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2018
MCM/ICM
Summary Sheet

Delicate Mathematics makes Perfect Energy Profile

Summary

Energy, which is of the same importance as water and oxygen, has been concerned greatly since the era of the industrial revolution. Nowadays, as the conflicts between energy consumption and global sustainability become gradually severe, counties around the world have to consider their future of energy. On this occasion, our paper is aimed at analyzing the energy usage in four U.S. states and designing future energy solutions for them. The four states include Arizona, California, New Mexico and Texas.

At the first stage, we make some basic process of the raw data of energy use over last 50 years. We divide all kinds of energy into four major groups, and classify the purposes of energy use based on the corresponding sector. By setting four typical indicators, we manage to create an "energy profile" for each sector. By observing the tendency of these "energy profiles" over the years, we conclude that: the Electricity Power Sector(EPS) has seen the most significant variation in its "energy profile", and it is mostly likely to be improved in the future.

Next, we mainly investigate the factors that largely contribute to the "energy profile" of a state. Having selected three potential factors, we examine and confirm the correlations between these factors and the existing indicators by Canonical Correlation Analysis(CCA). Moreover, we analyze each of the indicators by both Analytic Hierarchy Process(AHP) and Principle Components Analysis(PCA). Thus, we are able to give explanation for each state's "energy profile".

Based on our previous work, we have to predict the future energy profile for each state. Although the trends of some of the energy profiles are rather difficult to predict, we investigate their features and creatively generate a series of predicted points using our Prediction Model(PM), which fits the character of their trends quite well. Also, we predict the future trends of four states' energy profile with some indicators being modified, where we develop our Optimal Model(OM). By doing so, we finally determine the "future energy development target" for each of the four states. In addition, we compare the model results with indicators being assigned different values, and we also compare the prediction result with predetermined target and the one without any target. It is proved that our model will probably improve the "energy profile" of each of the state, which confirms that our model is reliable and can be applied in distinct conditions.

Keywords: Energy Profile; Canonical Correlation Analysis; Analytic Hierarchy Process; Principle Components Analysis; Optimization

Contents

1 Introduction

1.1 Restatement of the problem

To begin with, four U.S. states now would like to make some improvement in terms of their energy use as well as future development. Our first major task is to create an "energy profile" for each state, which describes how "well" a state is using energy. Then we are asked to build our models and analyze the reasons and factors contributing to each state's "energy profile". In addition, proper criteria for deciding whether an energy profile is "good enough" should also be investigated and provided. Next, we are asked to analyze the energy profile development over 50 years(1960-2009) for each state, along with predicting the tendency of energy profile from 2025 to 2050 without any government intervention. Then, the problem requires that we develop the new energy targets for the four states based on our analyses of their energy profile and predictions. Lastly, we are told to give out the possible actions that may help the states to meet their targets, and prepare a memo for the four states governors.

1.2 Literature review

Those researches over energy has been carried on for years. Beck et al.(2004) discussed the impact of policies on the development of renewable energy [2]. In 2007 Sims et al. evaluated the trend of greenhouse gas(GHG) emissions without government support or effective action in the future [6]. Pedrasa et al.(2010) constructed algorithmic enhancements to a decision-support tool that residential consumers can utilize to optimize their acquisition of electricity energy [5]. At the same time Destouni and Georgia further summarized the Energy Committee's scenario [4], where they estimated future renewable energy contributions to the global energy system, and other presentations were given at the Energy 2050 symposium. Besides, Cucchiella et al.(2013) made further study of renewable energy supply chain upon extant literature [3].

2 Problem analysis

2.1 Model the energy profile

2.1.1 Current energy profile

Given the data of more than 600 different energy articles, each of whom accounting for one specific usage, it is sensible that we came up with the idea that some proper filtering and simplification of the raw data shall be deployed. For the vantage that some of the data can be overlapping with each other, we may consider two major aspects in terms of energy classification:

1) The general group that a kind of energy belongs to, such as primary energy and secondary energy

2) The detailed purpose of the energy; for instance, whether some energy is used for industrial purpose or commercial purpose, since even the energy of the same family may differ in usage for different purposes

In addition, it is also necessary that we investigate the differences among 4 states, where each state shall have a corresponding energy profile. Thus, the characteristic variation trend of energy profile during last few decades in each state can be pictured. We may conclude the commonalities and differences by comparing the characteristic energy profile of each state.

2.1.2 Analyze the energy profile indicators

Based on the results obtained above, we may analyze the possible indicators that contribute to some sector. In other words, we may explore the reason why some sector's energy profile is shaped like that, or even the indicators that are mostly correlated to such energy profile.

2.1.3 Set the possible criteria

Most importantly, we shall set a series of possible criteria with regard to making assessment on existing energy profile for each state respectively. Besides, we shall examine the influence of existing new energy, which might imply the priority for developing new energy. Ultimately, this may enable us to make appropriate energy strategy for our four states.

2.2 Design new energy strategy

2.2.1 Determine the future target

After determining a set of proper criteria to examine how good a state's energy profile appears, we may then try to find out the contribution of each criterion respectively. Since we would have already known the internal relationship between those indicators and the corresponding energy profile, by analyzing the ideal energy profile backward we may obtain the detailed information of those indicators. Through comparing the current indicators and the ones that should have been achieved in the future, we are able to determine the objectives and set the development schemes in different aspects.

2.2.2 Consider the real situation

Nevertheless, there would be a number of constraints and restrictions that have to be considered. So, we are aimed to give out some more specific suggestions or possible solutions for the local governments, departments or non-government organizations.

3 Assumptions

1) The "industry" mentioned in this paper always belongs to secondary industry.
2) The influence will appear right after the improvement
3) The influence after current year will not be considered
4) Only 1% or no improvement of the two indicators can be made each year

4 The model

4.1 The existing energy profile overview

To begin with, we shall make classification for the energy first. In total there are 606 energy articles given, where all kinds of the essential energy are included. Throughout these articles, it could be noticed that they can be divided into 2 main groups: primary energy and secondary energy.
Primary energy among them can be seen as those being directly obtained from naturally-formed resources (i.e., coal, crude oil and natural gas). It is worth mentioning, that some clean energy which is being used directly shall also be considered as primary energy (e.g., the article "GEICB", which represents the direct

use of geothermal energy and heat pumps in the industrial sector, should be primary energy as well as coal; however, the electricity generated by geothermal energy belongs to secondary energy). Particulary, the article "Natural gasoline consumed by the industrial sector" is relatively special and we also consider it as primary energy.
Secondary energy can be summed up as those ones being extracted or processed from natural resources. For example, all the petrochemical products (e.g., petroleum and gasoline) are obtained by artificial process and belong to secondary energy family. Moreover, electricity that is generated by nuclear power, solar energy, hydro energy, etc. are considered as secondary energy. Particularly, ethyl alcohol is produced by petrochemicals and biomass, hence it belongs to secondary energy family, too.
The result of our brief energy classification can be concluded as:

Table 1: Energy classification-version 1

Primary energy	Secondary energy
Coal	
Crude oil	
Natural gas	Electricity
Geothermal energy	Petrochemical products
Solar energy	Ethyl alcohol
Hydro energy	
Wind energy	

However, such classification might not necessarily appropriate for figuring out the energy profile. Due to the fact that almost all kinds of petrochemical products can be seen as ramifications of the crude oil, which belongs to the primary energy; and electricity can be generated from almost any other type of energy listed on that table. Therefore, chance is are that different kinds of energy overlap with each other and makes the current classification unreliable. Considering that we are aimed to improve the current energy profile, we slightly re-adjust the classification standard with reference to official statistics [].

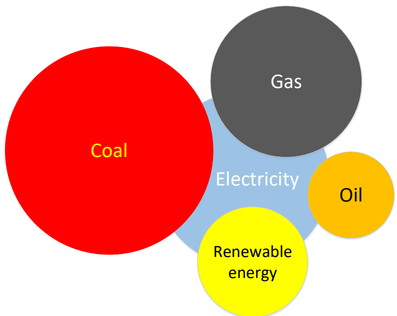
Table 2: Energy classification-version 2

Energy	Details
Coal	Coal and its ramifications, like coal coke
Oil	Crude oil and all the petrochemical products
Gas	Natural gas, including gaseous fuel
Renewable energy	Hydro, solar, wind, geothermal and biomass
Nuclear	Electricity generated by nuclear power

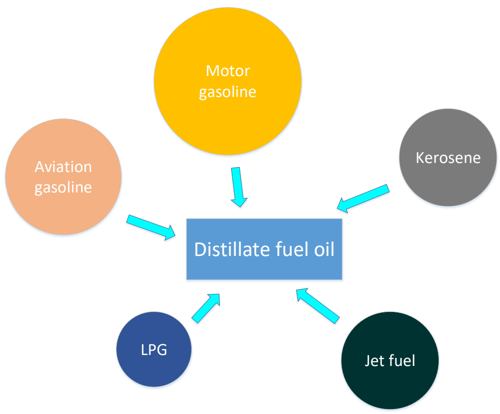
Here, the article "renewable energy" covers all the items, where the eccentric ethyl alcohol is taken into biomass energy family (and so is wood) []. The consumption of any renewable energy can be calculated as:

$$total\ consumption = direct\ consumption + the\ electricity\ produced\ by\ it$$

Similarly, we measure the consumption of nuclear by finding the electricity produced by it. Such method of energy classification is proved to be clearer, as none of these items overlap with each other. It is also noticeable that we exclude electricity from the list, as electricity can be generated by several other types of energy. In other words, the total consumption of all kinds of oil shall be equivalent to the sum of electricity-producing consumption and non-electricity-producing consumption. So, the ultimate energy profile would be the "net consumption" of five types of energy. Finally, we make one more slight modification, where we calculate "renewable energy" and "nuclear power" together as "clean energy", since these two type of energy share the same feature that they let out little emission. Both of them might be where the future is.



When counting the contribution of each articles to one kind of energy, it is impossible to take every single article into consideration. For instance, there are hundreds of articles of petrochemical products, and actually these articles can be basically summed as a few families (e.g., the article "distillate fuel oil" represents a large group of fuel oil); so we only need to focus on that few ones and search for the raw data accordingly.



Recalling that our first main target is to picture the characteristics of energy profile of different sectors in 4 states, we may divide all the sectors into 5 group-

s:**1)industrial sector; 2)transport sector; 3)commercial sector; 4)residential sector; 5)electric power sector**. Even though there are some other usage of energy, like "natural gas consumed as vehicle fuel", we believe it is safe to incorporate it into the transport sector.
For every state's each sector, the energy consumption versus time (in years) can be sketched as a graph. The graphes can thus illustrate the energy profile during half a century in one state. After analyzing the energy profile of each sector over the years, one common phenomenon is noticeable, that the energy profile of industrial and transport sector has not seen a significant change so far,and it seems that the proportions of those energy in both of the two sectors remain relatively steady. Meanwhile, the energy consumption of commercial and residential use probably comes down to electricity. Only electric power sector's energy profile has gone through great change over the years. This indicates we may put out concentration mainly on the energy profile of **electric power sector (EPS)**.

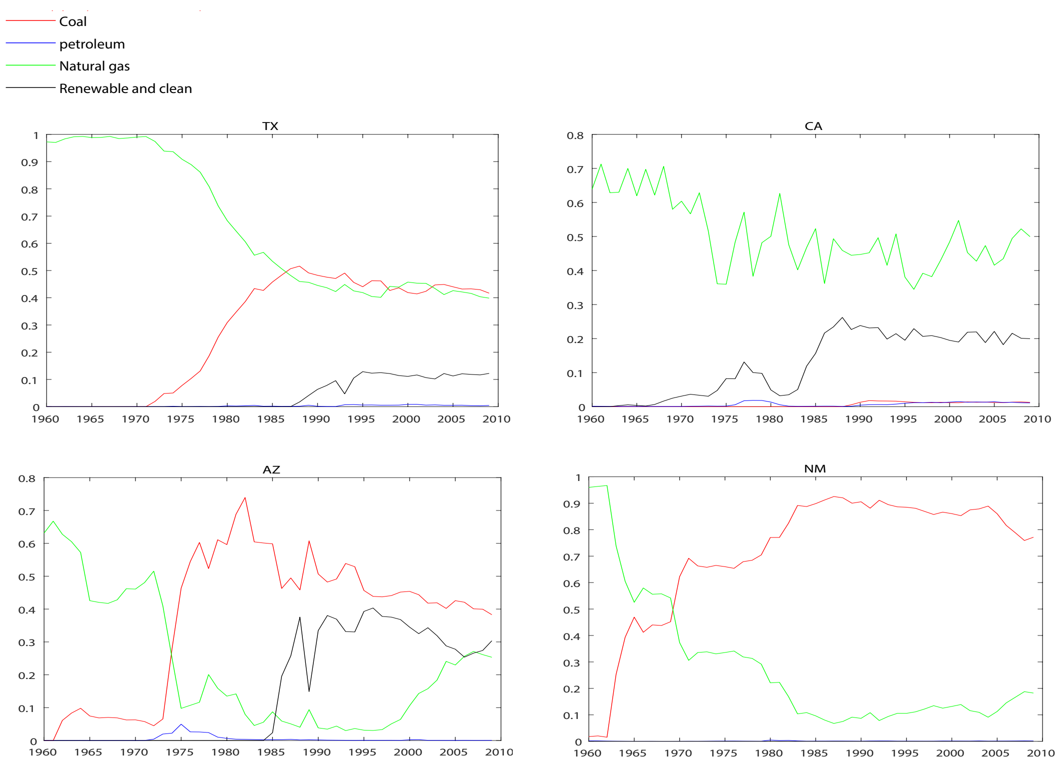


Figure 1: Energy profile of EPS versus time in 4 states

4.2 EPS energy profile model

Following the conclusion, that electric power sector (EPS) is likely to be the most potential one for new energy project to be deployed, we may now start to analyze the detailed energy profile of EPS and discuss the commonalities and difference in terms of four states' EPS energy use. In order to measure the developments or changes of EPS energy use over the years, we set several energy indicators:

1) **Convert ratio of electricity(CRE)**: this indicator is calculated as

$$CRE = \frac{actual\ electricity\ production}{total\ energy\ used\ for\ electricity\ production}$$

Sensibly a higher value of CRE means more advanced technology.

2) **Rate of import(RI)**: this indicator is calculated as

$$RI = \frac{amount\ of\ electricity\ that\ is\ imported}{total\ electricity\ consumption}$$

The value of RI reflects the external reliance of a state's electricity. In this case, a very high RI value usually correlates with an undesirable EPS energy profile, either for a well-developed region or an undeveloped one. For instance, Singapore has a very high RI value, so there can be quite some part of energy loss during shipping; the RI value of Sir Lanka, however, is rather high as well, and Sir Lanka is a country lacking industries and technology.

3) **Percentage of clean/renewable energy(PCE)**: this indicator is calculated as

$$PCE = \frac{total\ consumption\ of\ clean/renewable\ energy}{total\ energy\ consumption}$$

It is common that one kind of clean energy might be renewable as well, and we have considered this when counting clean/renewable energy. Generally, this indicator reflects how desirable a state's EPS energy profile is.

4) **Ratio of price to GDP(RPG)**: this value is calculated as

$$RPG = \frac{total\ price\ of\ electricity\ produced\ in\ one\ year}{the\ state\ GDP\ in\ the\ same\ year}$$

which is to measure the contribution of electricity price to the whole state, including local residents, units and enterprises. In other words, this value reflects the extent that electricity price accounts for society's burden.

5) **Ratio of CO_2 emission to total energy consumption(RCE)**: this indicator value is calculated as

$$RCE = \frac{the\ CO_2\ emission\ amount}{total\ energy\ consumption}$$

which represents the emission of CO_2 when one unit of energy is consumed. This value reflect how "clean" the energy is.

For each of the four indicators above, we may compare that of four states over the years. This enables us to figure out the similarities and distinctions among these states' EPS energy profile:

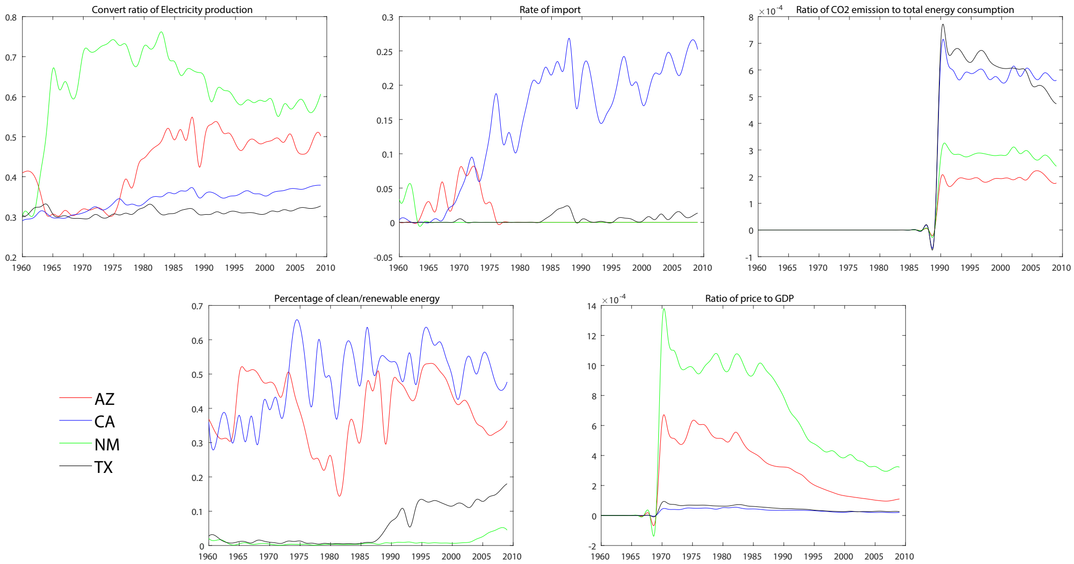


Figure 2: 5 EPS energy profile indicators versus time

According to the results, it can be found that the trends of 2 indicators-RPG and RCE-appear to be similar among some states, whereas that of other 3 indicators vary largely in different states. Due to the limitation of available statistics, there are no records for the RCE value in four states. As for the RI value, all the states excluding California witnessed their RI values vanishing during the later few decades, and the values are largely different among states. Therefore, it can be meaningless that we continue considering the indicator RI, and we may discard it. In general, each state's 4 indicators seem to be isolated from those of others'. Hence, it could be safely argued that these indicators may function well to characterize each state's EPS energy profile.

We may now find out the factors contributing to every state's character, in other words, the essential parameters that make a state differ from others. Having considered several aspects, we reasonably select 4 parameters and combine them into 3 prime factors:

1) **Ratio of industrial consumption to total consumption(RIT)**: this factor in one state is calculated as

$$RIT = \frac{industrial\ energy\ consumption}{total\ energy\ consumption}$$

which can roughly represent the proportion of industries in a state. For example, the RIT value of Texas is obviously higher than other three.

2) **Population(POP)**: the reason why we select population as one prime factor can be explained as: normally the larger a state's population is, the more diverse its industries will be, and there will also be more demand and social pressure. So we believe this may influence the whole energy profile.

3) **Unit GDP energy consumption(UEC)**: this factor has been wildly applied to measure how smart the energy is used, and we directly take this value since it might be tightly connected to a state's energy profile.

To investigate the correlation between 4 energy indicators and 3 prime factors, Canonical Correlation Analysis (CCA) can be applied, where $\mathbf{X} = [CRE\ PCE\ RPG\ RCE]^T$ and $\mathbf{Y} = [RIT\ POP\ UEC]^T$. However, due to the limitation of state numbers (only 4 states available), it is rather hard to find linear combinations by comparing 4 states' data of the same year. Since for each state, all these indicators and factors vary over the years, it might work if we compare the data from different years and thus calculate the correlation coefficients for each state. So, we calculate the coefficients of the **first-group canonical variables**.

Table 3: Canonical variable coefficients

	x_1	x_2	x_3	x_4	y_1	y_2	y_3
AZ	0.33	0.34	0.75	0.27	-0.045	-0.23	0.82
CA	-0.07	0.14	0.88	0.03	-0.14	0.4	1.5
NM	0.14	-0.47	0.82	0.16	-0.072	-0.46	0.54
TX	-0.20	0.20	0.52	0.56	-0.0092	-0.30	0.71

As thus we obtain the values of the **first-group canonical correlation coefficients** based upon the coefficients above. Moreover, we calculate the cumulative proportion of **X** to **Y**, which is even more convincing:

Table 4: Cumulative proportion that **X** contributes to **Y**

AZ	0.9527
CA	0.8857
NM	0.7308
TX	0.9692

Such result confirms that our selection of prime factors is quite reasonable, and each state's energy profile is tightly connected to RIT, POP and UEC. More specifically, we check all the correlated pairs and give out possible explanations for.(Here "$a \to b$" denotes element a and b are positively correlated, while vice versa for "$a \to -b$")

$CRE \to -POP$: this implies a place with larger population tends to have a lower energy convert ratio. In most cases, a place with a large population is not likely to be industry-dense, so less energy will be converted to electricity, thus makes the CRE value small.

$PCE \rightarrow -RIT$: this implies that a high percentage of clean/renewable energy is related to a lower proportion of industries in a region. Suppose a region has a very high proportion of clean/renewable energy in its energy profile, normally it should be well-developed in technology and relatively wealthy, the opportunity cost of electricity production shall also be high; such a place is not like to have large amounts of industries, but more likely to have business involved with high-tech or service, such as Japan.

$PCE \rightarrow UEC$: this implies a high percentage of clean/renewable energy may also consume more energy for unit GDP. Since the clean/renewable energy of current stage is still fresh and primary, so it is possible that the energy efficiency is rather low despite it is eco-friendly [3].

$RPG \rightarrow -RIT$: this implies that a low proportion of electricity price in GDP correlates to a high proportion of industry. This could be demonstrated, that a region with well-developed industries usually produces abundant electricity power, thus makes the electricity price take lower proportion in GDP.

$RPG \rightarrow UEC$: this one implies that a high ratio of electricity price in GDP is correlated to a high energy consumption for unit GDP. For the places without advanced technology, like some Africa countries, the electricity prices there are rather high and the unit GDP energy consumption can also be high, too.

4.3 Ideal energy profile model

At the ultimate stage, we may set the criteria accordingly. Recalling that we have already determined CRE, PCE, RPG and RCE as energy profile indicators, we first apply the Analytic Hierarchy Process(AHP) to analyze how desirable each state's ESP energy profile is. Our comparative matrix is:

$$\begin{array}{c c} & \begin{array}{cccc} CRE & PCE & RPG & RCE \end{array} \\ \begin{array}{c} CRE \\ PCE \\ RPG \\ RCE \end{array} & \begin{pmatrix} 1 & 1/2 & 3 & 1/2 \\ 2 & 1 & 8 & 2 \\ 1/3 & 1/8 & 1 & 1/8 \\ 1/2 & 1/2 & 8 & 1 \end{pmatrix} \end{array}$$

The weight for each indicator can thus be obtained respectively:

Table 5: Indicators' weight by AHP

CRE	PCE	RPG	RCE
0.1906	0.4809	0.0554	0.2732

And now we are able to score the EPS energy profile of 4 states:

Table 6: State score by AHP

State	AZ	CA	NM	TX
Score	0.57	0.59	0.67	0.78

It is true that we have already determined how desirable each state's EPS energy profile is. However, considering that these 4 energy profile indicators are not necessarily independent from each other, the result of AHP might not be reliable enough. In this case, we consider the Principle Component Analysis(PCA) to double check result above. Since there are only 4 indicators in total, we apply the method of "self comparison" again, where for each indicator, 4 groups of orthogonal linear combination are extracted based on 4 states' 50-year data. Then we calculate the mean value of the result of their own orthogonal linear combinations for each indicator, and thus obtain the weight for each indicator respectively. The same as before, we score the EPS energy profile of 4 states:

Table 7: State score by PCA

State	AZ	CA	NM	TX
Score	0.45	0.67	1.9	2.1

The result of the relative merits of the 4 states (i.e., the ranking of 4 states) turns out to be exactly the same as that of AHP, where Texas has the "best" energy profile. Therefore, it can be safely concluded that our analyses of energy profile indicators shall be quite authentic.

5 Future energy strategy

5.1 Prediction of EPS future energy profile

Having 50-year data of 4 states in hand, we can first predict the tendency of each energy profile indicator. Particularly, the existing tendency of NM and TX score is somewhat like a straight line, so we apply the Double Exponential Smoothing method to analyze the initial time sequence for all the states. But we soon realize the predicted scores for Arizona and California can be overestimated to a large extent, by Daniel test we find AZ score seems to be white noise, whereas the difference of CA score is white noise. Hence, we use normal distribution to generate a series of scores for AZ; and for CA we use the same method to determine a series of deviations, then every predicted score is generated by the corresponding deviation plus the previous score.

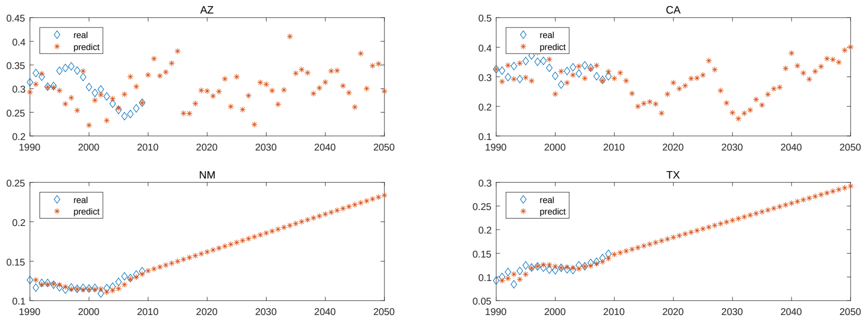


Figure 3: Predicted scores

The overall prediction seems reasonable, the existing tendency of AZ is hard to tell, so its predicted scores are rather sporadic. The tendency of CA is fluctuating but increasing, while the other 2 are predicted to increase steadily in the following decades.

5.2 Optimization model

Notation	Explanation
C_1	initial cost to improve PCE by 1%
C_2	initial cost to improve CRE by 1%
ρ_1, ρ_3	decrease of the cost of improvement as time elapses
ρ_2, ρ_4	increase of the cost of improvement as indicator grows
W_i	weight of each indicator
K_1	improvement in RCE as unit PCE be improved by 1%
K_2	improvement in CRE as unit RPG be improved by 1%
K_3	increase of GDP as RPG be improved by 1%
γ_i	increase of GDP in the $i-th$ year
x_j	each indicator value at the beginning of one year
α_i	binary value of improvement of PCE in the $i-th$ year
β_i	binary value of improvement of CRE in the $i-th$ year

And the core target function of this model is:

$$max\{W_1x_1(1+\beta_i\%)+W_2x_2(1+\alpha_i\%)+W_3x_3(1+k_2\beta_i\%)(1+\gamma_i\%)$$
$$+W_4x_4(1+k_1\alpha_i\%)+C_1(1-\rho_1)^i(1+\rho_2)^{\Sigma\alpha i}$$
$$+C_2(1-\rho_3)^i(1+\rho_4)^{\Sigma\beta i}\}$$

We are aimed to develop a model with consideration of cost, because it is the main reason why developing better energy profile is difficult.

The higher the indicators, the more difficult to improve, namely, more unit cost. However, with the time passing by, the technology would develop and thus

makes it easier to improve the indicators. In light of this, we assigned $\rho_1 - \rho_4$ and corresponding indices to be the change of cost.
In our perspective, if the ratio of renewable and clean energy increases, the emission of CO_2 will decrease; if the ratio of transfer of energy increases, the price of electricity will decrease. Since our data has been standardized, by which bigger data means better result. When we have 1% improvement on the ratio of renewable and clean energy, there would be k_1% improvement of the ratio of mission of CO_2 to total consumption of energy; when we have 1% improvement on the convertion of energy, there would be k_2% improvement of the ratio of price of electricity to GDP. Because GDP is important is this model, so we predict the GDP and its change rate.

Furthermore, we make three important assumptions, where

- An action works immediately once implemented.
- When actions are implemented, only the potential influence for current year will be considered.
- The improvement of α and β will be either 0 or 1. Therefore. Our goal is to choose the action from 4 options (0,0), (0,1), (1,0), (1,1) to optimize the gain of each year

The ultimate energy plan is as follow for all four states,

Table 8: Optimal energy strategy for all four states

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RPG	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CRE	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Year	15	16	17	18	19	20	21	22	23	24	25	26	27	28
RPG	1	1	1	1	1	1	1	1	1	1	0	0	1	0
CRE	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Year	29	30	31	32	33	34	35	36	37	38	39	40	41	
RPG	0	0	0	0	0	0	0	0	1	0	0	0	0	
CRE	0	0	0	0	0	1	0	0	0	0	0	0	0	

and here comes the profile of this plan with comparison to prediction.

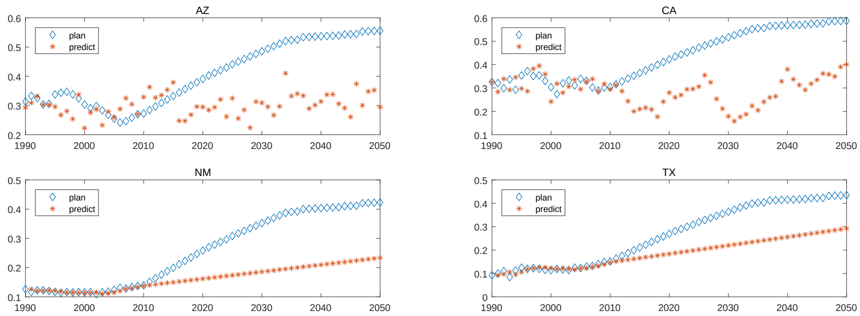


Figure 4: Comparison of energy profile with/without plan deployed

6 Sensitivity analysis

6.1 Model results analysis

In the optimization model, we have determined the initial number of each parameter. Now we may show the influence of change of them.

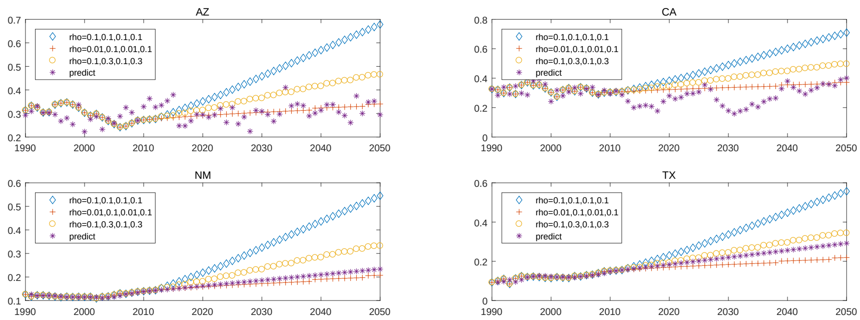


Figure 5: Change of ρ

The bigger ρ_1, ρ_3 are, the easier to change the variables in the future, and smaller ρ_2, ρ_4 make it less difficult to change when they are large, so that it is easy to improve the profile in this direction.

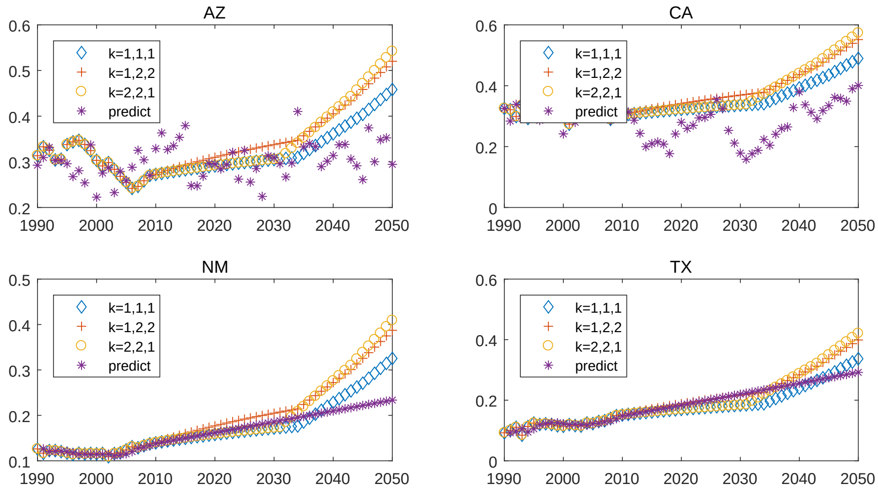


Figure 6: Change of k

The profile improves faster when k is larger because there is more contribution x_3, x_4 making. However, the change of k does not change the profile significantly.

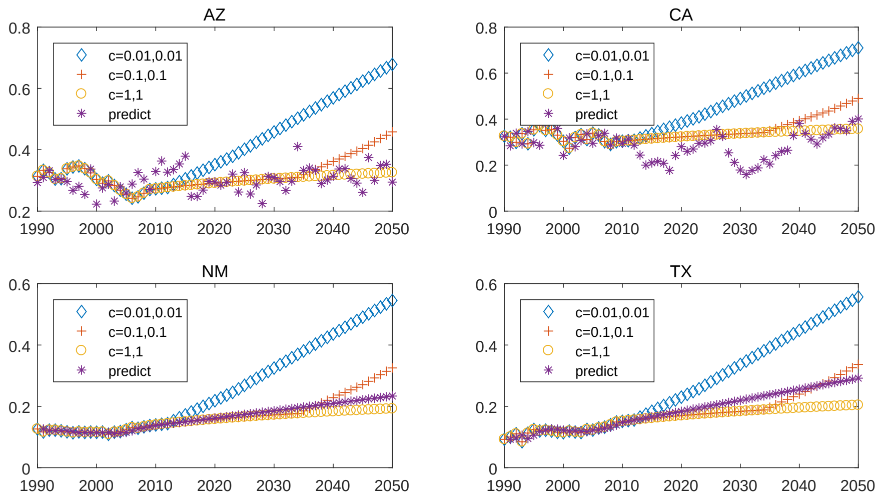


Figure 7: Change of C

C has a great influence on the improvement of the profile. If C is too large, it is not a wise decision to make the progress, which is exactly what governments and entrepreneurs facing.

6.2 Strengths and weaknesses

6.2.1 Strengths

- The selected indicator is reasonable
- The influential factors were analyzed with typical correlation analysis
- Different forecasting methods are selected according to the characteristics of different data, and the results are better
- Although there is a certain correlation between the criteria selected, the reliability is determined by the results of principal component analysis and analytic hierarchy process

6.2.2 Weaknesses

- There was no calculation of the impact of new energy on GDP in details
- The impact of current behavior on the future was not considered
- The transition time of new policy change was not considered
- In the use of typical correlation analysis, it is not enough to select the corresponding criteria value analysis dimension of four states in a certain year, and then substitute analysis with each calendar year data, which could be inaccurate to some extent
- When using principal component analysis for selecting one of four states corresponding criteria value analysis dimensions is not enough, with each week in a linear combination of the data of all in the alternative, has certain accuracy

7 Policies and actions

7.1 Policies that may change indicator values

1.Provide preferential policies to the target energy industry to promote the development of science and technology: The energy efficiency of the industry depends on the local energy situation, so we should select the target new energy field first. Because of the high technology portability. Energy organizations can focus on funding targeted energy companies and assist in the development of cooperation between states and states.

2.Market regulation without addition policy: As market is powerful enough to arise competition, it will cause the decrease of the price, which would contribute to the reduce of RPG. Therefore, deregulation is beneficial in the long run.

3.Subsidize the target's new energy industry, making it more profitable: As the requirement trend shows more capital would enter the industry in the future. Although the types of power plants that have been built for power generation can not be changed, power plants will be built in the future could be guide. Making clean/renewable energy cost lower than high polluted energy cost through policy adjustments, such as discount of land use, could make future energy company prefer to build renewable energy power plants.

4.Energy companies taxes on carbon emissions ratio per unit power: California and Texas have higher GDP and more developed economies, but the proportion of new energy is not higher than in the other two states. So the effect of simple market regulation on the increase of new energy ratio is not significant. Therefore introduced the government macroeconomic regulation and control policy to promoting the use of new energy sources. Meanwhile, take full account of the short-term costs of implementing new energy sources and set appropriate targets.

8 Further discussion

In the part of comparison between states, we used "self-comparison" to finish AHP and PCA. In the future, if there are data available about more states, more accurate results can be obtained. In addition, there are some factors relative but hard to quantify, such climate and geography, which can be discussed in the future as well.
In the part of optimization, because of restriction of computer, we cannot define variable as integer more than one or even decimals. Besides, we can also calculate the impact on the future, take account into the time it takes to make actions work, and get an overall optimal solution for n years.

9 Conclusion

In our model, we chose electric sector as the break point because of its importance and potential according to historical data. The rank of the profile of each state is, high to low, Texas, New Mexico, California and Arizona, which is convincing because it is proved by both AHP and PCA. Next, the prediction of the profile shows increase of California, New Mexico and Texas, and stability of Arizona. Finally, we optimized the profile of the states by each year, and get better results than the prediction as long as the parameters are in a proper range.

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MEMORANDUM

To: Governors of four states

From: Members of team 85083

Subject: Energy Profile Summary and Suggestions

Date: Feb, 13. 2018

Besides the stability of Arizona, other three states all have a significant increase of energy profile from 2009-2050. However, every state can do it better.

Base on my model, I give out a plan, which is suitable for all state. The plan is as follow:

Table 1: Optimal energy strategy for all four states

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RPG	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CRE	1	1	1	1	1	1	1	1	1	1	1	0	0	0
Year	15	16	17	18	19	20	21	22	23	24	25	26	27	28
RPG	1	1	1	1	1	1	1	1	1	1	0	0	1	0
CRE	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Year	29	30	31	32	33	34	35	36	37	38	39	40	41	
RPG	0	0	0	0	0	0	0	0	1	0	0	0	0	
CRE	0	0	0	0	0	1	0	0	0	0	0	0	0	

In this plan, 1 means 1% improvement of a part, and 0 means not.

Based on this model, I would like to give the following suggestions. 1. Provide more supports to new energy company and university to promote the development of new energy technology; 2. Replace energy with pollution with natural gas to lower CO_2 emission; 3. Macro-control to lower the price of renewable energy 4. As the increasing need of electricity, new power plants are needed. Provide preferential policy to encourage the build of new energy plant.