For office use only	Team Control Number	For office use only
T1 ________	**74303**	F1 ________
T2 ________		F2 ________
T3 ________	Problem Chosen	F3 ________
T4 ________	**C**	F4 ________

2018
MCM/ICM
Summary Sheet

Renewable Energy: Current, Evaluation and Future

Summary

Energy production and usage account for a large percentage of any economy, while they can be affected by many factors, such as the varying geographies and industries of different states.

In order to complete the first energy profile, we completed some data visualization. We have established temporal bar charts for the usage of renewable energy and their share in total energy, the temporal line chart for the various renewable energy usage in each state, and pie charts of various renewable energy sharing in 1960 and 2009. The specific work can be seen in 3.1. At the same time, we have done a polynomial fitting for usage of renewable energy. The two water-rich states AZ and CA rely more on hydroelectricity, while the inland states NM and TX emphasize on wind and wood and waste. We also used Pearson PMCC to describe the correlation between economy and renewable energy consumption. It reached 0.9915, indicating that the two are highly relevant.

To pick the best profile, we adopted analytic hierarchy process (AHP). Taking 2009 for example, we chose fourÂărepresentative indexes as nodes in criteria, and by comparing importance two by two, we obtained judgment matrix A and its consistency index CR indicates its satisfactory consistency (CR = 0.0199 < 0.1). By standardizing the eigenvector of theÂămaximum eigenvalue in A, we obtained final weights between goal and criteria. Then, we calculated weights vectors of criteria and alternatives, and we resulted in final weights' vector through weights' vectors we got before. Elements in the final weights vector represent the corresponding weights for states, and the maximal is the best. In our model California has the best profile.

To predict the energy profile of year 2025 and 2050, we built a 2-LSTM layer RNN network. The neural network uses back-propagation through time (BPTTT) to finish error correction. Each time of prediction the RNN receives an input of 8 timesteps, 10 features and outputs the next prediction. In our analysis, the model has a general performance.

Based on our previous work and predictions, especially the predicted average increases, we set up the targets of renewable energy usage for the four states in 2025 and 2050. The detailed targets can be seen in 4.1. To achieve the goal, States should invest more in clean renewable energy to reduce cost, take advantage of government money to intervene in energy prices, and adopt preferential policies.

Keywords: Renewable Energy, AHP, RNN, LSTM, Polynomial Fit, Energy Consumption

1 Restatement of the Problem

1.1 Background

Energy production and application play a significant role in today's economic activities. At the same time, the promotion of energy efficiency is a increasingly challenging issue to be resolved, due to a number of complex influence factors. For examples, the varying geographies, and industries of different states would affect the energy efficiency to some extent. Accordingly, the effective technologies related to energy saving and environment protection have received a surge of attentions in recent decades.

Along the U.S. border with Mexico, there are four states: California(CA), Arizona(AZ), New Mexico(NM) and Texas(TX). They aim to construct a realistic new energy compact for increased usage of cleaner, renewable energy sources. In order to facilitate the development of the compact targets in the four states, we are asked to perform data analysis and modeling to propose a set of goals for them in this paper.

1.2 Our Work

Aiming at above issues, the main solutions to the problems are elucidated as follows.

- We **reduce the data dimensionality** to simplify the problem and **make the data visible**. We draw some charts to show the historical data, then we get an energy profile for each of the four states.
- We develop a **non-linear fitting model**, we use the fitted results to discuss the similarities and differences between the four states, and discuss the possible influential factors of the similarities and differences.
- We use the **analytic hierarchy process(AHP)** to construct an **energy profile assessment model**. By the comparison of four states, we will determine one of them to have the "best" profile for use of cleaner, renewable energy in 2009.
- We build a **2-LSTM layer RNN network** with tanh activation function output. The neural network uses back-propagation through time (BPTTT) to finish error correction. Each time of prediction the RNN receives an input of 8 timesteps, 10 features and outputs the next increase (positive) or decrease (negative) amount of data.
- In the Part Two, we calculate the **average increases**. Based on it, we set up the targets of renewable energy usage and make three actions for the goal.
- Finally, we analyze our models in several aspects, including the sensitivity, strengths and weaknesses.

2 Assumption and Justification

In order to improve the accuracy of our model, we make the following simplifying assumptions, each of which is properly justified.

- **At a certain time, the amount of electricity generated by the power plant is equal to the amount of electricity consumed.** According to the law of conservation of energy, the electricity must follow the relation of $Electricity_{generate} = Electricity_{consume} + Electricity_{loss}$, but the loss of electricity is small and random, it is nearly impossible to consider the random loss.
- **Prices of natural gas (NG in MSN code) and natural gas (excluding supplemental gaseous fuels, NN in MSN code) are treated the same.** On building our prediction model, we found that NN is included in the total expenditures (TETCV) but there isn't detailed expenditures related to NN. We consider that the value of NG and NN are the same, through which we calculate the total expenditure of NN (NNTCV, if there is a MSN code) by $NNTCB * NGTCD$.
- **There are no external factors affecting the energy usage in the future prediction, especially external factors from the government or very-low-probability events.**

Based on the basic assumptions above, we can set out to construct our models.

3 Create Energy Profiles to Illustrate Situation

3.1 Data Analysis and Energy Profiles Description

In the data, there are 605 variables describing the energy usage in the four states from 1960 to 2009. Each of 605 variables has a five-letter abbreviation, where the first two letters represent the type of energy, the third and fourth letters represent the energy activity or energy-consuming sector, and the last letter represents the type of data. An example is shown in Figure 1.

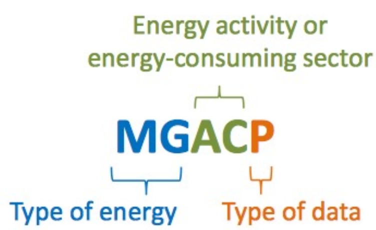

Figure 1: The meaning of the abbreviation

Because there are no collected information regarding energy production, we use the energy consumption to depict the energy profiles. Thus we should calculate total renewable energy consumption(RETCB) as the following equation:

$$RETCB = EMLCB+EMTCB+GETCB+HYTCB+SOTCB+WWTCB+WYTCB$$

The EMLCB means energy losses and co-products from the production of fuel ethanol(unit: Billion Btu).

After calculating RETCB, we draw several charts(the unit: Billion Btu) for each of four states. Specifically, these charts are composed of the rate between renewable energy

Table 1: Corresponding Variables

MSN	Description	Unit
EMTCB	Fuel ethanol excluding denaturant total consumed.	Billion Btu
GETCB	Geothermal energy, total consumed.	Billion Btu
HYTCB	Hydroelectricity, total consumed.	Billion Btu
SOTCB	Solar energy, total consumed.	Billion Btu
WWTCB	Wood and waste total consumed.	Billion Btu
WYTCB	Wind energy, total consumed.	Billion Btu

consumption and total energy consumption, the percentage of every renewable energy usage in 1960 and 2009, and the trend for every renewable energy usage.

3.2 Non-linear Fitting Model to Characterize Energy Profiles

We build a non-linear fitting model to describe the evolution for the energy profiles. In order to fit the data better, we make a fifth power operation in Equations (1), where x_p means several random years from 1960 to 2009, y_p means the corresponding renewable energy consumption(unit: Billion Btu), a_q is the numerical coefficient, c is the numerical constant.

$$\begin{cases} a_1x_1^5 + a_2x_1^4 + a_3x_1^3 + a_4x_1^2 + a_5x_1 + c = y_1 \\ a_1x_2^5 + a_2x_2^4 + a_3x_2^3 + a_4x_2^2 + a_5x_2 + c = y_2 \\ a_1x_3^5 + a_2x_3^4 + a_3x_3^3 + a_4x_3^2 + a_5x_3 + c = y_3 \\ a_1x_4^5 + a_2x_4^4 + a_3x_4^3 + a_4x_4^2 + a_5x_4 + c = y_4 \end{cases} \tag{1}$$

We take geothermal energy total consumption(GETCB) in California as an example, and elect a set of x_p and y_p values in Table 2.

Table 2: A Numerical Example for Variables

p	1	2	3	4
x_p	1960	1980	2000	2009
y_p	359.0397	52699.14	127599.7	127461.1

Then we define the matrix A and matrix B:

$$A = \begin{bmatrix} 1 & x_1^5 & x_1^4 & x_1^3 & x_1^2 & x_1 \\ 1 & x_2^5 & x_2^4 & x_2^3 & x_2^2 & x_2 \\ 1 & x_3^5 & x_3^4 & x_3^3 & x_3^2 & x_3 \\ 1 & x_4^5 & x_4^4 & x_4^3 & x_4^2 & x_4 \end{bmatrix}, B = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}$$

And they meet the following equation:

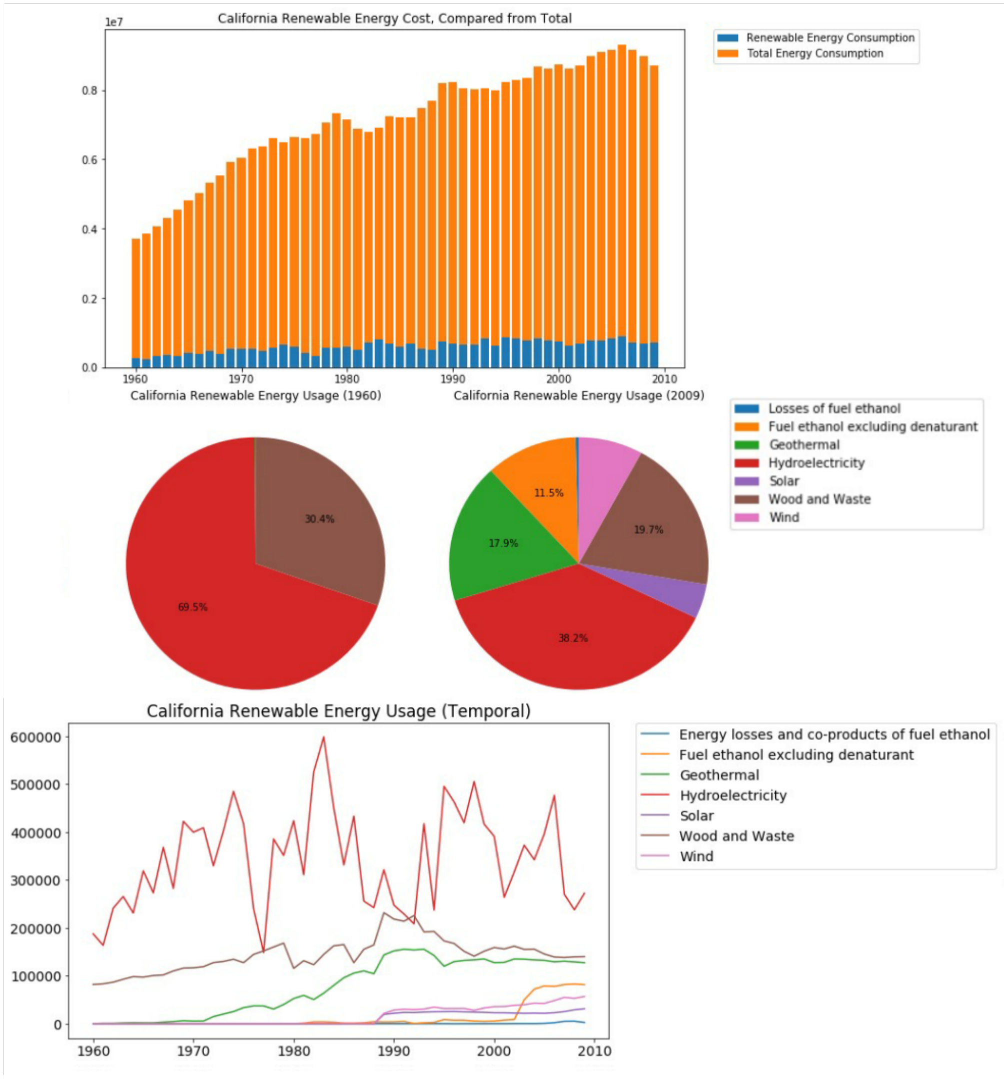

Figure 2: The renewable energy usage in California

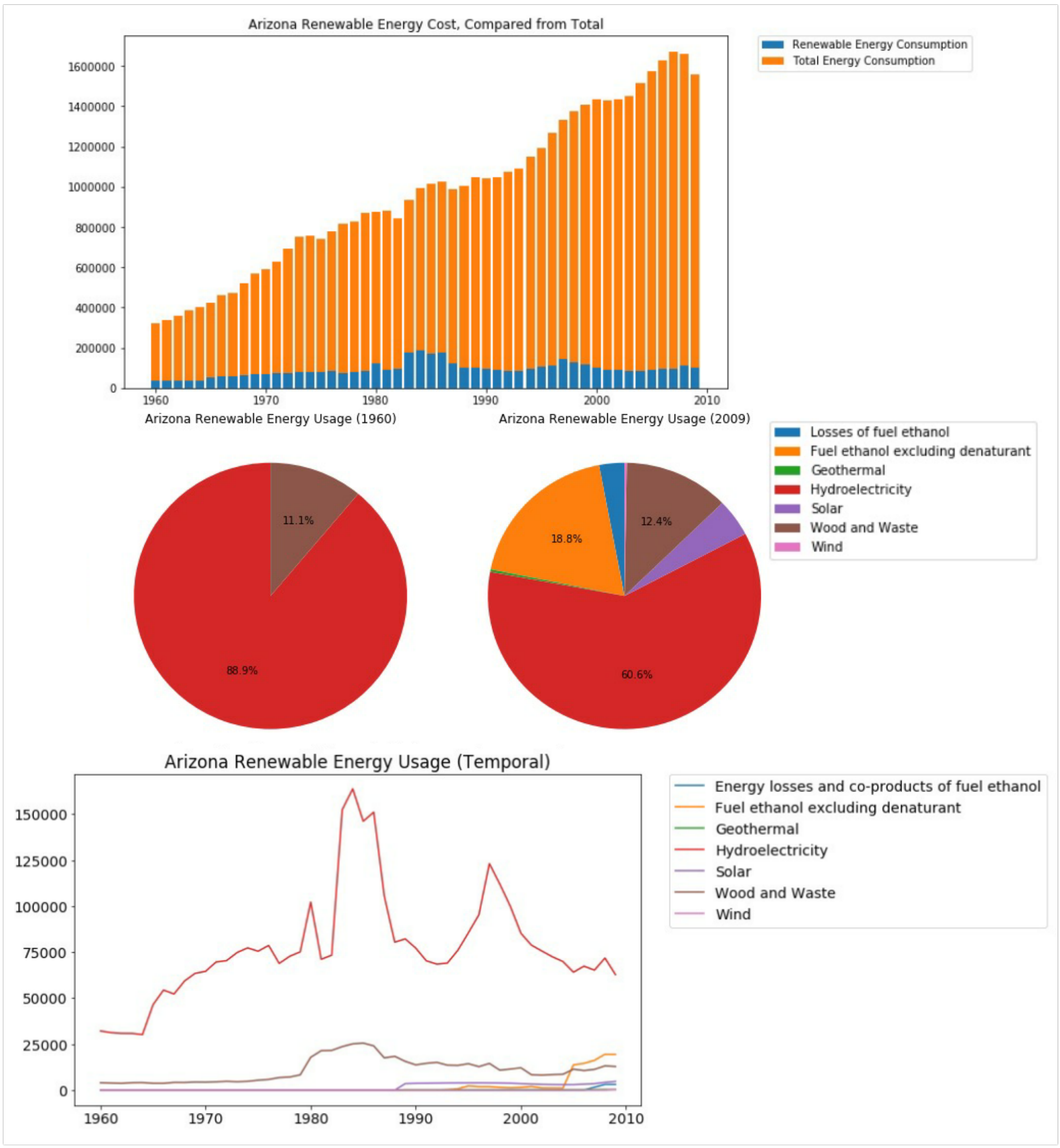

Figure 3: The renewable energy usage in Arizona

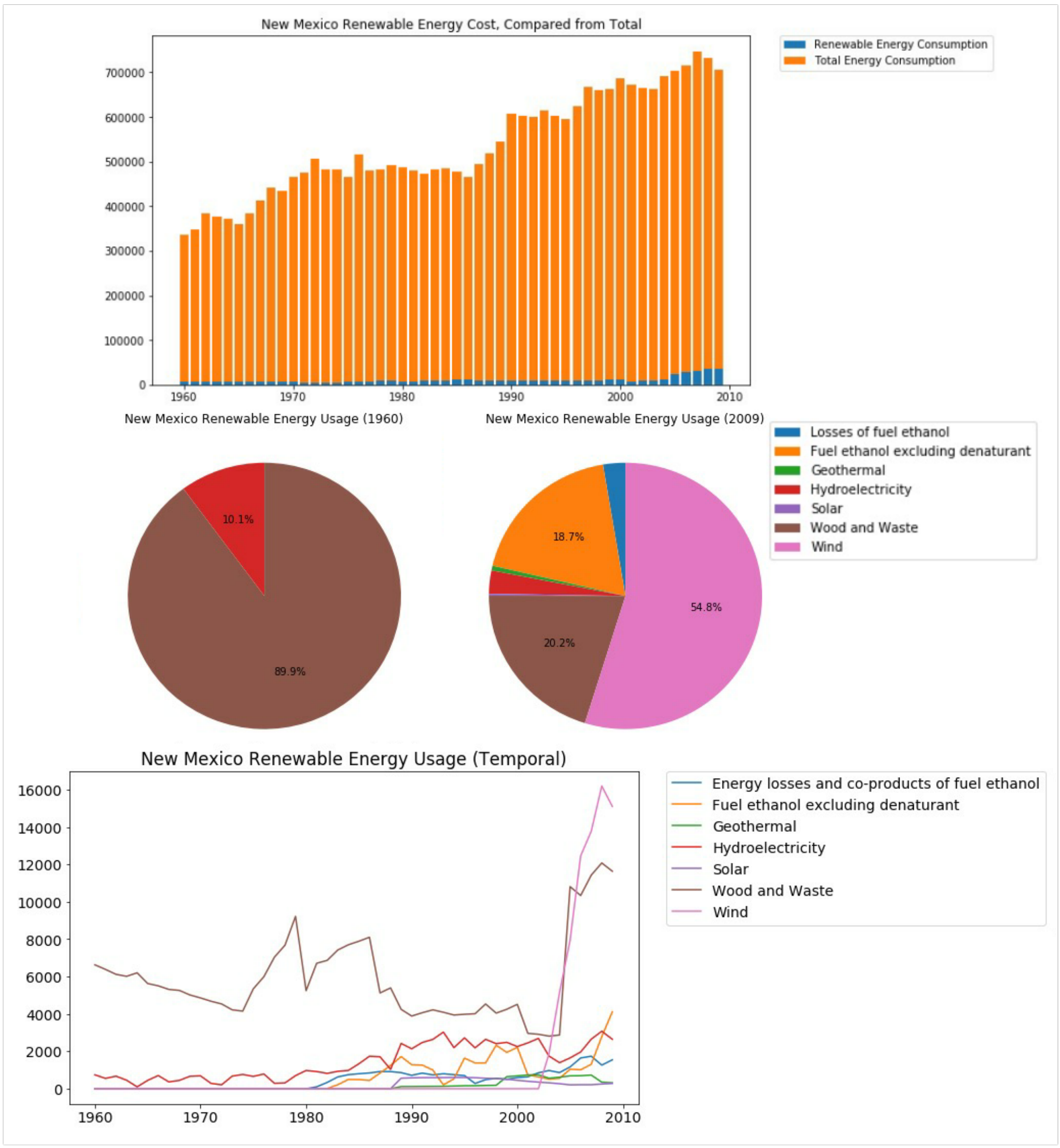

Figure 4: The renewable energy usage in New Mexico

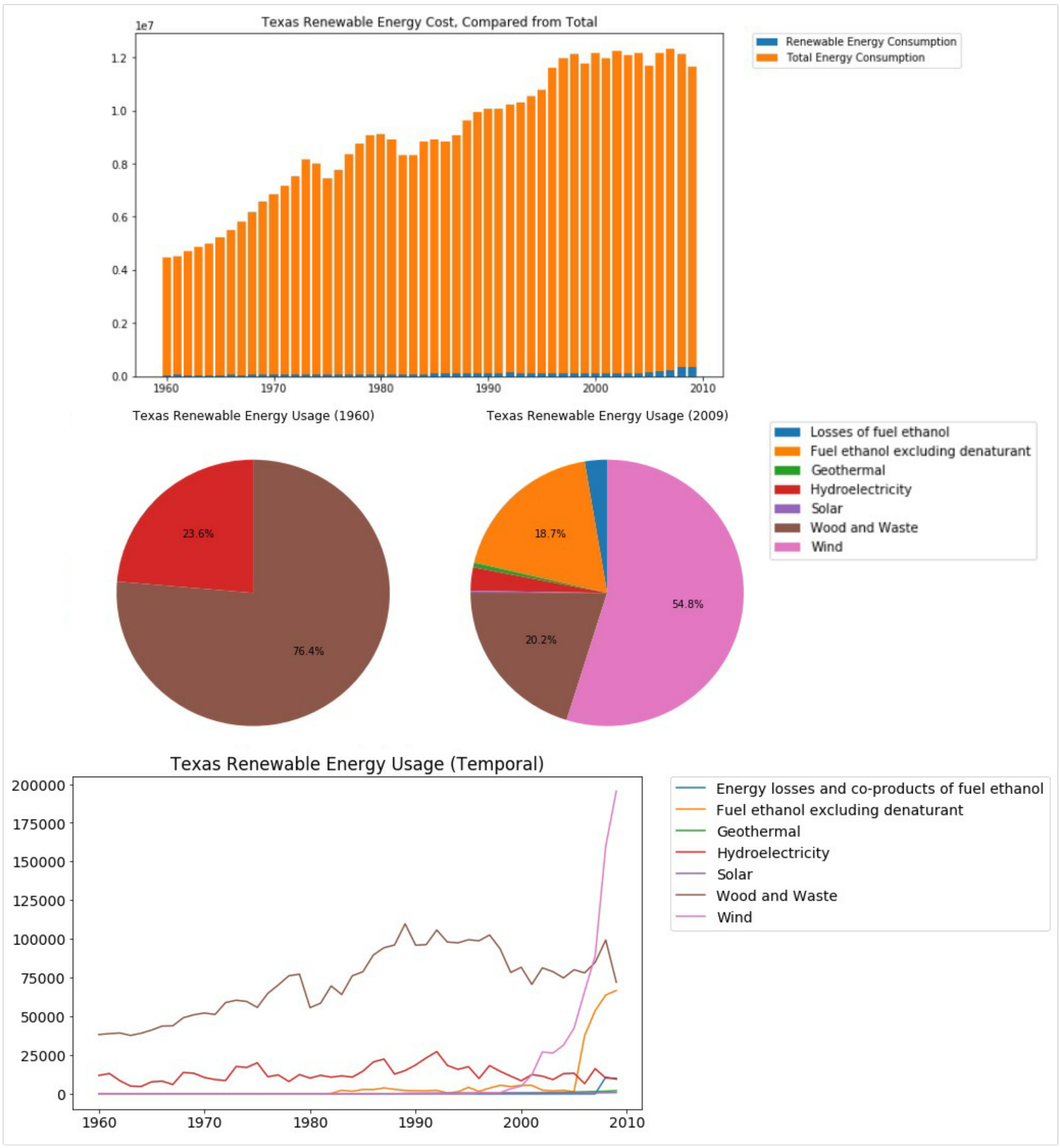

Figure 5: The renewable energy usage in Texas

$$B = A \cdot \begin{bmatrix} c \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix}$$

Multiply A^T on both sides of the equation, and then we get

$$A^T B = A^T A \cdot \begin{bmatrix} c \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} \Rightarrow (A^T A)^{-1} A^T B = \begin{bmatrix} c \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix}$$

Thus, we can know the value of c and $a_q (q = 1, 2, 3, 4, 5)$. We calculate them by computer and get the fitted curves shown in Figure 6. We set years as x-axis and the renewable energy consumption(the unit: Billion Btu) as y-axis to see the evolution of renewable energy usage over time.

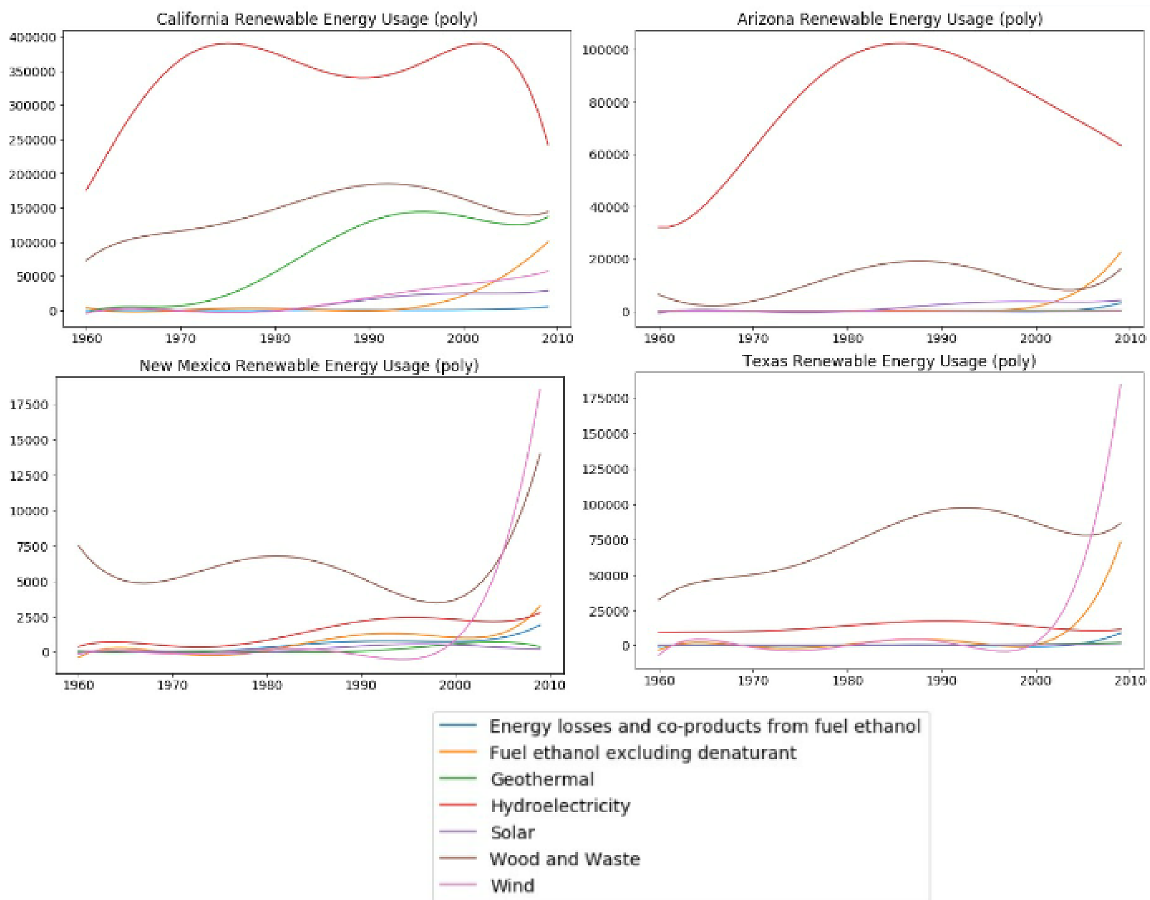

Figure 6: The fitted curves

From above results, we discuss the similarities and differences between the four states.

Similarities: Because of the wide distribution of water, California and Arizona similarly uses hydroelectricity as 1st or 2nd renewable energy source. Especially for California, whose big amount of bay areas has brought huge amount of hydroelectricity to the state. However, for the other two states, New Mexico and Texas, they do not have so much water resources but are filled with mountains and plates, which has provided good resource for woods and waste, and wind energy. The two states both adopt wind energy or wood and waste as the 1st or 2nd main source of renewable energy.

Differences: It seems that Texas is encouraging the of wind energy, since wind energy has had an exponential growth during the recent years (before 2009). Arizona is a little dangerous for the decrease of renewable energy consumption, since the main source hydroelectricity is dropping and other energy without significant rising. It is good for California to develop various kinds of renewable energy, for the increase of wood and waste, geothermal, fuel ethanol and wind energy; and New Mexico is rapidly developing wind energy, and wood and waste.

Besides, we search for the Gross Domestic Product (GDP) data on BEA's website of U.S. Department of Commerce and get the GDP of 4 states in 2009:

Table 3: The GDP of the four states

State	GDP(million dollars)
CA	35635.38371
AZ	103493.2854
NM	356634.8206
TX	12704.2602

and calculate Pearson Product-Moment Correlation Coefficient (PPMCC) to investigate the possible relationship between renewable energy consumption and economy situation. And the formula of PPMCC:

$$\frac{cov(x,y)}{\sigma_x \sigma_y}$$

The result is 0.99146756553962478. Therefore we demonstrate that there is strong tie between economy situation and consumption of renewable energy. Strongest state like California has the most consumption of renewable energy.

3.3 AHP-based Energy Profile Assessment Model

3.3.1 Energy Profile Assessment Model

In order to evaluate and compare the energy profiles of the four states, we use AHP to construct an energy profile assessment model. The model is composed of three parts: goal, criteria and alternatives. The goal is "best" profile, the alternatives are the four states, while the criteria will be defined below. And every node in the system is related to another one more or less.

We select four indexes as the criteria:

1. **Cleaner, renewable energy sources price.** The cost of energy sources depends on technological development and resource conditions, so the price can reflect the state's energy exploitation and usage.
2. **Proportion for consumption of cleaner, renewable energy sources.** The proportion can have a explicit reflection on the popularity of renewable energy.
3. **Growth trend of cleaner, renewable energy.** The trend can show a state's development trend and demand for renewable energy.
4. **Cleaner, renewable energy's balance degree.** The balance degree can give the general outline of a state's renewable energy usage structure.

The AHP hierarchy for the "best" profile is shown in Figure 7.

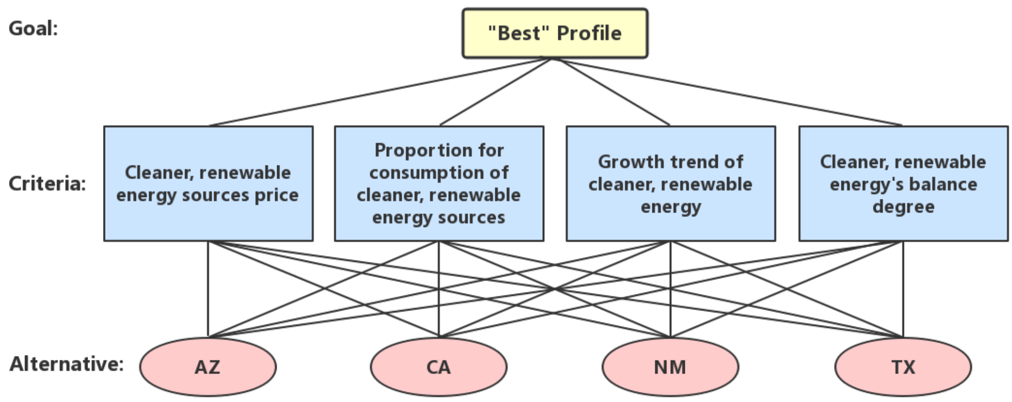

Figure 7: AHP hierarchy

3.3.2 Calculation of Weights Using AHP

First, we compare the four factors, two by two, with their contribution to the goal. By conducting a fuzzy assessment to determine the factors' weights, we get the judgment matrix A:

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

We make the consistency check on A. Its consistency index CR indicates its satisfactory consistency($CR = 0.0199 < 0.1$). Then we calculate the weights of the four factors:

$\omega^{(1)} = \begin{bmatrix} 0.5005 & 0.7639 & 0.3879 & 0.1249 \end{bmatrix}$, and the data in the final weights between goal and criteria ($\omega_k^{(1)}$) is calculated by $\omega_{kj}^{(1)} = \dfrac{\omega_j^{(1)}}{\sum \omega_j^{(1)}}$($j = 1, 2, 3, 4$,which presents the four weights). So we get

$$\omega_k^{(1)} = \begin{bmatrix} 0.2816 & 0.4298 & 0.2182 & 0.0703 \end{bmatrix} \tag{2}$$

Then we calculate the weights of alternatives. As we use accurate data here, the consistency check is not required. We list the symbols used in AHP in Table 4. ($i = 1, 2, 3, 4$, which represents the four states.)

Table 4: Symbols in AHP

Symbol	Description
x_{Pi}	The price of cleaner, renewable energy sources in each of the four states(the unit: Million Dollar per Billion Btu).
x_{Ri}	The proportion for consumption of cleaner, renewable energy sources in each of the four states.
x_{Gi}	The difference between consumption of cleaner, renewable energy sources in two consecutive years in each of the four states.
x_{Di}	The variance for consumption of every cleaner, renewable energy source in each of the four states.

Cleaner, renewable energy sources price. For a state every year, if $ELISB > 0$, then $total\ non-renewable\ energy\ costs = CLTCV + (NNTCB * NGTCD * 0.001) + (PATCV - EMTCV) + NUETV + (ELIMV - ELEXV) + (ELISB * ELIMD * 0.001)$, and if $ELISB \leq 0$, then $total\ non-renewable\ energy\ costs = CLTCV + (NNTCB * NGTCD * 1000) + (PATCV - EMTCV) + NUETV + (ELIMV - ELEXV)$. Using the known data, we can get $x_{Pi} = (TETCV - total\ non-renewable\ energy\ costs)/RETCB$.

With the price of energy sources x_{Pi} increasing, the weights of price for the four states become smaller. So we make x_{Pi} negative and make the normalization to it:

$$x'_{Pi} = \frac{(-x_{Pi}) - \min\limits_{1 \leq i \leq 4}\{-x_{Pi}\}}{\max\limits_{1 \leq i \leq 4}\{-x_{Pi}\} - \min\limits_{1 \leq i \leq 4}\{-x_{Pi}\}} (i = 1, 2, 3, 4) \tag{3}$$

where $x'_{Pi} \in [0, 1]$ is the normalized cleaner and renewable energy sources price. We define the weights as matrix ω_1 and calculate the weight for each state by

$$\omega_{1i} = \frac{x_{Pi}}{\sum x_{Pi}} (i = 1, 2, 3, 4) \tag{4}$$

, and we obtain $\omega_1 = \begin{bmatrix} 0.1046 & 0.3548 & 0.5406 & 0 \end{bmatrix}$.

Proportion for consumption of cleaner, renewable energy sources. From Section 3.1, we can obtain the rate of every renewable energy source's consumption in each of the four states in 2009, then we can figure out the total proportion for the consumption of renewable energy sources in each of the four states x_{Ri} through addition. To be specific, we first define the weights as matrix ω_2, and then calculate it by Equation (4), finally we can get $\omega_2 = \begin{bmatrix} 0.2905 & 0.3635 & 0.2171 & 0.1289 \end{bmatrix}$.

Growth trend of cleaner, renewable energy. We use the difference between the energy consumption in 2008 and 2009 x_{Gi} to depict the growth trend. We make a non-dimensional treatment to x_{Gi} by Equation (3) similarly and calculate it by Equation (4), then we obtain $\omega_3 = \begin{bmatrix} 0 & 0.6172 & 0.1170 & 0.2658 \end{bmatrix}$.

Cleaner, renewable energy's balance degree. For every state, we calculate the variance x_{Di} of seven indexes including EMLCB, EMTCB, GETCB, HYTCB, SOTCB, WWTCB, WYTCB, then we compute the reciprocal to maximize the variance. We define the weights as matrix ω_4 and calculate the weight for each state by

$$\omega_{4i} = \frac{1/x_{Di}}{\sum 1/x_{Di}}(i = 1, 2, 3, 4)$$

, then we obtain $\omega_4 = \begin{bmatrix} 0.1469 & 0.4297 & 0.2493 & 0.1741 \end{bmatrix}$.

Thus, we get the weights of alternatives to criteria(the order: AZ, CA, NM, TX):

$$\omega_k^{(2)} = \begin{bmatrix} \omega_1^T & \omega_2^T & \omega_3^T & \omega_4^T \end{bmatrix} = \begin{bmatrix} 0.1046 & 0.2905 & 0 & 0.1469 \\ 0.3548 & 0.3635 & 0.6172 & 0.4297 \\ 0.5406 & 0.2171 & 0.1170 & 0.2493 \\ 0 & 0.1289 & 0.2658 & 0.1741 \end{bmatrix} \tag{5}$$

Finally, according to Equations (2) and (5), we can calculate the final weights of alternatives to the goal:

$$\omega = \omega_k^{(2)} \cdot \omega_k^{(1)} = \begin{bmatrix} 0.1647 & 0.4211 & 0.2886 & 0.1257 \end{bmatrix}^T$$

From above results, it can be clearly observed that the weight value of CA is the largest(i.e.,0.4114), so California has the "best" profile for use of cleaner and renewable energy in 2009.

3.4 LSTM RNN Model to Predict Future Energy Profiles

Our model can be described by the diagram 8. The input shape is (8, 10), in which 8 means the sequential timesteps of LSTM to learn from, and 10 means the features (EMLCB, EMTCB, GETCB, HYTCB, SOTCB, WWTCB, WYTCB, RETCB, REPRB, TETCB, average price of renewable energy, TETCD, GDPRV).

3.4.1 Principle of Calculation

Normally every two neighboring layers are fully connected. Without an activation function, outputs of each layers is a dot production with weights on its corresponding connecting edges, $W = (w_1, ..., w_n)$:

$$Y = X\dot{W}$$

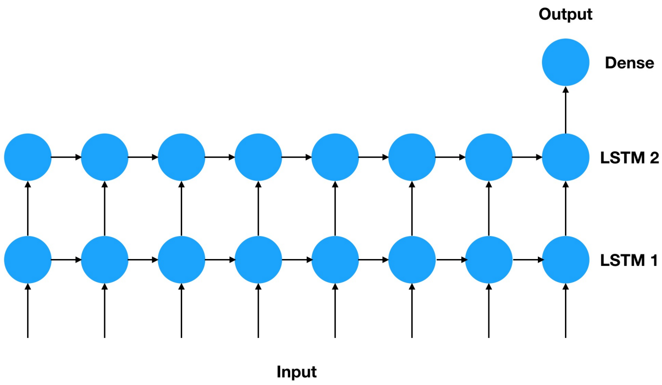

Figure 8: Our Model

, which makes up the working process of a layer, and which is how the dense layers in our RNN model work. Besides, activation function is used to avoid the "xor problem" and enhance the effect of back-propagation error correcting. We use the tanh activation function, and from our trying results, the tanh function in the last layer has the best performance. On the last layer, we get the output of prediction as

$$Y_{final} = tanh(Y) = \frac{e^Y - e^{-Y}}{e^Y + e^{-Y}}$$

Different from the basic neuron cells, an RNN cell can remember and recognize features inside a temporal sequential, which is especially useful for the predictions of sequences, like weather forecast or stock market prediction.

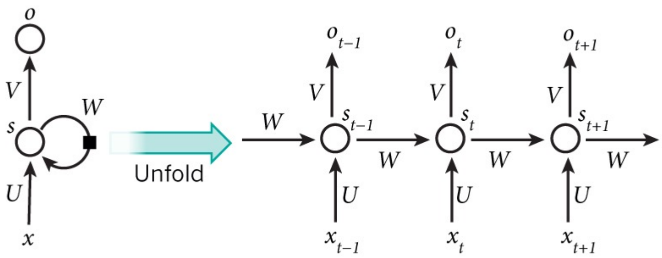

Figure 9: RNN

A calculation result of RNN can be described as

$$h_t = W_{x_t} + h_{t-1}$$

, in which h_t is the hidden state of the t-th timestep. It is calculated by a dot production of weight matrix W, which is the same one in the dense feed-forward layer, adding its previous state h_{t-1}. However, simple RNN cells can only record futures within several timesteps; it performs weakly when there is significant distance between the patterns.

In mid-1990s, Sepp Hochreiter and Juergen Schmidhuber et al. introduced a new kind of RNN called Long-Short Term Memory. The LSTM preserves the error for backtracking along time and layer. LSTM stores the information in a gated unit outside the normal flow of the recycle network. These units can store, write or read information, just as the data in the computer's memory.

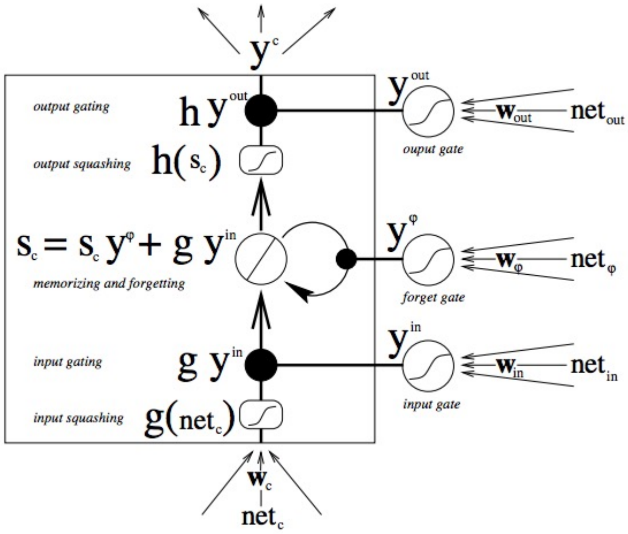

Figure 10: LSTM

These gates open or close based on the received signals and, similar to nodes in a neural network, filter the information with its own set of weights and decide whether or not to allow the information to pass, based on its strength and content being imported.

3.4.2 Back-Propagation Through Time

The back-propagation of the normal feed-forward network starts with the final error and moves backward through the outputs, weights and inputs of each hidden layer, assigning a proportion of the error to each weight by calculating the partial derivative of the weight and the error.

Recurrent networks use a special method of back-propagation, called Back-Propagation along Time, or BPTT. Specifying that the loss function is cross entropy. Here y_t is the correct value of output and y'_t is the actual output.

$$E_t(y_t, y'_t) = -y_t log(y'_t)$$

$$E_t(y, Y') = \sum_t E_t(y_t, y'_t) = -\sum_t y_t log(y'_t)$$

Since LSTM accepts a whole sequence as training data, the total value of error is defined as sum of error on each time step. Our work is to minimize the error and produce better learning functions (weights).

$$\frac{\partial E_3}{\partial W_3} = \frac{\partial E_3}{\partial y'_3}\frac{\partial y'_3}{\partial W_2} = \frac{\partial E_3}{\partial y'_3}\frac{\partial y'_3}{\partial y'_2}\frac{\partial y'_2}{\partial W_1}$$

We add the "contribution" to the gradient at every moment. That is, since W is used at every moment for the output we care about, we need to back-propagate the gradient from all times through the network at time t = 3 to time t = 0:

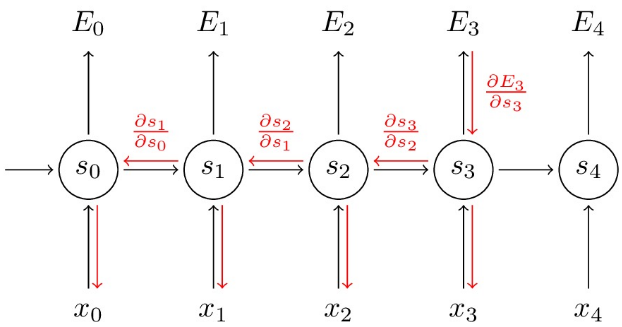

Figure 11: BPTT

Regardless of whether recurrent or not, neural networks are in fact only nested complex functions of the form $f(g(h(x)))$. Adding the time factor simply extends the series of functions.

3.4.3 Predicted Energy Profiles

Through our model we generated the predicted energy profile of 2025 and 2050, for the four states California, Arizona, New Mexico, Texas.

Energy Profile for California. In our prediction in the next 40 years, California still heavily rely on Hydroelectricity as major renewable energy, and the traditional wood and waste performs as a second one, however it increases the production of carbon dioxide, which is not so good, compared to other energy sources. As the strongest state in economy contribution of the United States, California still need huge increase on the usage of renewable energy.

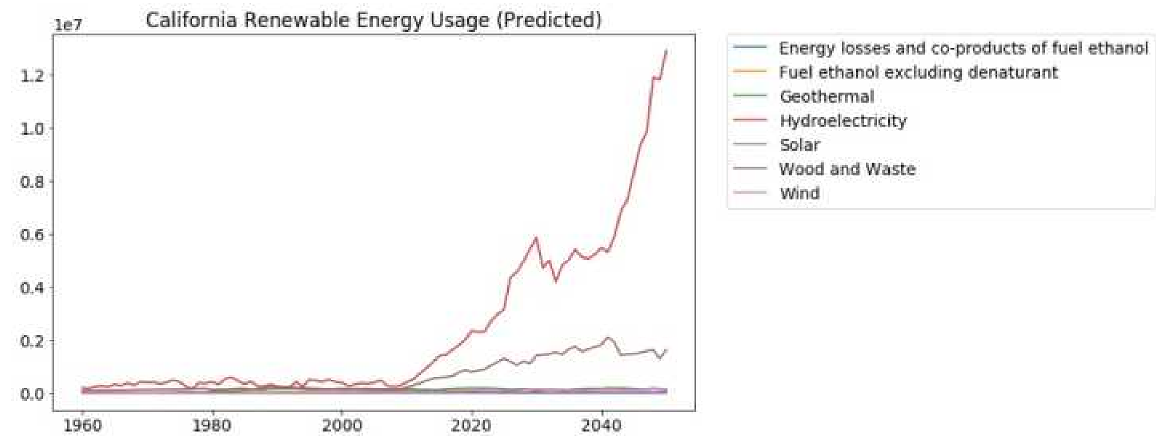

Figure 12: Predicted energy profile in CA

Energy Profile for Arizona. Just like California, Arizona uses hydroelectricity as main renewable energy source. Wind energy has had an increase on the usage. But, it is encouraging that the usage of renewable energy of Arizona has taken a large proportion.

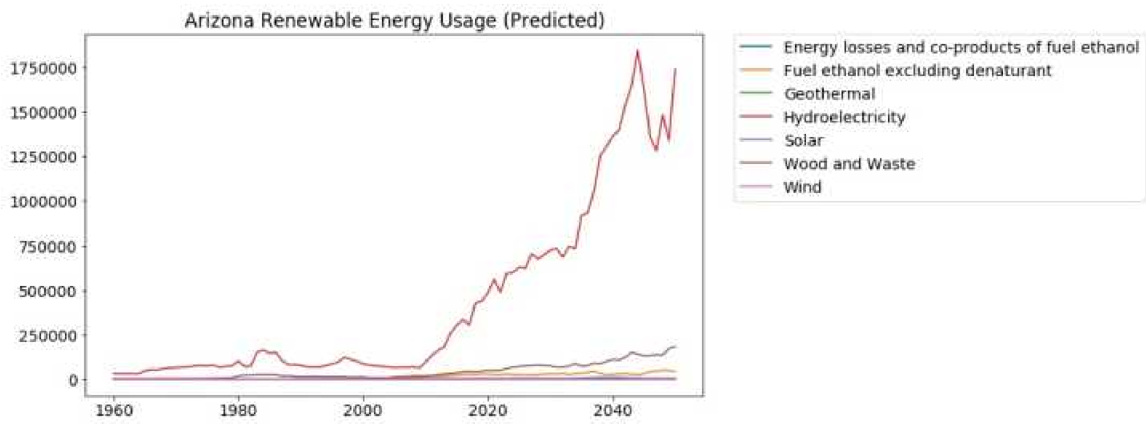

Figure 13: Predicted energy profile in AZ

Energy Profile for Texas. Texas mainly uses wood and waste as main source of renewable energy; and Significant progress has also been made in the use of other renewable energy, especially the wind energy, hydroelectricity and fuel ethanol. However, the proportion of renewable energy is still low, compared to other states.

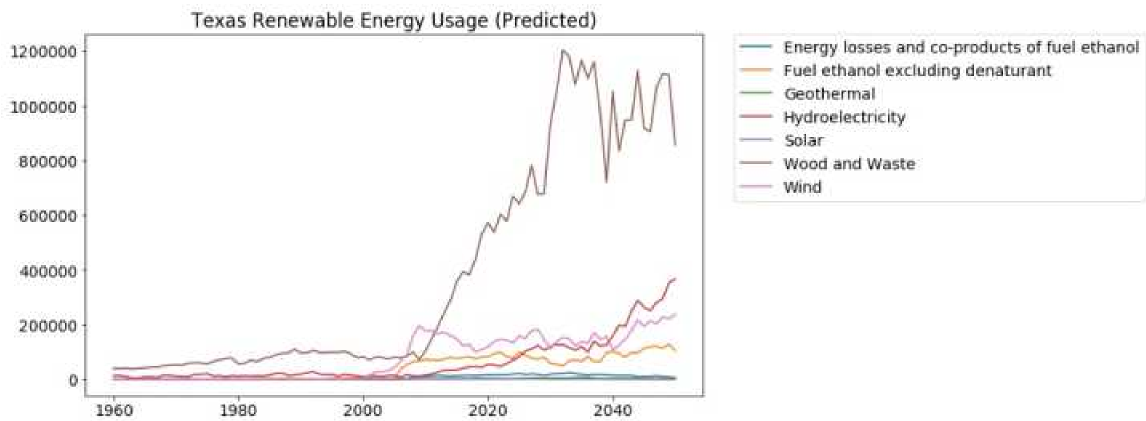

Figure 14: Predicted energy profile in TX

Energy Profile for New Mexico. New Mexico does not perform so good in our renewable energy profile. Though the total energy cost is high, renewable energy usage is even lower than Texas. However, it's possible that wind energy take more proportion in the usage of renewable energy.

4 The New Four-state Energy Compact

4.1 The Renewable Energy Usage Targets

We set up the targets of renewable energy usage for the four states in 2025 and 2050, based on our predictions of average increases.

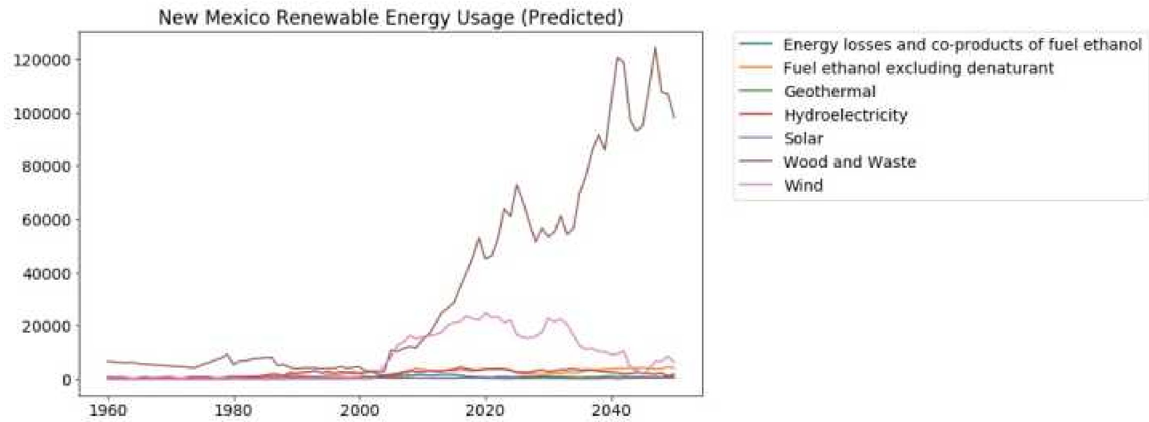

Figure 15: Predicted energy profile in NM

From our predictions of average increase during 2009 to 2050, we set the targets of renewable energy for every state:

California (CA), 2009-2025

- 222000 Billion Btu increase of renewable energy consumption per year

- 160000 Billion Btu increase of hydroelectricity per year

- 51000 Billion Btu increase of wood and waste per year

California (CA), 2025-2050

- 266000 Billion Btu increase of renewable energy consumption per year

- 190000 Billion Btu increase of hydroelectricity per year

- 12000 Billion Btu increase of wood and waste per year

Arizona (AZ), 2009-2025

- 37000 Billion Btu increase of renewable energy consumption per year

- 35000 Billion Btu increase of hydroelectricity per year

- 3600 Billion Btu increase of wood and waste per year

- 400 Billion Btu increase of fuel ethanol per year

Arizona (AZ), 2025-2050

- 15300 Billion Btu increase of renewable energy consumption per year

- 13000 Billion Btu increase of hydroelectricity per year

- 4400 Billion Btu increase of wood and waste per year

- 700 Billion Btu increase of fuel ethanol per year

New Mexico (NM), 2009-2025

- 6000 Billion Btu increase of renewable energy consumption per year

- 3900 Billion Btu increase of wood and waste per year

- 100 Billion Btu increase of wind energy per year

New Mexico (NM), 2025-2050

- 7000 Billion Btu increase of renewable energy consumption per year
- 1000 Billion Btu increase of wood and waste per year
- 413 Billion Btu increase of wind energy per year

Texas (TX), 2009-2025

- 33300 Billion Btu increase of renewable energy consumption per year
- 27000 Billion Btu increase of wood and waste per year
- 4500 Billion Btu increase of hydroelectricity per year
- 2313 Billion Btu increase of wind energy per year
- 200 Billion Btu increase of fuel ethanol per year

Texas (TX), 2025-2050

- 11700 Billion Btu increase of renewable energy consumption per year
- 8600 Billion Btu increase of wood and waste per year
- 1300 Billion Btu increase of hydroelectricity per year
- 3130 Billion Btu increase of wind energy per year
- 200 Billion Btu increase of fuel ethanol per year

4.2 Actions Taken to Achieve the Goals

We mentioned 3 actions the four states may adopt to achieve their goals. States should invest more in clean renewable energy to reduce cost, increase market competitive power and then improve the market share; take advantage of government money to intervene in energy prices in order to maintain cleaner and renewable energy at a proper proportion to total energy; the government can adopt preferential policies, since it can increase enterprise research input and encourage the development of relevant enterprises.

Action One

States should invest more in clean renewable energy to reduce cost, increase market competitive power and then improve the market share.Correspondingly, demand for clean, renewable energy will increase,which can boost the gross.This instrument can be a long-term and effective one as well as multi-win i.e. getting permanent clean renewable energy access technologies, accelerating the promotion of clean renewable energy and optimizing the energy structure, but it will have a long period.

Action Two

The government intervenes in price. Take advantage of government money to intervene in energy prices in order to maintain cleaner and renewable energy at a proper proportion to total energy. This approach is able to have a steady situation of clean and renewable energy overall, not supposed to be long-term.

Action Three

The government can adopt preferential policies. It can increase enterprise research input and encourage the development of relevant enterprises, which can promote the scale of the cleaner and renewable energy industry indirectly. Thereby, it can promote development of clean renewable energy. However,it requires state to have good capacity of coordination, and it is long-term.

5 Sensitivity Analysis

The non-linear fitting model:

We tried to adjust the highest power of the fit. The results show that when the power is lower (2 or 3), the fitting effect is very poor, and the distance between the original data points is far. When the power is higher (6 or 7), there will be plenty of abnormal changes on data without growth. After trying, we think that the power of 5 can take into account of both the two problems.

The AHP model:

We compare final weights of AZ in 2009 with only one kind of data having error,and find error of Proportion for consumption of cleaner, renewable energy sources and Cleaner, renewable energy's balance degree is approximately linear. Error of Cleaner, renewable energy sources price is non-linear. Error of Cleaner, renewable energy's balance degree doesnâĂŹt change,only because the element 0 in weights vector.

	2009				
价格（AZ）	-40.96601624	-45.96601624	-50.96601624	-55.96601624	-60.96601624
最终权值（AZ）	0.1879	0.1769	0.1647	0.1512	0.1361
占比（AZ）	0.05116298	0.06116298	0.07116298	0.08116298	0.09116298
最终权值（AZ）	0.1376	0.1517	0.1647	0.1766	0.1877
趋势（AZ）	-6676.3615	-7676.3615	-8676.3615	-9676.3615	-10676.3615
最终权值（AZ）	0.1647	0.1647	0.1647	0.1647	0.1647
均衡度（AZ）	0.1983	0.2383	0.2783	0.3183	0.3583
最终权值（AZ）	0.168	0.1661	0.1647	0.1635	0.1626

Figure 16: Data

It can cooperate with ANNïijŇwhich has prediction errorïijŇto perform error evaluation.

The RNN(LSTM) model:

Because we used random initializers in initializing the weights in neural network, each training and predicting time it generates different results, even with the same parameter. Therefore we are not able to evaluate the model by different parameters.

6 Strength and Weakness

6.1 Strength

- In the non-linear fitting model, polynomial fitting can visually show the change of data and help people quickly understand the trend of data changes.

- In the AHP model, we conduct a fuzzy assessment between goal and criteria, which consider the four factors comprehensively and make qualitative evaluation quantitative.
- The RNN (LSTM) model has proven to be general and we have got a reasonable result for our prediction. And the LSTM model is able to remember the time-sequence-related features, which cannot be finished by polynomial fitting.

6.2 Weakness

- In the non-linear fitting model, the polynomial fitting process can not yet show more detailed changes in the data, and the results obtained using the least-squares method tend to average as the data rapidly changes, and we may continue to optimize to fit The curve shows more features.
- In the AHP model, the fuzzy assessment may have some subjective judgment errors or unreasonable places.
- In the RNN(LSTM) model, there are huge variations in more prediction results, which means that it is still immature and needs more consideration.

Memo

Dear Sir/Madam:

It is our pleasure to perform data analysis and modeling on their development of a set of goals for their interstate energy compact. As we can see, there is huge amount of data on all kinds of energy indexes,as well as complex formula relationships between them,which is hard to deal with.However, we are willing to take effort to give it a relatively comprehensive presentation and analysis. We believe we can obtain good result and hope to offer you some help.

According to our analysis and prediction,we set up the targets of renewable energy usage for the four states in 2025 and 2050, based on our predictions of average increases. California would have 222000 Billion Btu increase of renewable energy consumption per year before 2025, and 266000 Billion Btu increase per year before 2050; AZ would have 37000 Billion Btu before 2025, and 15300 Billion Btu before 2050; NM would have 6000 Billion Btu before 2025, and 7000 Billion Btu before 2050; TX would have a 33300 Billion Btu increase of renewable energy consumption per year before 2025, and 11700 Billion Btu increase per year before 2050.

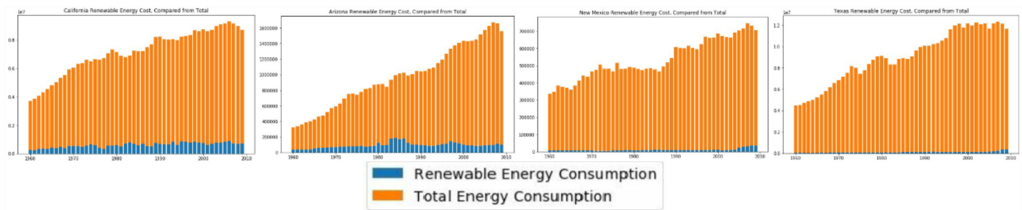

Figure 17: The rate of renewable energy from 1960 to 2009(CA, AZ, NM, TX)

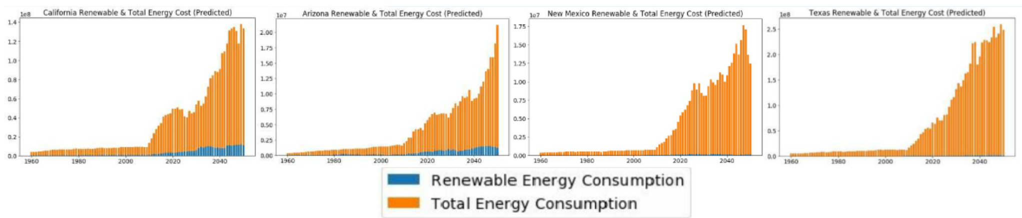

Figure 18: The rate of renewable energy predicted(CA, AZ, NM, TX)

Also,we recommend 3 actions the four states may adopt to achieve their goals. States should invest more in clean renewable energy to reduce cost, increase market competitive power and then improve the market share; take advantage of government money to intervene in energy prices in order to maintain cleaner and renewable energy at a proper proportion to total energy; the government can adopt preferential policies, since it can increase enterprise research input and encourage the development of relevant enterprises.

Really hope our study to be helpful to you and the new energy compact.

Yours Sincerely.