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MCM/ICM Summary Sheet.

Summary

In recent years, with the growth of world's energy demand, energy issue become a hot spot. Governments are actively seeking cooperation in energy area. However, it is difficult to analyze energy utilization situation properly in different regions. In this paper, we establish a series of statistical models to describe and evaluate the profiles of clean energy of four states. We also give suggestions for governors to develop cooperative goals.

First, we describe the energy profile of four states. We process and rebuilt the dataset for observation and evaluation. Based on the dataset, we built several charts to visualize their energy profiles and the change in decades. Next, to characterize the evolution of energy profile during 1960-2009, we build a **Multiple Linear Regression Model.** To judge the efficiency and cleanliness of energy usage, we choose Non-renewable Energy Consumption Per Unit of GDP (NECP) as the evaluation criteria and select three tested factors as independent variables. From calculation results, the coefficients of factors represent different influence on NECP.

Then, we set a system to evaluate the profile of clean energy. To improve the reliability of system, we collect some expanded data from authorized websites as indicators. Our system is based on **Entropy Weight Method** and **Fuzzy Decision Model** to ensure the weights and values of indicators are measured properly. We quantify all indicators as triangular fuzzy numbers according to the established ten-level standard and build the fuzzy decision matrix. Finally, we rank the clean energy usage of four states: **Arizona>California>New Mexico>Texas.**

Furthermore, we predict the future energy profile based on **ARIMA Time Series Model.** With the model we can obtain a more accurate prediction with less data. After the empirical test for 1960-2009, the R^2 suggest we have reliable predictions on GDP, NECP and total energy consumption.

In Part Ⅱ, we set goals from both common side and independent side for four states based on our prediction and evaluation standard. Finally, at the end of the paper,

Contents

1 Introduction

1.1 Background

In recent years, to achieve the goal of sustainable developing, there are four states of U.S. - California (CA), Arizona (AZ), New Mexico (NM), and Texas (TX) - that have different industries and varying geographies along the U.S. border with Mexico, wish to form a realistic new interstate energy compact focused on increased usage of cleaner, renewable energy sources.

Although many studies have investigated the relation between energy consumption and economic growth, few studies have paid attention to this relationship by breaking down the different energy sources and distinguishing by economic sectors. Therefore, based on the 50 years of statistics data of the four states provided by U.S. Energy Information Administration (EIA), this paper analyzes the production and usage conditions of energies, develops several models to predict the future development, and sets goal for future.

1.2 Problem Statement and Motivation

For convenience, we divide the problem into four sub-problems

1. present the energy profile of the four states
2. evaluate the usage of renewable energy sources
3. predict the future energy profile
4. set renewable energy usage targets for the four states

To tackle the first problem, we select a set of parameters to analyze the data from developing trends and overall conditions, and rank them among four states. Then, we choose NECP(non-renewable energy consumption per unit of GDP) to describe the cleanliness and efficiency of energy usage, using multiple linear regression to analyze the relation between NECP and three factors, including RECR (renewable energy consumption ratio), IECR (industrial energy consumption ratio), and POP (population).

For the second problem, besides attached database, we take the imported electricity and the emission of main pollutant into account. Based on entropy weight method, we calculated the weight of each indicator and use fuzzy decision matrix to build the evaluation model.

As for the third problem, we use ARIMA time series model to predict NECP (non-renewable energy consumption per unit of GDP). The empirical test with data from 1960 to 2009 has reliable R^2, which proves the feasibility of our model.

And to tackle the forth problem, based on our analyses and predictions, we set total goals for the compact of four states and independent goals for each state.

2 Assumptions

- The impact of technological progress is constant.
- Neglect sharp fluctuations in the short term.
- All the data collected is actual and believable.
- New types of energy are not considered.

3 Terminology and Definitions

Symbol	Definitions
GDP	Gross Domestic Product
ESI	Energy Security Index, the ratio of total energy production and total energy consumption
NECP	non-renewable energy consumption per unit of GDP
$N\grave{E}CP$	the goal of non-renewable energy consumption per unit of GDP
TNECP	total non-renewable energy consumption per unit of GDP for all four states
EPR	energy's real average price
RECR	renewable energy consumption ratio in total energy consumption
REPR	renewable energy production ratio in total energy production
IECR	industrial energy consumption ratio in total energy consumption
POP	population
R^2	goodness-of-fit
I_{ij}	The j^{th} evaluation index of the I^{th} evaluation object.
M_j^+	Fuzzy positive expectation of the j^{th} evaluation index
M_j^-	Fuzzy negative expectation of the j^{th} evaluation index
w_j	The weight of the j^{th} evaluation index

μ_i	Degree of membership of the i^{th}evaluation object
F	Fuzzy index matrix

4 The Energy Profile of four states

4.1 Building the Profile

To have a comprehensive energy profile, we build the profile from two aspects: the trends and the overall conditions.

Firstly, we use diagrams to describe the trends over 50 years.

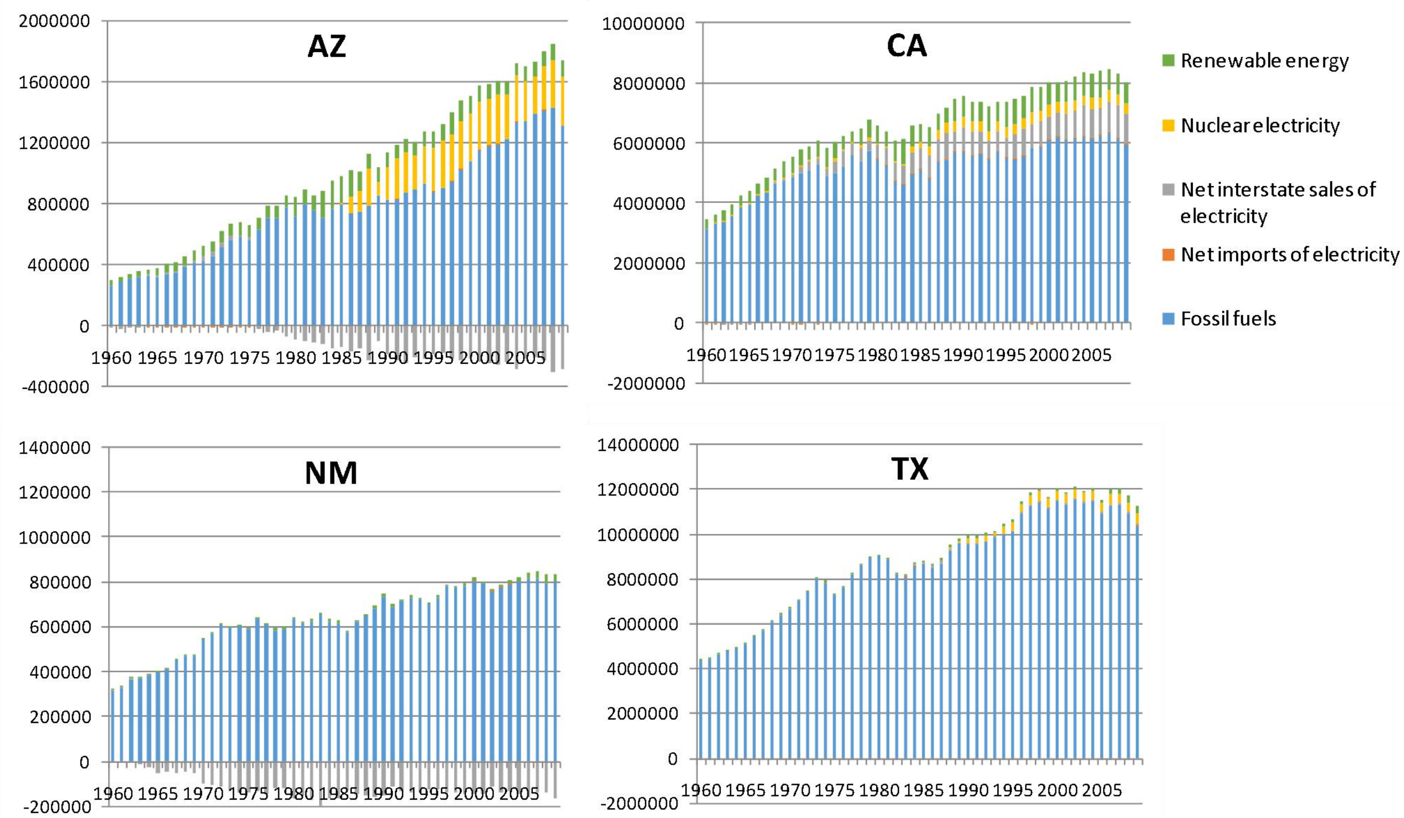

Figure 1 Total Energy Consumption Calculated by Fuel Types(unit: Billion Btu)

Figure 1 plot the total energy consumption of four states from 1906-2009. In a rough view, all the four states have their energy consumption growing in the 50 years, but the consumption of four states decreased almost simultaneously in some periods of time(around 1974,1981,1994 and 2008).Besides, the usage of cleaner energy (calculated by the means of nuclear energy and renewable energy) also keeps growing from 1960 to 2009.

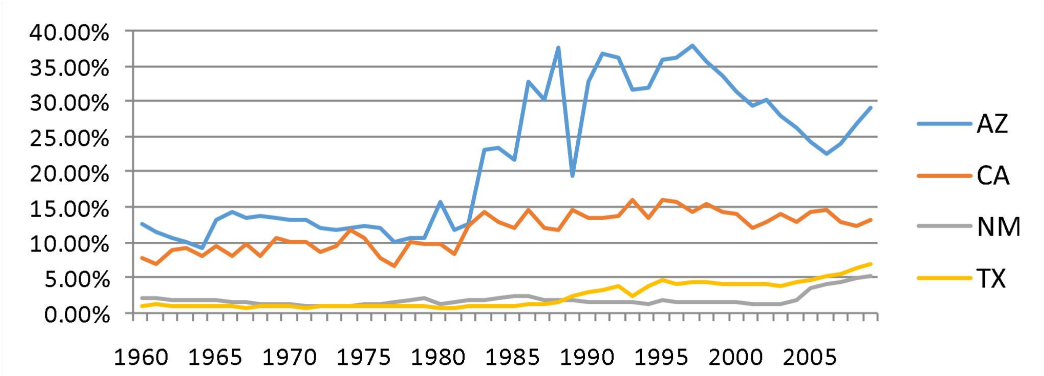

Figure 2 The Proportion of Clean Energy in Total Energy Consumption

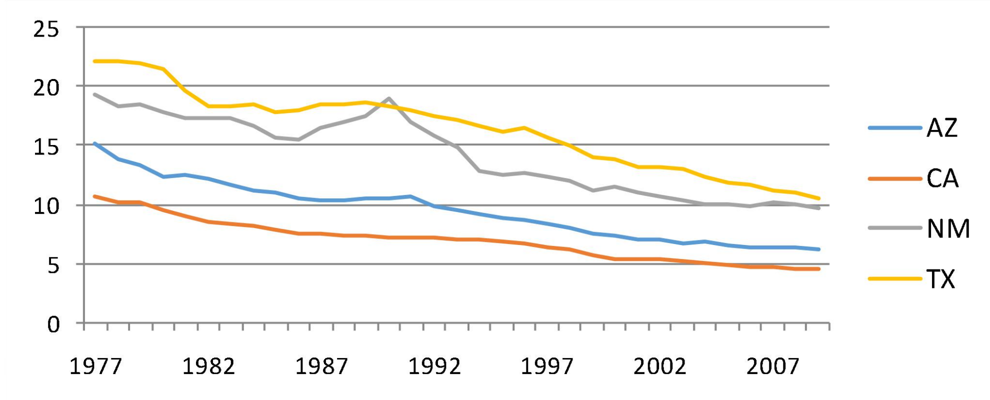

Figure 3 Total Energy Consumed per Dollar of Real GDP

(unit: Thousand Btu per chained dollar)

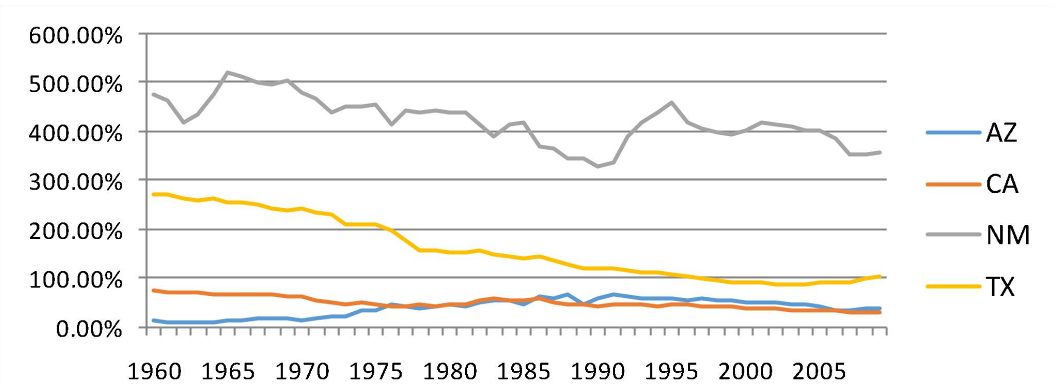

Figure 4 Energy Security Index

(the ratio of total energy production and total energy consumption)

Figure 2,3 and 4 describe some indexes related to production and consumption.

From Figure 2, we can know that the proportion of clean energy consumed is growing with fluctuation. AZ has the highest proportion while TX has the lowest.

As for the energy consumed per GDP that is described in Figure 3, CA costs least energy per GDP while TX costs most. But all four states have their costs decreasing in 50 years(except NM which had its cost increased from 1986 to 1990).

Figure 4 describes the security of energy usage (the dependency on outside energy). From the figure, NM and TX are typical energy-output states whose energy production is much larger than consumption. On the contrary, AZ and CA's energy production is not enough for their energy consumption.

Secondly, to have a overall view, we give each state a profile and rank the parameters involved out of four states. Data in the profile is describes the average condition of four states from 1960 to 2009.(e.g. average fossil fuels proportion = total fossil fuels consumption added from 1960 to 2009 / total energy consumption added from 1960 to 2009)

Arizona(AZ)					
Energy Consumption					
by fuel types	**Proportion**	**Rank**	by sectors	**Proportion**	**Rank**
Fossil Fuels	88.69%	3	**Industrial**	21.29%	4
Net imports of electricity	-0.01%	3	**Transportation**	35.35%	2
Net interstate sales of electricity	-13.47%	3	**Commercial**	20.94%	1
Clean Energy	24.79%	1	**Residential**	22.43%	1
Other Statistics					
	Value	**Rank**		**Proportion**	**Rank**
Total energy consumed per dollar of real GDP	8.41	3	**Energy Security Index**	45.15%	4

California (CA)					
Energy Consumption					
by fuel types	**Proportion**	**Rank**	by sectors	**Proportion**	**Rank**
Fossil Fuels	79.71%	4	**Industrial**	28.10%	3
Net imports of electricity	0.08%	1	**Transportation**	36.52%	1
Net interstate sales of electricity	8.14%	1	**Commercial**	16.62%	2
Clean Energy	12.08%	2	**Residential**	18.75%	2
Other Statistics					
	Value	**Rank**		**Proportion**	**Rank**
Total energy consumed per dollar of real GDP	15.30	1	**Energy Security Index**	146.33%	2

New Mexico(NM)					
Energy Consumption					
by fuel types	**Proportion**	**Rank**	by sectors	**Proportion**	**Rank**
Fossil Fuels	120.02%	1	**Industrial**	36.15%	2
Net imports of electricity	0.00%	2	**Transportation**	33.68%	3
Net interstate sales of electricity	-21.96%	4	**Commercial**	15.63%	3
Clean Energy	1.95%	4	**Residential**	14.54%	3
Other Statistics					
	Value	**Rank**		**Proportion**	**Rank**
Total energy consumed per dollar of real GDP	13.03	2	**Energy Security Index**	417.34%	1

Texas(TX)					
Energy Consumption					
by fuel types	**Proportion**	**Rank**	by sectors	**Proportion**	**Rank**
Fossil Fuels	97.09%	2	**Industrial**	57.67%	1
Net imports of electricity	-0.01%	3	**Transportation**	21.21%	4
Net interstate sales of electricity	0.13%	3	**Commercial**	9.49%	4
Clean Energy	2.79%	3	**Residential**	11.62%	4
Other Statistics					
	Value	**Rank**		**Proportion**	**Rank**
Total energy consumed per dollar of real GDP	15.30	1	**Energy Security Index**	146.33%	2

4.2 Analyse the Profile

4.2.1 How to measure the energy condition

To build up a model to describe how the energy profile has evolved, we take three main aspects into account:

1.the relation between energy condition and the decrease of total energy consumed per dollar of real GDP

2. the relation between energy condition and the increase of clean energy usage

3. the relation between energy condition and the negative impact on GDP

Reconsider these relations, we can simplify them into two sides: the GDP growth and the consumption of non-renewable energy and clean energy.

Thus, in this model, we choose non-renewable energy consumption per unit of GDP (NECP) to describe the cleanliness and efficiency of energy usage. As for the indicators, to cover all the three aspects above, we choose five factors which may influence the result, including the energy's real average price (EPR), renewable energy consumption ratio(RECR), renewable energy production ratio (REPR),industrial energy consumption ratio (IECR) and population(POP).

4.2.2 Multiple Linear Regression

Step1: We assume the multiple linear regression between NECP and five factors as below:

$$NECP = \lambda_1 EPR + \lambda_2 RECR + \lambda_3 REPR + \lambda_4 IECR + \lambda_5 POP + c$$

To observe the relationship between the non-renewable energy consumption of unit GDP and these five factors, we should calculate the coefficients of each factors.

Before calculating the coefficients, to eliminate the numerical influence, we calculate the average of each factor. The operation makes the coefficients of factors directly reflect the magnitude of the influence of these factors on NECP.

Moreover, since we make the same operation to all factors, the coefficients' relative size keep unchanged, so it will not influence the accuracy of this model.

Step2: We use Matlab to build a multiple linear regression to fit between NECP and five factors. The coefficients of factors are given in **Table 1**.

Table 1

	EPR	RECR	REPR	IECR	POP	c	R^2
AZ	-0.5691	-4.0392	-0.5690	2.6114	-4.1722	13.8363	0.9816
CA	-1.0921	-2.8290	1.6219	1.1731	-9.0160	16.2443	0.9827
NM	-3.0202	-5.9314	5.9786	0.1205	-19.7283	36.5023	0.9469
TX	-0.3490	-0.8335	1.4032	12.6452	-16.3478	19.3998	0.9917

From the table above, we can find that the relative coefficients of EPR and REPR are significantly lower in the function. To simplify the model, we removed these two factors and set up a ternary linear regression model:

$$NECP = \lambda_1 RECR + \lambda_2 IECR + \lambda_3 POP + c$$

Use Matlab to make the fitting again. The new coefficients are given in **Table 2.**

Table2

	λ_1	λ_2	λ_3	c	R^2
AZ	-3.7445	2.3860	-4.0735	12.5302	0.9748
CA	-1.5186	3.2052	-8.0685	12.4842	0.9733
NM	-0.0132	-3.3271	-21.5172	38.7790	0.9243
TX	0.5207	4.7200	-19.8066	30.4838	0.9865

4.2.3 The Practical Analysis of Our Factors

- **Population** is the most significant factor affecting NECP of these four states. The NECP of all four states decrease due to the growth of population. This is because the increase in the labor force can increase GDP, thereby reducing NECP.

- **Industrial energy consumption ratio** (IECR) of Arizona, California and Texas has a negative effect to NECP. Its increase will cause NECP in these three states increase, which means the industrial sectors of three states still use a lot of non-renewable energy and clean energy ratio is lower. While the IECR of New Mexico has a positive effect to NECP, we can think its industrial department uses more clean energy than other departments, or maybe other departments use too little clean energy. Whatever, the energy efficiency of New Mexico is not satisfactory.
- **Renewable energy consumption ratio** has significant impact on NECP only in Arizona. This shows that the energy efficiency of Arizona state is stable. And its technology of clean energy is more advanced and mature so that the increase in RECR has less impact on energy consumption per unit of GDP.

5 Evaluate the Usage of Clean Energy

5.1 Decisive Indicators

Among current studies and documents, we have no authoritative criterion to assess a state's usage of clean energy. Other than that, the attached database doesn't have adequate indicators which are directly related to clean energy.

Having considered diverse indicators, we finally decide nine indicators which are related to the usage condition of clean energy, as given in **Table 3.** We classify the indicators into two types: positive indicators(which have positive relation with the usage of clean energy) and negative indicators(which have negative relation).

Table 3

	Definition	Unit	Type
I_1	Total Energy Consumed per Dollar of Real GDP	MMBtu/$	Negative
I_2	Consumption of Renewable Energy	Billion Btu	Positive
I_3	Consumption of Nuclear Energy	Billion Btu	Positive
I_4	Consumption of Electricity Outside the State (add net imports of electricity and net interstate sales of electricity)	Billion Btu	Positive
I_5	Growth Rate of Renewable Energy(2008-2009)	Percent	Positive

I_6	Growth Rate of Nuclear Electricity (2008-2009)	Percent	Positive
I_7	Emission of CO_2	Million metric tons	Negative
I_8	The Percentage of NO_x Emission in US Total NO_x Emission	Percent	Negative
I_9	The Percentage of Sulfides Emission in US Total Sulfides Emission	Percent	Negative

5.2 Determine the Weight of Indicators Base on Entropy Weight Method

To determine the value of indicators in evaluation, we use entropy weight method to standardize the dispersion degree of different indicators into values between 0 to 1.

Assume there are **n states and m indicators**, we use I_{ij} to describe the i^{th} state under the j^{th} indicator. (i=1,2,3,n; j=1,2,...,m)

For positive indicators,

$$I'_{ij} = \frac{I_{ij} - \min\{I_{1j},\cdots,I_{ij}\}}{\max\{I_{1j},\cdots,I_{ij}\} - \min\{I_{1j},\cdots,I_{ij}\}}$$

For negative indicators,

$$I'_{ij} = \frac{\max\{I_{1j},\cdots,I_{ij}\} - I_{ij}}{\max\{I_{1j},\cdots,I_{ij}\} - \min\{I_{1j},\cdots,I_{ij}\}}$$

(To simplify writing, we still use I_{ij} to describe the results I'_{ij})

Use P_{ij} to describe the proportion of sample *i* (the i^{th} state) under the j^{th} indicator

$$p_{ij} = \frac{I_{ij}}{\sum_{i=1}^{n} I_{ij}}$$

Then, calculate the entropy of I_j,

$$e_j = -k\sum_{i=1}^{n} p_{ij}\ln(p_{ij})$$

$(k = 1/\ln(\text{n})$ to ensure $e_j \geq 0)$

The diversity of entropy is

$$d_j = 1 - e_j$$

and the value of indicator j is

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

In this problem, there are four states and nine indicators.

Set **n = 4 and m = 9**, then we input the data into a Matlab program that calculates the weight of each indicator, as given in **Table 4.**

Table 4

Indicator	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
Weight	0.1323	0.1536	0.0814	0.1764	0.0879	0.1073	0.1008	0.0813	0.0790

5.3 Evaluation Based on the Fuzzy Decision Model

To calculate the priority of indicators, we use fuzzy decision algorithm, along with the weights based on entropy method to build the model.

Step 1: Quantify primary evaluation degrees from 1 to 10 and build up a standard to match degrees and triangular fuzzy numbers. The standard is given in **Table 5**. The symbol of evaluation degree is written as h (h=1,2,...,10) while triangular fuzzy number is written as f.

Table 5

Degree (h)	1	2	3	4	5
Quantified Fuzzy Numbers (f)	（5,10,15）	（15,20,25）	（25,30,35）	（35,40,45）	（45,50,55）
Degree (h)	6	7	8	9	10
Quantified Fuzzy Number (f)	（55,60,65）	（65,70,75）	（75,80,85）	（85,90,95）	（95,100,105）

*Step 2:*Build a n × m fuzzy indicator matrix I in which I_{ij} is the j^{th} indicator of the i^{th} state. Set up 10 evaluation degrees, which are written as h (h=1,2,...,10).

For the j^{th}column, introduce discrimination value a,

$$a_{ij} = \frac{I_{ij} - \min I_j}{\max I_j - \min I_j}$$

if $a_{ij} \in \left[\frac{h-1}{10}, \frac{h}{10}\right]$,the primary evaluation degree of I_{ij} is h.

From the relation between h and f in Table 3, we can quantify the corresponding triangular fuzzy number f_{ij}. Then build the matrix of triangular fuzzy numbers

$$F = (f_{ij})_{\mathrm{m\times n}}$$

Standardize *F* to build the standardized matrix of triangular fuzzy numbers

$$R = (y_{ij})_{\mathrm{m\times n}}$$

Step 3: Build the triangular fuzzy numbers of indicator's weight in Table 2. Combine them as a vector *w*.

$$w = [(w_1,w_1,w_1),(w_2,w_2,w_2),\cdots,(w_m,w_m,w_m)]$$

(m is the total number of states)

Then, weighted the standardized matrix *R*, and we get the fuzzy decision matrix

$$D = (r_{ij})_{\mathrm{m\times n}} \ ,$$

in which

$$r_{ij} = w_j \Theta\, y_{ij} = (w_j^{(1)} y_{ij}^{(1)}, w_j^{(2)} y_{ij}^{(2)}, w_j^{(3)} y_{ij}^{(3)})$$

(i=1,2,...,n; j=1,2,...,m)

Step 4: We use M^+ to describe the fuzzy positive ideal and M^- to describe the fuzzy negative ideal.

$$M^+ = (M_1^+,M_2^+,\dots,M_{3j}^+),\ \ M^- = (M_1^-,M_2^-,\dots,M_{3j}^-)$$

The component $M_j^+ = \max\{r_{1j},r_{2j},\dots,r_{nj}\}$ is the maximum fuzzy number among the fuzzy numbers of column *j* in the fuzzy decision matrix *D*, and $M_j^- = \min\{r_{1j},r_{2j},\dots,r_{nj}\}$ is the minimum fuzzy number among the fuzzy numbers of the j^{th}column in the fuzzy decision matrix *D*.

Then, we build equations to calculate the distance between condition of state *i* and M^+, M^-. Use d_i^+ and d_i^- to symbolize them.

$$d_i^+ = \sqrt{\sum_{j=1}^{3j} (r_{ij} - M_j^+)^2}\ ,\ d_i^- = \sqrt{\sum_{j=1}^{3j} (r_{ij} - M_j^-)^2}\ ,\ i=1,2,\dots,n$$

Step 5: Assume the membership degree between the i^{th}state and fuzzy positive ideal M^+ is μ_i.

$$\mu_i = \frac{d_i^-}{d_i^+ + d_i^-}$$

(i=1,2,...,n)

In this problem, there are four states and nine indicators.

Set **n = 4 and m = 9**, then we input the data into a Matlab program, the results are given in **Table 6**.

Table 6

	Arizona (AZ)	California (CA)	New Mexico (NM)	Texas (TX)

d_i^+	0.2472	0.2977	0.3382	0.3380
d_i^-	0.4118	0.3846	0.3582	0.2985
μ_i	0.6249	0.5637	0.5144	0.4690

Since μ_i has positive relation with the evaluation of the usage of clean energy, we can rank the usage of clean energy among four states from best to worst:

AZ>CA>NM>TX

Arizona has the best profile of clean energy.

6 Predict the Future Energy Profile

6.1 Prediction Based on the ARIMA Time Series Model

Considering that we have no future data of the indicators used in the evaluation of part 5, if we use previous model to evaluate future energy condition indirectly, the error of prediction cannot be neglected. So in this question, we use ARIMA(p,D,q) model of total energy consumption, real GDP, and NECP(non-renewable energy consumption per unit of GDP) to predict the energy profile of each state from 2025 to 2050.

ARIMA(p,D,q) time series model calculates D-order difference of the data, then the model puts the data into equation ARMA(p,q) :

$$X_t = \varphi_1 X_{t-1} + \cdots + \varphi_p X_{t-p} + a_t - \theta_1 a_{t-1} - \cdots - \theta_{t-q} a_{t-q}$$

(X_t:the time series after calculation of D-order difference; a_t: white noise sequence)

With a Matlab program, first, we build the ARIMA(p,D,q) time series model of total energy consumption for each state.Based on the model, we predict the NECP from 2025 to 2050 for each state, as plotted in **Figure 5**.

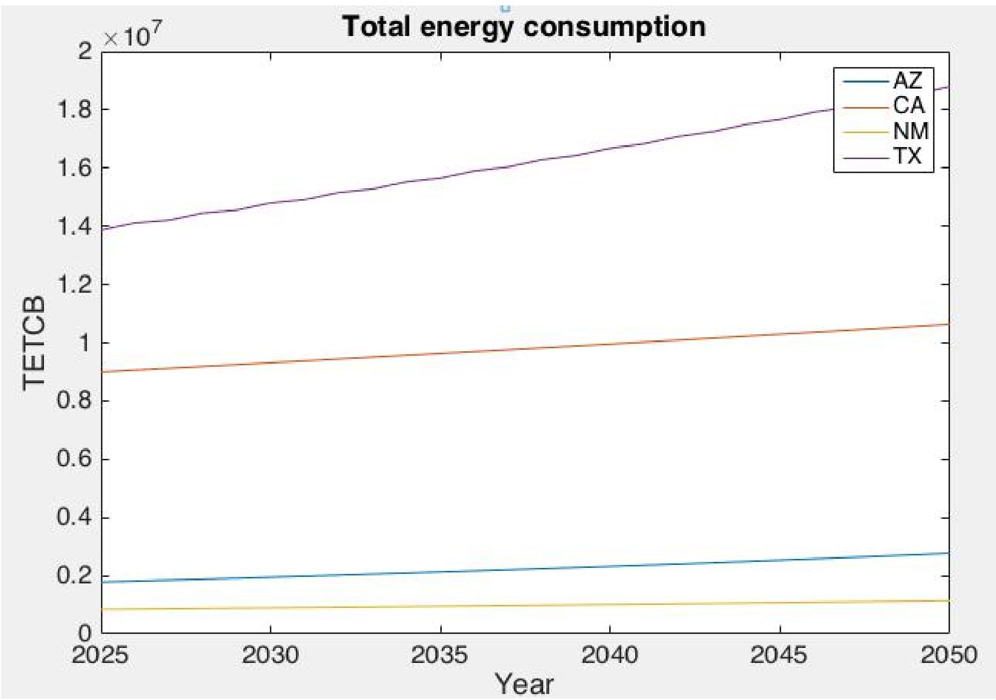

Figure 5

Using data from 1960-2009 to have a empirical test in Matlab, we have the goodness-of-fit, as given in Table 5. From **Table 7** we can know that the time series model fits the data well.

Table 7

State	AZ	CA	NM	TX
R^2	0.9947	0.9876	0.9665	0.9880

And the prediction of total energy consumption in 2025 and 2050 is given in **Table 8**.

Table 8

	2025	2050
AZ	1.7384×10^6	2.7676×10^6
CA	0.9001×10^7	1.0637×10^7
NM	0.8474×10^6	1.1435×10^6
TX	1.3867×10^7	1.8802×10^7

According to our prediction, Texas(TX)'s will have the most total energy consumption and fastest growth, Mexico(NM)'s condition is similar to Arizona(AZ), using less energy.

Secondly, we do the same work for the real GDP from 2025 to 2050, as plotted in **Figure 6**.

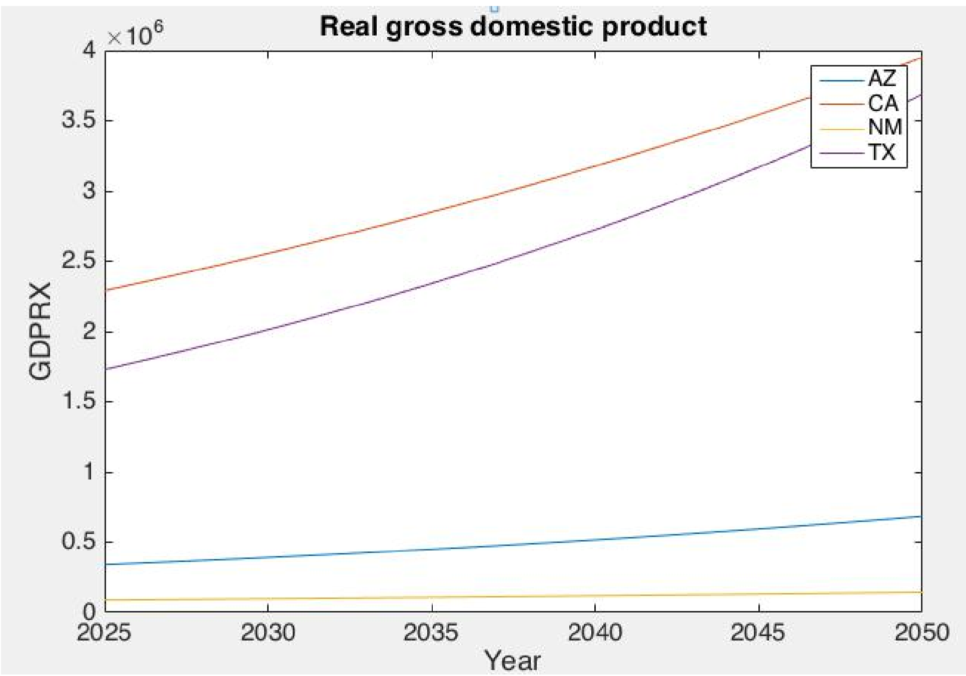

Figure 6

The goodness-of-fit of empirical test:

Table 9

State	AZ	CA	NM	TX
R^2	0.9969	0.9956	0.9932	0.9944

And the real GDP prediction in 2025 and 2050 is given in **Table 10**

Table 10

	2025	2050
AZ	3.3975×10^5	6.8204×10^5
CA	2.2906×10^6	3.9502×10^6
NM	0.8757×10^5	1.4257×10^5
TX	1.7297×10^6	3.6867×10^6

According to our prediction, California(CA)'s and Texas(TX)'s GDP will have the best GDP development. New Mexico(NM)'s situation is worrying.

Finally, to describe the usage of clean energy, we build the ARIMA(p,D,q) time series model of NECP(non-renewable energy consumption per unit of GDP). The prediction from 2025 to 2050 for each state is plotted in **Figure 7**.

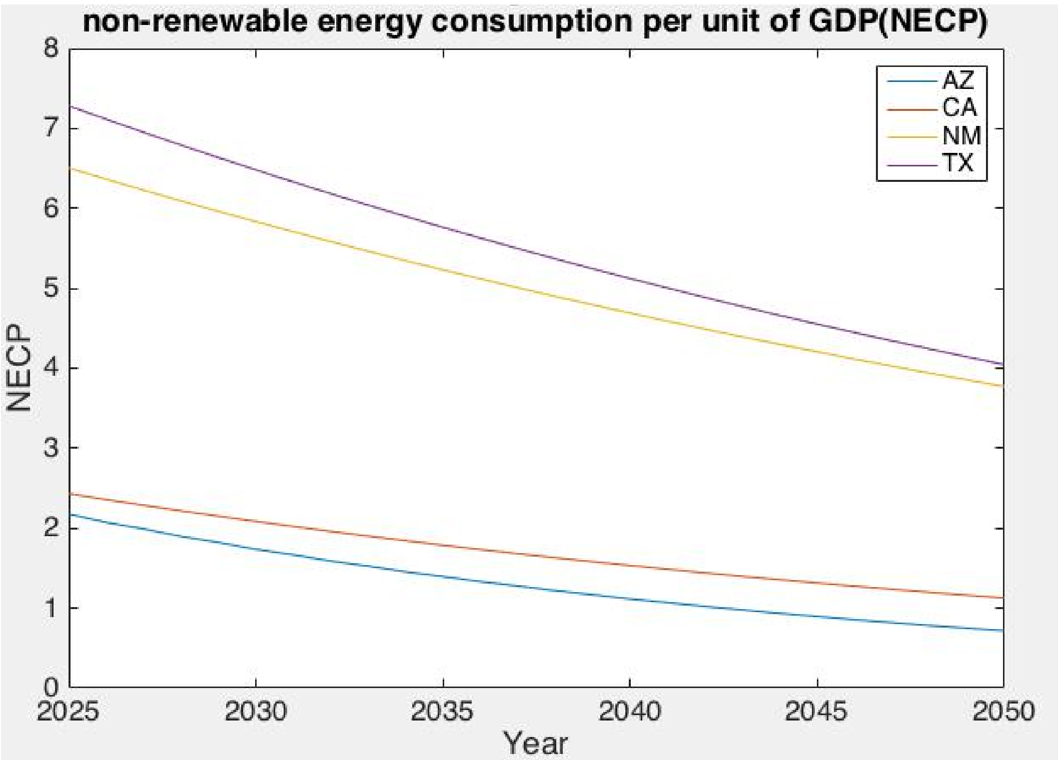

Figure 7

The goodness-of-fit of empirical test is given in Table 11.

Table 11

State	AZ	CA	NM	TX
R^2	0.9574	0.9885	0.9569	0.9863

And the non-renewable energy consumption per unit of GDP in 2025 and 2050 is given in **Table 12**.

Table 12

	2025	2050
AZ	2.1768	0.7163
CA	2.4320	1.1270
NM	6.5052	3.7710
TX	7.2809	4.0455

According to our prediction, Arizona(AZ) has the best usage of clean energy, California(CA)'s condition is similar to AZ, while New Mexico(NM) and Texas(TX)'s condition is worse.

7 Set up Goals for Future

7.1 Goals Setting

7.1.1 Total goals

To determine the overall level of energy consumption, we calculated the total non-renewable energy consumption per unit of GDP for all four states (TNECP), that is, each states' NECP multiplied by GDP, divided by the total GDP of the four states. Then, using the ARIMA (p, D, q) model again, establish a time series model of TNECP and predict the TNECP of 2025 and 2050: 3.9572, 1.9776.

The goal of the energy contract is to achieve a win-win situation of energy and economic development in all four states. After the formation of the contract, technology sharing and reduction of barriers to energy import and export will inevitably lead to the convergence of the NECP of the four states. The states' GDP growth rate of all four states will increase, and the rate of reduction of NECP will be faster. However, least developed states will receive more new technology， which means GDP growth and NECP reduction will be faster than technology more mature states. Then, under this converging trend, the NECP arithmetic average of the four states will tend to tighten to the TNECP. Of course, NECP's arithmetic average can't be exactly equal to the TNECP, because GDP and NECP will be affected by various factors. However, under the contract, the arithmetic mean is likely to reach the TNECP predictive value.

Currently, the average forecast of the four states' NECP in 2025 and 2050 is 4.5987, 2.4149. We can set the TNECP projections in 2050 as the target for the four states' NECP arithmetic mean in 2050. Suppose that this rate of approach to the total NECP predictions is equal year by year, then since the contract started in 2010, by 2025, the difference between NECP average and TNECP forecast should aim to reduce 37.5%, based on the original forecast.

Table 13

	2025	2050
prediction	4.5987	2.4149
goals	4.3581	1.9776

7.1.2 States goals

Using total goals as the general objective of the contract, we can calculate the respective goals of each state in a converging trend. Taking the NECP of the four states in 2009 as the parameter, that is, the higher the unit NECP in 2009 is, the larger the difference between the predicted value and the target value is. We can get the following model:

$$4\varepsilon = \omega_1 \Delta NECP_{AZ} + \omega_2 \Delta NECP_{CA} + \omega_3 \Delta NECP_{NM} + \omega_4 \Delta NECP_{TX}$$

(ε represents the difference between the predicted mean NECP and the target average NECP)

According to the data of 2009, we get the coefficient:

Table 14

ω_1	ω_2	ω_3	ω_4
0.1622	0.1457	0.3340	0.3581

Using these coefficient, calculate the states goals in 2025

Table 15

	AZ	CA	NM	TX
NECP	2.0207	2.2918	6.1838	6.9363

And the states goals in 2050

Table 16

	AZ	CA	NM	TX
NECP	0.4326	0.8721	3.2769	3.4191

7.2 The Policy Advice for Governments

Next, we give each state three certain actions and some other actions. The most important part of the contract is technology sharing and reducing resource transportation costs, which can bring fastest reduction of NECP. For the four states, we can calculate the specific requirements of the three factors based on the model established.

$$NECP = \lambda_1 RECR + \lambda_2 IECR + \lambda_3 POP + c$$

We assume that the difficulty of changing the three factors is equal, and the greater the change, the harder it will be to change, so we will consider to accomplish the goal by changing the same rate of the three factors, and we hope all three factors will move in a favorable direction. So we can establish the following equation:

$$\grave{NECP}_t = (1 \pm x)^{t-2010}\ (\lambda_1 RECR_{2009} + \lambda_2 IECR_{2009} + \lambda_3 POP_{2009}) + c$$

($\grave{NECP}_t$ is the goal of NECP in t^{th}year, the sign of the coefficient of X is the opposite of λ_i)

Using Matlab, we can get the certain number of X. If each of the state want to achieve the goal in 2025, their factors annual change rate on average between 2010-2025 should be:

Table 17

	RECR	IECR	POP
AZ	2.41%	-2.41%	2.41%
CA	1.65%	-1.65%	1.65%
NM	1.11%	1.11%	1.11%
TX	0.16%	-0.16%	0.16%

If each of the state want to achieve the goal in 2050, their factors annual change rate on average between 2010-2050 should be:

Table 18

	RECR	IECR	POP
AZ	1.20%	-1.20%	1.20%
CA	0.86%	-0.86%	0.86%
NM	0.63%	0.63%	0.63%
TX	0.35%	-0.35%	0.35%

8 Conclusions

AZ and CA have the better energy profile. AZ has the highest proportion of clean energy in total energy consumption, while CA has the best energy efficiency. NM has a terrible clean energy profile with the highest energy security index, and TX has the worst efficiency. Population (POP), proportion of renewable energy in total energy consumption (PREC), proportion of industrial in total energy consumption (IREC) significantly affected non-renewable energy consumption per unit of GDP (NPEC). Based on Data in 2009, AZ has the best clean energy profile. Without any new policy, AZ and CA will still have the best usage of clean energy from 2025 to 2050 and the situation of NM is worrying.

We suggestion is having NECP's arithmetic average reduced to 4.3581 thousand

Btu per dollar by 2025 and reduced to 1.9776 thousand Btu per dollar by 2050 as the total goal of all four states. And for each state, the higher the NECP in 2009 is, the larger the difference between the predicted value and the target value is. Governors can achieve goals by controlling PERC, IREC, POP change to be a same rate.

9 Strengths and Weaknesses

- **Strengths**

Our multiple linear regression model removes the effect of numerical size, and we also consider the goodness of fit, so our model is acceptable.

In evaluating the usage of clean energy, we use entropyweightmethod (EWM) to give a weight vector of indicators. This avoids the error of subjective assignment and improve the accuracy of our model.

In the establishment of triangular fuzzy Numbers, we adopt the unified index quantification standard. It excludes the influence of the numerical size. So, our evaluation system is objective and credible.

- **Weaknesses**

In our multiple linear regression model, we choose the factors subjectively, so the factors are not comprehensive.

Our evaluation system of usage of clean energy only has nine indicators. It not cover all factors influencing the result.

10 A Memo to Governors

- **Energy profile**

From 1960 to 2009，Arizona(AZ) and California(CA) have better energy profiles, while situations of New Mexico(NM) and Texas(TX) are unsatisfying. NM has the highest energy security index, which may lead to its terrible energy efficiency and low usage of clean energy. TX has the worst energy efficiency. AZ has the highest proportion of clean energy in total energy consumption(RER), while CA has the lowest energy consumption per unit of GDP. AZ and CA have less non-renewable energy consumption per unit of GDP(NECP) than other two states. But almost all four states have their costs decreasing in 1960-2009.

Considering the features that affect NECP， population is the most powerful features for all four states. Population growth means the reduction of NECP. At the same time, the proportion of renewable energy in total energy consumption (RECR) significantly affect the NECP of AZ. And proportion of industrial sector in total energy consumption (IECR) significantly affected the NECP of CA.

- **Energy profile prediction**

Using the ARIMA(p, D, q) model to predict the GDP, total energy consumption(TETCB) and NECP without any new policy. AZ and CA will still have the best usage of clean energy, and CA and TX will have the best GDP development. However, the NECP of TX is too high, besides, TX will have the largest total energy consumption and fastest energy consumption growth. NM will have the worst situation, meaning the necessity of its policy changes..

- **Total goals**

Based on the predictions of NECP and TNECP of all four states, we suggest the total goal of all four states' average NECP reduces to 4.3581 by 2025 and reduces to 1.9776 by 2050.

Reference

[1]Zhi-hong, ZOU, Yi , YUN, Jing-nan SUN. Entropy method for determination of weight of evaluating indicators in fuzzy synthetic evaluation for water quality assessment[J]. Journal of Environmental Sciences,2006,18(5).

[2]RajendranVidhya, Rajkumar Irene Hepzibah. A comparative study on interval arithmetic operations with intuitionistic fuzzy numbers for solving an intuitionistic fuzzy multi–objective linear programming problem[J]. International Journal of Applied Mathematics and Computer Science,2017,27(3).

[3]Adam Grabowski. The Formal Construction of Fuzzy Numbers[J]. Formalized Mathematics,2015,22(4).

[4]Lei Ming. Research on energy consumption structure in China [D]. Shanghai jiaotong university,2007.

[5] Zhang Wei, Wu Wenyuan. Research on the energy efficiency of the whole element of the metropolitan area based on environmental performance [J]. Economic research,2011,46(10):95-109.

[6]Wang Guangqing. Research on Regional Sustainable Development Theory and Decision-Supporting System [D]. TIANJIN: Tianjin University, 2004.

[7]BP, British Petroleum, Statistical Review of World Energy, 2010.

[8]IEA, International Energy Agency, CO2 emissions from fuel combustion, 2014.

[9]https://www.eia.gov/U.S. Energy Information Administration (EIA)