanarayana, A gentle introduction to backpropagation (Apr. 2014).

[2] S. Wang, Multi-scale analysis of the water resources carrying capacity of the liaohe basin based on ecological footprints, Journal of Cleaner Production (2013) 158–166.

[3] W. L. S. Liu, On assessment of sustainable development level of regional water rsource using artificial neural networks.

[4] Z. Hailong, China's new energy development research, Ph.D. thesis, Jilin University (2014).

[5] S. Ling, W. K. Li, On fractionally integrated autoregressive moving-average time series models with conditional heteroscedasticity, Publications of the American Statistical Association.

[6] W. Y. C. W. Yongjin, W. Na, Impact of changes in population, households and household size on resource consumption - based on ipat equation and structural decomposition analysis model, Ecological Economy (6) (2015) 23–27.

[7] G. Shuhua, Z. L. Ping, Renewable energy resources evaluation system and method, China Population Resources and Environment (2) (1999) 46–50.

[8] J. Freeman, A user's guide to principal components, Technometrics 43 (6) (1992) 641–641.

Appendices

Program List
1.The code used to make the area chart

```
x=1960:2009;
y1=xlsread('Consumption.xls','AZ','B2:J51');
area(x,y1);
xlabel('Year');
ylabel('Consumption');
```

```
x=1960:2009;
y2=xlsread('Consumption.xls','CA','B2:J51');
area(x,y2);
xlabel('Year');
ylabel('Consumption');
```

```
x=1960:2009;
y3=xlsread('Consumption.xls','NM','B2:J51');
area(x,y3);
xlabel('Year');
ylabel('Consumption');
```

```
x=1960:2009;
y4=xlsread('Consumption.xls','TX','B2:J51');
area(x,y4);
xlabel('Year');
ylabel('Consumption');
```

2.The code used to make the energy proportion curve

```
TheProportionOfFossilFuelsAZ vs. Year
General model Sin2:
     f(x) =  a1*sin(b1*x+c1) + a2*sin(b2*x+c2)
Coefficients (with 95% confidence bounds):
       a1 =        5.017  (-287.3, 297.3)
       b1 =    0.0009969  (-0.05866, 0.06065)
       c1 =        126.7  (-1.244, 254.6)
       a2 =      0.05704  (0.04441, 0.06968)
       b2 =       0.2216  (0.2028, 0.2404)
       c2 =       -185.5  (-222.8, -148.1)

Goodness of fit:
  SSE: 0.03977
  R-square: 0.855
  Adjusted R-square: 0.8386
  RMSE: 0.03007

General model Sin2:
     f(x) =  a1*sin(b1*x+c1) + a2*sin(b2*x+c2)
Coefficients (with 95% confidence bounds):
       a1 =       0.9382  (-1.81, 3.686)
       b1 =     0.003223  (-0.05867, 0.06511)
       c1 =        121.2  (-9.238, 251.7)
       a2 =      0.02213  (-0.04846, 0.09271)
       b2 =       0.1233  (-0.05693, 0.3036)
       c2 =        10.23  (-348.2, 368.7)

Goodness of fit:
  SSE: 0.00953
  R-square: 0.8152
  Adjusted R-square: 0.7942
  RMSE: 0.01472

General model Sin2:
```

```
      f(x) =  a1*sin(b1*x+c1) + a2*sin(b2*x+c2)
Coefficients (with 95% confidence bounds):
        a1 =       1.177  (-1.805, 4.158)
        b1 =     0.02632  (-0.06747, 0.1201)
        c1 =       75.04  (-110.9, 261)
        a2 =      0.1912  (-2.79, 3.172)
        b2 =     0.06945  (-0.1777, 0.3166)
        c2 =       118.3  (-371.7, 608.3)

Goodness of fit:
  SSE: 0.000393
  R-square: 0.8767
  Adjusted R-square: 0.8627
  RMSE: 0.002989

General model Sin2:
      f(x) =  a1*sin(b1*x+c1) + a2*sin(b2*x+c2)
Coefficients (with 95% confidence bounds):
        a1 =      0.9915  (0.99, 0.993)
        b1 =    0.009547  (0.008863, 0.01023)
        c1 =       108.4  (107, 109.8)
        a2 =   -0.005761  (-0.007425, -0.004097)
        b2 =      0.2997  (0.2799, 0.3196)
        c2 =      -344.7  (-384.1, -305.3)

Goodness of fit:
  SSE: 0.0006274
  R-square: 0.9611
  Adjusted R-square: 0.9567
  RMSE: 0.003776
















The proportion of renewable energy.
General model Sin3:
      f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
        a1 =      0.1324  (0.1256, 0.1393)
        b1 =     0.04229  (0.03629, 0.04828)
        c1 =       43.67  (31.72, 55.61)
        a2 =      0.0211  (0.0131, 0.0291)
        b2 =      0.3172  (0.2814, 0.353)
        c2 =      -376.8  (-447.8, -305.7)
        a3 =     0.02394  (0.01692, 0.03097)
        b3 =      0.4863  (0.4523, 0.5203)
        c3 =       54.64  (-12.78, 122.1)

Goodness of fit:
```

```
  SSE: 0.01115
  R-square: 0.8417
  Adjusted R-square: 0.8108
  RMSE: 0.01649

General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =      0.1392  (-5.057, 5.335)
       b1 =     0.05312  (-1.486, 1.593)
       c1 =       21.74  (-3029, 3072)
       a2 =     0.03919  (-5.119, 5.198)
       b2 =       0.115  (-3.743, 3.973)
       c2 =       27.81  (-7624, 7680)
       a3 =    0.006153  (-0.0812, 0.09351)
       b3 =      0.2602  (-0.4152, 0.9356)
       c3 =      -6.156  (-1349, 1337)

Goodness of fit:
  SSE: 0.01054
  R-square: 0.2596
  Adjusted R-square: 0.1151
  RMSE: 0.01603

General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.03235  (-1.311, 1.376)
       b1 =     0.07386  (-1.224, 1.372)
       c1 =      -19.74  (-2595, 2555)
       a2 =     0.03528  (-0.5909, 0.6615)
       b2 =      0.1421  (-2.711, 2.995)
       c2 =       -26.3  (-5686, 5633)
       a3 =      0.0202  (-1.293, 1.333)
       b3 =       0.198  (-1.05, 1.446)
       c3 =       117.2  (-2357, 2591)

Goodness of fit:
  SSE: 0.000573
  R-square: 0.8203
  Adjusted R-square: 0.7852
  RMSE: 0.003738

General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.02556  (-1.927, 1.978)
       b1 =     0.04159  (-2.102, 2.185)
       c1 =       43.83  (-4214, 4302)
       a2 =     0.01253  (-1.96, 1.985)
       b2 =     0.08998  (-3.915, 4.095)
       c2 =       76.51  (-7877, 8030)
       a3 =    0.003882  (-0.02299, 0.03075)
       b3 =      0.2536  (-0.1153, 0.6224)
       c3 =       6.431  (-724.8, 737.6)

Goodness of fit:
  SSE: 0.000318
```

```
  R-square: 0.6865
  Adjusted R-square: 0.6253
  RMSE: 0.002785


The proportion of nuclear energy.
(AZ) General model Sin2:
     f(x) =  a1*sin(b1*x+c1) + a2*sin(b2*x+c2)
Coefficients (with 95% confidence bounds):
       a1 =       0.728  (-59.27, 60.73)
       b1 =     0.02875  (-2.37, 2.428)
       c1 =       200.4  (-4573, 4974)
       a2 =      0.2046  (-2.144, 2.553)
       b2 =      0.1376  (-0.63, 0.9051)
       c2 =       249.5  (-1279, 1778)

Goodness of fit:
  SSE: 0.0186
  R-square: 0.7012
  Adjusted R-square: 0.6226
  RMSE: 0.03129

(CA) General model Sin2:
     f(x) =  a1*sin(b1*x+c1) + a2*sin(b2*x+c2)
Coefficients (with 95% confidence bounds):
       a1 =      0.0606  (0.04994, 0.07127)
       b1 =     0.03157  (0.02282, 0.04033)
       c1 =       63.55  (46.3, 80.79)
       a2 =     0.01022  (0.007912, 0.01252)
       b2 =      0.2172  (0.1969, 0.2375)
       c2 =      -173.5  (-213.7, -133.2)

Goodness of fit:
  SSE: 0.001341
  R-square: 0.9439
  Adjusted R-square: 0.9375
  RMSE: 0.005521

(TX) General model Sin2:
     f(x) =  a1*sin(b1*x+c1) + a2*sin(b2*x+c2)
Coefficients (with 95% confidence bounds):
       a1 =      0.0377  (0.02687, 0.04853)
       b1 =     0.07327  (0.02311, 0.1234)
       c1 =       149.9  (50.15, 249.6)
       a2 =    0.004349  (-0.001431, 0.01013)
       b2 =      0.3589  (0.01488, 0.7029)
       c2 =      -123.7  (-811, 563.5)

Goodness of fit:
  SSE: 0.0002407
  R-square: 0.8733
  Adjusted R-square: 0.8337
  RMSE: 0.003878
```

3.The code used to make the growth rate fit curve of energy

```
Fossil fuel consumption growth rate:
AZ:
```

```
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.03936  (0.03436, 0.04436)
       b1 =     0.04589  (-0.09525, 0.187)
       c1 =       49.21  (-232.5, 330.9)
       a2 =      0.0287  (0.003041, 0.05437)
       b2 =      0.2133  (0.1188, 0.3077)
       c2 =      -142.3  (-329.9, 45.41)
       a3 =    0.009263  (0.003786, 0.01474)
       b3 =       0.431  (0.3792, 0.4828)
       c3 =      -289.9  (-393.1, -186.8)

Goodness of fit:
  SSE: 0.004834
  R-square: 0.791
  Adjusted R-square: 0.7446
  RMSE: 0.01159


CA:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.03393  (-0.4392, 0.5071)
       b1 =      0.0602  (-1.291, 1.412)
       c1 =       21.27  (-2670, 2713)
       a2 =     0.02562  (-0.6752, 0.7264)
       b2 =      0.1332  (-0.7042, 0.9707)
       c2 =       17.44  (-1646, 1681)
       a3 =     0.01385  (0.008479, 0.01922)
       b3 =      0.5719  (0.5395, 0.6043)
       c3 =      -4.184  (-68.51, 60.14)

Goodness of fit:
  SSE: 0.005003
  R-square: 0.7333
  Adjusted R-square: 0.674
  RMSE: 0.01179


NM:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.05732  (-0.8153, 0.9299)
       b1 =     0.02103  (-0.3705, 0.4125)
       c1 =       99.33  (-682.8, 881.5)
       a2 =      0.0175  (-0.007135, 0.04214)
       b2 =       0.189  (0.06682, 0.3111)
       c2 =      -93.12  (-335.4, 149.1)
       a3 =     0.01297  (0.007609, 0.01833)
       b3 =      0.6878  (0.6547, 0.721)
       c3 =       53.84  (-11.92, 119.6)

Goodness of fit:
  SSE: 0.005107
  R-square: 0.7552
```

```
 Adjusted R-square: 0.7008
 RMSE: 0.01191


TX:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =    0.03289  (0.02271, 0.04307)
       b1 =     0.0466  (-0.008696, 0.1019)
       c1 =       48.2  (-62.05, 158.5)
       a2 =    0.01849  (0.01141, 0.02557)
       b2 =     0.2133  (0.1688, 0.2578)
       c2 =     -141.5  (-229.7, -53.26)
       a3 =    0.01206  (0.008916, 0.0152)
       b3 =     0.6927  (0.6729, 0.7124)
       c3 =      45.17  (5.924, 84.42)

Goodness of fit:
  SSE: 0.001773
  R-square: 0.9064
  Adjusted R-square: 0.8856
  RMSE: 0.007018
```

```
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =    0.07748  (0.05827, 0.09669)
       b1 =     0.4454  (0.4228, 0.4681)
       c1 =     -32.59  (-77.66, 12.47)
       a2 =      0.252  (-13.37, 13.87)
       b2 =   0.007731  (-0.4164, 0.4319)
       c2 =      125.9  (-721.2, 973.1)
       a3 =    0.04363  (0.02582, 0.06145)
       b3 =     0.5987  (0.5547, 0.6428)
       c3 =     -55.04  (-142.6, 32.56)

Goodness of fit:
  SSE: 0.0536
  R-square: 0.8001
  Adjusted R-square: 0.7557
  RMSE: 0.03859
```

```
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.2168  (-30.65, 31.09)
       b1 =   0.005598  (-0.801, 0.8122)
       c1 =      130.2  (-1485, 1745)
       a2 =    0.02429  (-0.001102, 0.04967)
       b2 =     0.6168  (0.4842, 0.7494)
       c2 =     -89.54  (-352.9, 173.8)
       a3 =     0.0333  (0.007019, 0.05959)
       b3 =     0.4645  (0.3681, 0.5608)
```

```
        c3 =       -69.75   (-261, 121.5)

Goodness of fit:
  SSE: 0.0559
  R-square: 0.4619
  Adjusted R-square: 0.3424
  RMSE: 0.03941
```

```
General model Sin3:
     f(x) =
                     a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
        a1 =       0.4155   (-36.8, 37.63)
        b1 =      0.01613   (-1.552, 1.584)
        c1 =        112.6   (-2991, 3216)
        a2 =      0.09907   (-0.3736, 0.5717)
        b2 =       0.1488   (-0.08767, 0.3853)
        c2 =       -9.252   (-479.1, 460.6)
        a3 =       0.0374   (0.008434, 0.06636)
        b3 =       0.4396   (0.3754, 0.5038)
        c3 =       -19.35   (-146.8, 108.1)

Goodness of fit:
  SSE: 0.1319
  R-square: 0.6677
  Adjusted R-square: 0.5939
  RMSE: 0.06053
```

```
General model Sin3:
     f(x) =
                     a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
        a1 =       0.1769   (-7.087, 7.441)
        b1 =      0.02584   (-1.118, 1.17)
        c1 =        87.15   (-2174, 2348)
        a2 =       0.1321   (-1.891, 2.155)
        b2 =       0.1863   (-0.7066, 1.079)
        c2 =       -83.53   (-1852, 1685)
        a3 =       0.1141   (-2.111, 2.339)
        b3 =       0.2544   (-0.3062, 0.8151)
        c3 =         61.1   (-1050, 1172)

Goodness of fit:
  SSE: 0.02677
  R-square: 0.8564
  Adjusted R-square: 0.8244
  RMSE: 0.02727
```

4.The code used to make the growth rate fit curve of Fossil Fuels energy

```
Fossil fuel consumption growth rate:
AZ:
General model Sin3:
     f(x) =
                     a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
```

```
Coefficients (with 95% confidence bounds):
       a1 =     0.03936  (0.03436, 0.04436)
       b1 =     0.04589  (-0.09525, 0.187)
       c1 =       49.21  (-232.5, 330.9)
       a2 =      0.0287  (0.003041, 0.05437)
       b2 =      0.2133  (0.1188, 0.3077)
       c2 =      -142.3  (-329.9, 45.41)
       a3 =    0.009263  (0.003786, 0.01474)
       b3 =       0.431  (0.3792, 0.4828)
       c3 =      -289.9  (-393.1, -186.8)

Goodness of fit:
  SSE: 0.004834
  R-square: 0.791
  Adjusted R-square: 0.7446
  RMSE: 0.01159


CA:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.03393  (-0.4392, 0.5071)
       b1 =      0.0602  (-1.291, 1.412)
       c1 =       21.27  (-2670, 2713)
       a2 =     0.02562  (-0.6752, 0.7264)
       b2 =      0.1332  (-0.7042, 0.9707)
       c2 =       17.44  (-1646, 1681)
       a3 =     0.01385  (0.008479, 0.01922)
       b3 =      0.5719  (0.5395, 0.6043)
       c3 =      -4.184  (-68.51, 60.14)

Goodness of fit:
  SSE: 0.005003
  R-square: 0.7333
  Adjusted R-square: 0.674
  RMSE: 0.01179


NM:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.05732  (-0.8153, 0.9299)
       b1 =     0.02103  (-0.3705, 0.4125)
       c1 =       99.33  (-682.8, 881.5)
       a2 =      0.0175  (-0.007135, 0.04214)
       b2 =       0.189  (0.06682, 0.3111)
       c2 =      -93.12  (-335.4, 149.1)
       a3 =     0.01297  (0.007609, 0.01833)
       b3 =      0.6878  (0.6547, 0.721)
       c3 =       53.84  (-11.92, 119.6)

Goodness of fit:
  SSE: 0.005107
  R-square: 0.7552
  Adjusted R-square: 0.7008
  RMSE: 0.01191

```

```

TX:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =     0.03289  (0.02271, 0.04307)
       b1 =      0.0466  (-0.008696, 0.1019)
       c1 =        48.2  (-62.05, 158.5)
       a2 =     0.01849  (0.01141, 0.02557)
       b2 =      0.2133  (0.1688, 0.2578)
       c2 =      -141.5  (-229.7, -53.26)
       a3 =     0.01206  (0.008916, 0.0152)
       b3 =      0.6927  (0.6729, 0.7124)
       c3 =       45.17  (5.924, 84.42)

Goodness of fit:
  SSE: 0.001773
  R-square: 0.9064
  Adjusted R-square: 0.8856
  RMSE: 0.007018
```

5.The code used to make the growth rate fit curve of Nuclear energy

```
Nuclear energy consumption growth rate:
AZ:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =      0.5486  (-1963, 1964)
       b1 =      0.1546  (-306, 306.3)
       c1 =       20.65  (-6.121e+05, 6.122e+05)
       a2 =      0.6457  (-1149, 1150)
       b2 =      0.2789  (-334.6, 335.2)
       c2 =         102  (-6.694e+05, 6.697e+05)
       a3 =      0.3037  (-1073, 1073)
       b3 =      0.3804  (-101.1, 101.9)
       c3 =         562  (-2.023e+05, 2.035e+05)

Goodness of fit:
  SSE: 0.02153
  R-square: 0.8745
  Adjusted R-square: 0.7832
  RMSE: 0.04424

CA:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
       a1 =       2.219  (-3333, 3337)
       b1 =      0.1487  (-9.249, 9.546)
       c1 =      -154.8  (-1.883e+04, 1.852e+04)
       a2 =      0.2715  (-2.465, 3.007)
       b2 =      0.2861  (-0.03864, 0.6108)
       c2 =     -0.7948  (-647.3, 645.7)
       a3 =       2.218  (-3331, 3335)
```

```
        b3 =      0.1615  (-9.858, 10.18)
        c3 =      -38.96  (-1.995e+04, 1.987e+04)

Goodness of fit:
  SSE: 0.6961
  R-square: 0.673
  Adjusted R-square: 0.6003
  RMSE: 0.1391


NM:0

TX:
General model Sin3:
     f(x) =
                    a1*sin(b1*x+c1) + a2*sin(b2*x+c2) + a3*sin(b3*x+c3)
Coefficients (with 95% confidence bounds):
        a1 =      0.1818  (-3.661, 4.024)
        b1 =      0.2526  (-1.332, 1.837)
        c1 =      -113.4  (-3287, 3060)
        a2 =      0.1604  (-3.803, 4.124)
        b2 =      0.3707  (-1.023, 1.764)
        c2 =       42.78  (-2747, 2833)
        a3 =      0.0297  (0.005882, 0.05351)
        b3 =       1.902  (1.713, 2.09)
        c3 =       120.8  (-256.6, 498.2)

Goodness of fit:
  SSE: 0.006792
  R-square: 0.9309
  Adjusted R-square: 0.8617
  RMSE: 0.02914
```

6.The code used to make The impact factors of CA changes over time

```
A=xlread('ProblemCData','AZ','A1:A48')
for i=1:48;
    a=A([i,i+1,i+2],[1,2,3]);
    b=B([i,i+1,i+2],[1,2,3]);
    t=a\b;
    x=[x,t];
end
x

A=xlread('ProblemCData','CA','A1:A48')
for i=1:48;
    a=A([i,i+1,i+2],[1,2,3]);
    b=B([i,i+1,i+2],[1,2,3]);
    t=a\b;
    x=[x,t];
end
x

A=xlread('ProblemCData','NM','A1:A48')
for i=1:48;
    a=A([i,i+1,i+2],[1,2,3]);
    b=B([i,i+1,i+2],[1,2,3]);
    t=a\b;
```

```
    x=[x,t];
end
x

A=xlread('ProblemCData','TX','A1:A48')
for i=1:48;
    a=A([i,i+1,i+2],[1,2,3]);
    b=B([i,i+1,i+2],[1,2,3]);
    t=a\b;
    x=[x,t];
end
x
```

7.The code used to judge matrix consistency

```
Average Price Judgment Matrix Consistency Test
A=xlsread('ProblemCData.xlsx','The average size','E1:H4');
[n,n]=size(A);

x=ones(n,100);
y=ones(n,100);
m=zeros(1,100);
m(1)=max(x(:,1));
y(:,1)=x(:,1);
x(:,2)=A*y(:,1);
m(2)=max(x(:,2));
y(:,2)=x(:,2)/m(2);
p=0.0001;i=2;k=abs(m(2)-m(1));
while  k>p
   i=i+1;
   x(:,i)=A*y(:,i-1);
   m(i)=max(x(:,i));
   y(:,i)=x(:,i)/m(i);
   k=abs(m(i)-m(i-1));
end
a=sum(y(:,i));
w=y(:,i)/a;
t=m(i);
disp('Weight vector');disp(w);
disp('Maximum eigenvalue');disp(t);
        %The following is the consistency check
n=4;
CI=(t-n)/(n-1);RI=[0 0 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 ...
    1.54 1.56 1.58 1.59];
CR=CI/RI(n);
if CR<0.10
    disp('The consistency of this matrix is acceptable!');
     disp('CI=');disp(CI);
     disp('CR=');disp(CR);
else
     disp('The consistency of this matrix is not acceptable!');
end


Weight vector
    0.2332
    0.3240
    0.1995
```

```
      0.2432

Maximum eigenvalue
       4

The consistency of this matrix is acceptable!
CI=
       0

CR=
       0
Consumption rate judgment matrix consistency test
A=xlsread('ProblemCData.xlsx','Rate of consumption','E1:H4');
[n,n]=size(A);

x=ones(n,100);
y=ones(n,100);
m=zeros(1,100);
m(1)=max(x(:,1));
y(:,1)=x(:,1);
x(:,2)=A*y(:,1);
m(2)=max(x(:,2));
y(:,2)=x(:,2)/m(2);
p=0.0001;i=2;k=abs(m(2)-m(1));
while  k>p
   i=i+1;
   x(:,i)=A*y(:,i-1);
   m(i)=max(x(:,i));
   y(:,i)=x(:,i)/m(i);
   k=abs(m(i)-m(i-1));
end
a=sum(y(:,i));
w=y(:,i)/a;
t=m(i);
disp('Weight vector');disp(w);
disp('Maximum eigenvalue');disp(t);
          %The following is the consistency check
CI=(t-n)/(n-1);RI=[0 0 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 ...
    1.54 1.56 1.58 1.59];
CR=CI/RI(n);
if CR<0.10
   disp('The consistency of this matrix is acceptable!');
    disp('CI=');disp(CI);
    disp('CR=');disp(CR);
else
    disp('The consistency of this matrix is not acceptable!');
end

Consumption rate weights and consistency checks:
Weight vector
      0.1049
      0.3709
      0.0309
      0.4933

Maximum eigenvalue
       4

The consistency of this matrix is acceptable!
CI=
       0
```

```

CR=
     0
Import spending consistency test
A=xlsread('ProblemCData.xlsx','Import expenditure size','E1:H4');
[n,n]=size(A);

x=ones(n,100);
y=ones(n,100);
m=zeros(1,100);
m(1)=max(x(:,1));
y(:,1)=x(:,1);
x(:,2)=A*y(:,1);
m(2)=max(x(:,2));
y(:,2)=x(:,2)/m(2);
p=0.0001;i=2;k=abs(m(2)-m(1));
while  k>p
  i=i+1;
  x(:,i)=A*y(:,i-1);
  m(i)=max(x(:,i));
  y(:,i)=x(:,i)/m(i);
  k=abs(m(i)-m(i-1));
end
a=sum(y(:,i));
w=y(:,i)/a;
t=m(i);
disp('Weight vector');disp(w);
disp('Maximum eigenvalue');disp(t);
         %The following is the consistency check
CI=(t-n)/(n-1);RI=[0 0 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 ...
    1.54 1.56 1.58 1.59];
CR=CI/RI(n);
if CR<0.10
   disp('The consistency of this matrix is acceptable!');
    disp('CI=');disp(CI);
    disp('CR=');disp(CR);
else
    disp('The consistency of this matrix is not acceptable!');
end
Consistency check:
Weight vector
    0.0337
    0.8361
    0.0075
    0.1227

Maximum eigenvalue
     4

The consistency of this matrix is acceptable!
CI=
     0

CR=
     0
Standard Judgment Matrix Consistency
A=xlsread('ProblemCData.xlsx','Standard judgment matrix','A1:C3');
[n,n]=size(A);

x=ones(n,100);
y=ones(n,100);
```

```
m=zeros(1,100);
m(1)=max(x(:,1));
y(:,1)=x(:,1);
x(:,2)=A*y(:,1);
m(2)=max(x(:,2));
y(:,2)=x(:,2)/m(2);
p=0.0001;i=2;k=abs(m(2)-m(1));
while  k>p
    i=i+1;
    x(:,i)=A*y(:,i-1);
   m(i)=max(x(:,i));
    y(:,i)=x(:,i)/m(i);
    k=abs(m(i)-m(i-1));
end
a=sum(y(:,i));
w=y(:,i)/a;
t=m(i);
disp('Weight vector');disp(w);
disp('Maximum eigenvalue');disp(t);
          %The following is the consistency check
CI=(t-n)/(n-1);RI=[0 0 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 ...
    1.54 1.56 1.58 1.59];
CR=CI/RI(n);
if CR<0.10
   disp('The consistency of this matrix is acceptable!');
    disp('CI=');disp(CI);
    disp('CR=');disp(CR);
else
    disp('The consistency of this matrix is not acceptable!');
end
Consistent results test
Weight vector
    0.2590
    0.0653
    0.6757

Maximum eigenvalue
    3.0195

The consistency of this matrix is acceptable!
CI=
    0.0098

CR=
    0.0188

Total ranking weight calculation code
fid=fopen('txt3.txt','r');
n1=3;n2=4;
a=[];
for i=1:n1
tmp=str2num(fgetl(fid));
a=[a;tmp]; %Read the criteria layer judgment matrix.
end
for i=1:n1
str1=char(['b',int2str(i),'=[];']);
str2=char(['b',int2str(i),'=[b',int2str(i),';tmp];']);
eval(str1);
for j=1:n2
tmp=str2num(fgetl(fid));
eval(str2); %Read three standard judgment matrices.
```

```
end
end
ri=[0,0,0.58,0.90,1.12,1.24,1.32,1.41,1.45]; %Consistency index
[x,y]=eig(a);
lamda=max(diag(y));
num=find(diag(y)==lamda);
w0=x(:,num)/sum(x(:,num));
cr0=(lamda-n1)/(n1-1)/ri(n1)
for i=1:n1
[x,y]=eig(eval(char(['b',int2str(i)])));
lamda=max(diag(y));
num=find(diag(y)==lamda);
w1(:,i)=x(:,num)/sum(x(:,num));
cr1(i)=(lamda-n2)/(n2-1)/ri(n2);
end
cr1, ts=w1*w0, cr=cr1*w0
```