Analysis of the Environmental Sustainability of a Megacity through a Cobenefits Indicator System—The Case of Shanghai

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Abstract: Based on the synergistic control of greenhouse gas emissions and air pollution, a co-benefits indicator system was established to evaluate the co-benefits of city policies for megacities with regard to energy conservation and environmental sustainability. Shanghai was chosen as a typical case study, owing to its relatively high level of progress in terms of urbanization and its complex economic, social, and ecological development problems. In this indicator system, 23 indicators were screened, based on the driver-pressure-state-impact-response (DPSIR) framework. Economic, social, and ecological development data for Shanghai from 2005 to 2018 were collected and analyzed using an entropy method. This was followed by the application of a weighted average method to determine the indicator weights and co-benefits index (CBI) for Shanghai. The results yield variations in the weights of the indexes. The weight of the tertiary industry production proportion in the GDP was the highest, owing to the government promotional policies, whereas the weight of the annual average temperature was the smallest, as global warming only becomes significant when the time span is much longer. In such a short time span (i.e., 14years), the change in the annual average temperature is relatively insignificant. The Co-benefit Index also varied over time; it showed a growing trend over the 14 years, increasing from 0.375 in 2005 to 1.365 in 2018, i.e., a 264% increase. This indicates that the efforts taken in Shanghai and their effects were positive, overall. Four suggestions were proposed, based on the results of the analysis: a) control the amount of total energy consumption and change the energy structure to reduce carbon and air pollution emissions; b) adjust the structure of industry, especially by increasing the proportion of tertiary industries; c) increase investments in environmental protection; and d) cooperate with regional partners to limit the occurrence of acid rain. The applicability of this approach and research prospects are also discussed.

Keywords: co-benefit index; DPSIR; transition to the sustainable city; climate change; negative externalities in cities

1. Introductions

In the past 100 years, the average surface temperature of the earth has risen by 0.4–0.8 °C. Many scientists believe that this is unique compared to any previous increase in surface temperature in the past, i.e., this rise is not a natural phenomenon. The extensive usage of fossil fuels by humans has led to massive emissions of greenhouse gases such as carbon dioxide, which have intensified the greenhouse effect and increased the earth’s surface temperature. Furthermore, the rate of change is increasing. The Intergovernmental Panel on Climate Change forecasted that the average temperature will rise by a further 1.4–5.8 °C by 2100 [1]. Increases in surface temperature are causing polar icecaps...
to melt, sea levels to rise, severe weather events to occur, and so on. Such hazards are interfering with and damaging the natural ecosystem and threatening the survival of human beings. Sulfur dioxide, nitric oxide, solid particulates, and other substances emitted from the burning of fossil fuels have been polluting the atmosphere since the beginning of the industrial age. Past hazardous events caused by severe air pollution, such as photochemical smog in Los Angeles [2], the London Smog Disaster of 1952 [3], and Japan’s Yokkaichi asthma event of 1961, could occur again in the future. Balancing between the demands of economic development and environmental protection is a challenge, not only for developing countries, but for the entire human race [4]. Therefore, policy makers should understand the sustainable development concept and follow sustainable development goals [5,6].

Greenhouse gases and air pollutants have similar origins; they are primarily emitted from the burning of fossil fuels. By synchronizing the creation and execution of climate policy and air pollution management, the cost of reducing emissions may significantly decrease, and some side benefits may occur simultaneously (e.g., improvements of public health) [7]; the benefits of addressing multiple problems with similar origins in policy making and execution are called “co-benefits”, and are the primary focus of this study.

In the research on co-benefits, Western countries hold the lead, in both the number of quantification studies and in the diversity of study subjects. Quantification studies have covered topics such as modeling predictions and monetization. The study subjects vary between global, national, and regional schemes. Wagner et al. evaluated the cost and potential of greenhouse gas emissions for the years 2020 and 2030 for the countries listed in Annex I of the United Nations Framework Convention on Climate Change [8]. A greenhouse gas–air pollution interactions and synergies model (GAINS) was applied using a scenario analysis method from the study. It was determined that it is possible to reduce greenhouse gas emissions at a relatively low cost. The study also found differences in cost for different countries and departments. Chen et al. developed four scenarios to estimate the energy demands and carbon emissions from 2020 to 2050 in China; the authors argued that it is vital for sustainable development to keep global warming to well below 2 °C [9]. The health co-benefits associated with the reduction in different pollutants were also estimated; the results show that industry and the electricity conversion and transportation sectors will reap the greatest health co-benefits in China, as NOx reduction plays a dominant role in maintaining a good standard of air quality. Jiang et al. focused on the two main categories of biomass pellet production, showing that strew pellet production not only contributes to regional sustainable development and localized energy transition, but also that it helps to mitigate global greenhouse gas emissions [10]. The amount of research on co-benefits in China has been increasing since 2000. However, most studies have focused on a single micro aspect, i.e., one specific engineering technology for reducing emissions. For example, Alimujiang et al. analyzed the synergy and co-benefits of reducing CO₂ and air pollutant emissions by using electric and plug-in hybrid electric private cars, taxis, and buses in Shanghai [11]. Mao et al. evaluated the cost-effectiveness and sensitivity of the technology and structural emission reductions in the electricity industry [12]. They found that it would be possible to achieve reductions in sulfur dioxide, nitric oxide, and carbon dioxide emissions by implementing energy conservation-prioritizing, technological emission reduction measures, front-end and production process control measures, and new power-generating technology structural reduction measures. Ma and Chen selected 22 energy-saving and emission-reduction measures to evaluate mission reduction potential, cost reduction and co-benefits, in order to shed light on the best means to mitigate CO₂ emissions by the iron and steel industry in China [13]. Sun et al. applied a new analytical method to study the environmentally sustainable development in Guangxi and its economic zone, i.e., the co-benefit approach combined with the Environmental Kuznets Curve [14]. Their research showed that further measures to control the amount of energy consumption and adjust energy consumption structures are needed. Currently, researchers in China still have not progressed past using the quantity of emission reductions as the evaluation criterion. This has resulted in descriptions of the co-benefits of single techniques within single sectors in most research studies.
Cities are the engines and foundations of national economic development in China. Many cities in China have concentrated on industries, high resource consumption, and a high population density [15]. Coal, which is the most consumed resource in China, is crucial to urbanization and industrial development, and it also causes very high carbon emissions and pollutants. Cities are the main sites where greenhouse gases and air pollutant gather [16]. Furthermore, megacities (cities with residential populations higher than 10 million) emit more carbon and air pollutants than smaller ones. In the current research progress worldwide, although the importance of co-reductions in air pollutants and greenhouse gases has been recognized, the related studies have generally only focused on one specific industry or field, instead of comprehensive areas.

This research study attempted to formulate a co-benefits index (CBI) system for evaluating a degree of co-benefit implementation and for further establishing suggestions for the co-management of greenhouse gases emission and air pollution from the perspective of a megacity. Shanghai, as the most representative and the most urbanized megacity in China, was selected as the object of study.

2. Methodology

The CBI system established for megacities is fundamentally a comprehensive assessment system, in contrast to previous (individual) studies. This approach was chosen for its ability to describe the co-benefit effects of cities from multiple aspects, and to formulate a comprehensive and summarized evaluation. Therefore, the critical indexes were selected based on the driver-pressure-state-impact-response (DPSIR) research context, to calculate the weight of each index and obtaining the comprehensive evaluation index.

2.1. Driver-Pressure-State-Impact-Response (DPSIR) Research Framework

The DPSIR research framework was invented by the European Environment Agency. It can describe the relationships between environmental problems and human interferences well [17]. In the DPSIR model, driver represents the demand induced by social and economic developments, such as economic activities. Pressure represents the environmental pressure induced by the developments, such as the excessive release of industrial exhausts and wastewater. State represents the phenomena regarding physical, biological, and chemical quantity and quality changes induced by the environmental pressure, such as the conditions of cities under such pressure. Impact represents the effect of the state on the resources, environment, society, economy, and human activities. Response represents the management by government, human groups, and individual persons to reduce, dampen, and/or adapt to the environmental changes. Currently, DPSIR research frameworks are mostly applied to evaluations of multiple types of ecosystems, the sustainable utilization of resources, environmental management abilities, agricultural sustainability, and soil and water conservation [18–20]. DPSIR has become an effective tool for determining the relationships between environmental states and environmental problems [21]. Figure 1 shows the framework of DPSIR.
Based on the DPSIR framework, a system of nine major levels of CBI for measuring the environmental sustainability of megacities was established, as follows. The drive (D) is induced by the economic development within a city, and its population growth; the pressure (P) is induced by the same factors. The states (S) of the air pollution level, greenhouse gas emission level, and industrial structure, etc. are induced by the intensity of energy consumption. The impacts (I) on the air, water quality, and other environmental indexes are also induced by the intensity of energy consumption. The reaction (R) is taken in response to such effects (e.g., by the government). The drive, pressure, and state are induced in the modified co-benefit after the reaction, formulating a two-way response mechanism. Specific indexes for each level were selected from multiple sustainable development index systems, city development indexes with low carbon emissions, and other ecological indexes.

2.2. Entropy Method

Weight is a relative concept, and indicates the relative importance of one index to the entire system in comprehensive evaluations. The determination of the weight of an index can be based on subjective and/or objective assignment. Subjective assignment relies more on the importance of each index to the evaluator assigning the weight, and thus results in differences in weight among different evaluators. Examples of the most common subjective assignment methods are the expertise evaluation method and the analytic hierarchy method. Objective assignment relies on a statistical analysis of data to calculate the weight of each index and includes methods such as factor analysis, entropy, and multiple correlation coefficients [22]. Thus, the objective assignment method was selected for determining the weight for each index in this research study.

Based on the DPSIR framework, the CBI systems for megacities were divided into a framework level, element level, and index level. Details can be found in Table 1. Therefore, the calculation of co-benefit effect indexes was subdivided into two steps: the weight calculation of each index in the index level using the entropy method and a comprehensive index calculation of the CBIs, using a weighted average method.

The entropy method effectively avoided the overlapping in the accessed information of each index, and the subjectivity in the weight determination. The effective value of each index can be determined relatively objectively and accurately. The entropy method does not have any limitations on the distribution of data, and therefore fits multi-index systems [23]. Currently, it is widely applied for comprehensive analysis in many economic and social systems, such as in assessments of city sustainability [24,25], intensive land-use [26–28], and urbanization progress [29–31]. The fundamental concept of the entropy method concerns determining an objective weight for each index based on its variability. Assuming that there are n indexes and that the time span of the research is m years, a matrix $X = (x_{ij})_{m,n}$ can be formulated from all data [32]. For a given index $x_i$, the higher the variability of each index value $x_{ij}$, the more information it assesses, and the smaller the respective information entropy $e_i$. If the variability of $x_{ij}$ for a given index $x_i$ is small, it indicates that less information is assessed by the index, its importance in the comprehensive assessment system is less, and its information entropy is larger. Thus, the weight of the index is smaller.

As the calculations for the entropy method involve theories such as logarithms and entropy, negative values cannot be directly used as inputs. For certain extreme values, relative changes were made. For example, transformations of the base unit, order of magnitude, and positive/negative orientations of each index were required, owing to the existence of discrepancies. Therefore, an extreme classification method was used for normalizing the raw data before the application of the entropy method [33].

(1) Normalization of indexes

When index is positive (benefit indexes)

$$X_{tij} = \frac{X_{ij} - X_{\min}}{X_{\max} - X_{\min}}$$  (1)
When index is negative (cost indexes)

\[ X_{ij}^\prime = \frac{X_{\text{max}} - X_{ij}}{X_{\text{max}} - X_{\text{min}}} \]  

(2)

where \( X_{ij}^\prime \) is a normalized index value. \( X_{ij} \) is the current value of an index. \( X_{\text{max}} \) is 1.05 times the maximum value of an index during the time span of the research. \( X_{\text{min}} \) is 1.05 times the minimum value of an index during the time span of the research.

(2) Weight determination

Converting normalized index values \( X_{ij}^\prime \) to weight \( R_{ij} \)

\[ R_{ij} = \frac{X_{ij}^\prime}{\sum_{i=1}^{m} X_{ij}^\prime} \]  

(3)

Calculating the entropy \( e_i \) of index \( X_i \)

\[ e_i = -\left( \frac{1}{\ln m} \right) \sum_{j=1}^{m} R_{ij} \ln R_{ij} \]  

(4)

Calculating the effectiveness value \( d_i \) of index \( X_i \)

\[ d_i = 1 - e_i \]  

(5)

Calculating the weight \( W_i \) of index \( X_i \)

\[ W_i = \frac{d_i}{\sum_{i=1}^{m} d_i} \]  

(6)

2.3. Comprehensive Index Calculation

By referring to previous sustainability studies including city sustainability evaluations [34–36], evaluations of low-carbon emission city developments [37–39], and evaluations of ecofriendly city developments [40,41], and after weighting each parameter, the comprehensive index can be calculated through the weighted average method, as follows:

\[ \text{CBI} = \sum_{i=1}^{j} W_i X_{ij} \]  

(7)

In the above, CBI is the co-benefits index. \( W_i \) is the weight of ith index. \( X_{ij} \) is the value of the ith index in the jth year.

A description of co-benefits indicator system and a special introduction of the index level are provided in Tables 1 and 2, respectively.

| Framework Level | Element Level | Index Level | Type       |
|-----------------|---------------|-------------|------------|
| Drive(D)        | Level of economic development in a city | Regional GDP | Economy    |
|                 | Average regional GDP per person       |             | Economy    |
| Industry structures | Weight of first industry production in GDP | Economy    |
|                 | Weight of second industry production in GDP | Economy    |
|                 | Weight of third industry production in GDP | Economy    |
| Populations     | Residential population              | Social      |
Table 1. Cont.

| Framework Level | Element Level                  | Index Level                          | Type                  |
|-----------------|--------------------------------|-------------------------------------|-----------------------|
| Pressure(P)     | Intensity of energy consumptions | Amount of energy consumption        | Economy/Environment   |
|                 |                                 | Average energy consumption per person| Economy/Environment   |
|                 |                                 | Energy consumption per unit GDP      | Economy/Environment   |
|                 | Level of air pollutant emissions | PM$_{2.5}$ average annual concentration | Environment          |
|                 |                                 | PM$_{10}$ average annual concentration| Environment          |
|                 |                                 | SO$_2$ average annual concentration  | Environment          |
|                 |                                 | NO$_2$ average annual concentration  | Environment          |
| State(S)        | Level of greenhouse gas emissions| Carbon emission                      | Environment           |
|                 |                                 | Average carbon emission per person   | Environment/Social    |
|                 |                                 | Carbon emission per 10k GDP          | Environment/Economy   |
| Impact(I)       | Air pollution                   | Frequency of acid rain               | Environment           |
|                 |                                 | Average regional dust settling       | Environment           |
|                 | Greenhouse effect               | Average annual temperature           | Environment           |
| React(R)        | Governmental acts               | Flexibility index of energy resource | Economy               |
|                 |                                 | Average public green land per person | Environment/Social    |
|                 |                                 | Investment in eco-protection         | Environment           |

Table 2. Description of co-benefits indicator system for megacities.

| Framework Level | Index Level                          | Positivity/Negativity | Note                                                                 |
|-----------------|-------------------------------------|-----------------------|----------------------------------------------------------------------|
| Drive(D)        | GDP                                 | +                     | Positive during the research time span (2005–2018). May need to be adjusted according to research time span change and city development. |
|                 | Regional GDP per person             | +                     |                                                                      |
|                 | Weight of first industry production in GDP | -                    | Currently megacities in China are facing industrial transformation from robust, high-polluting first and secondary industry to intensive, low-polluting tertiary industry. |
|                 | Weight of second industry production in GDP | -                    |                                                                      |
|                 | Weight of third industry production in GDP | +                    |                                                                      |
|                 | Residential population              | -                     | May need to be adjusted according to research time span change and city development.   |
| Pressure(P)     | Amount of energy consumption        | -                     |                                                                      |
|                 | Average energy consumption per person | -                    | Energy consumption refers to traditional fossil fuel consumption. For megacities in China, these parameters can be typically considered as negative. |
|                 | Energy consumption per unit GDP     | -                     |                                                                      |
|                 | Energy consumption of industry added value | -                    |                                                                      |
| State(S)        | PM$_{2.5}$ average annual concentration | -                    |                                                                      |
|                 | PM$_{10}$ average annual concentration| -                    |                                                                      |
|                 | SO$_2$ average annual concentration  | -                     |                                                                      |
|                 | NO$_2$ average annual concentration  | -                     |                                                                      |
|                 | Carbon emission                     | -                     |                                                                      |
|                 | Average carbon emission per person  | -                     |                                                                      |
|                 | Carbon emission per 10k yuan GDP    | -                     |                                                                      |
| Impact(I)       | Frequency of acid rain              | -                     |                                                                      |
|                 | Average regional dust settling      | -                     |                                                                      |
|                 | Average annual temperature          | -                     |                                                                      |
| React(R)        | Flexibility index of energy resource | -                    |                                                                      |
|                 | Average public green land per person | +                    |                                                                      |
|                 | Investment in eco-protection        | +                     |                                                                      |
2.4. Case Study

This research aimed to establish a CBI system for ecological development for megacities in China, and selected Shanghai as a typical case. The term megacity refers to cities with residential populations higher than 10 million. Shanghai has become ideal in this regard, owing to its relatively better progress in urbanization, and its complex economic, social, and ecological development problems. It not only faces transformation problems in regard to energy and industry structures, but is also under pressure from population growth, pollution, and other cumulative issues arising from long-term development. By selecting Shanghai as a representative case study and using the co-benefits index system, the current measures and policies can be evaluated, and the results of the study can provide references and recommendations for promoting environmentally sustainable development in Shanghai. More importantly, the results of this study can also be disseminated and replicated to other megacities in both China and other developing countries for long-term sustainable development.

2.5. Data Collecting and Processing

After the indexes were determined, the research data for Shanghai for the 14 year research time span (2005–2018) were collected from the following sources: (1) the Shanghai Statistical Yearbook; (2) the Bulletin of Shanghai Environmental Situation; (3) the China Energy Statistics Yearbook; and (4) the thematic data sheets of the National Bureau of Statistics of China-Environmental Statistics [42].

The carbon emission data were calculated using Kaya’s formula as follows [43]:

\[ C = \left( \frac{C}{E} \right) \left( \frac{E}{GDP} \right) \left( \frac{GDP}{P} \right) \times P \]  

(8)

where \( C \) is the carbon emission, \( E \) is the energy consumption per use, and \( P \) is the population. The emission coefficient is different for different energy source. The above formula can be transformed as follows [44]:

\[ C = \sum iC_i = \sum i \frac{E_i}{E} \times \frac{C_i}{E} \times \frac{E}{GDP} \times \frac{GDP}{P} \times P \]  

(9)

In the above, \( E_i \) and \( C_i \) are the energy consumption and carbon emissions of different energy sources per use, respectively.

The above can be further simplified as:

\[ C = \sum iC_i = \sum i \frac{E_i}{E} \times \frac{C_i}{E} \times E \]

(10)

where \( \frac{C_i}{E_i} \) is the carbon emission coefficient. This can be found in the 2006 Intergovernmental Panel on Climate Change (IPCC) National Guide of Green House Gas Emissions [45], and its unit can be transformed as shown in Table 3.

| Type of Energy        | Carbon Emission Coefficient (10^4 tons Carbon/10^4 tons Standard Coal) |
|-----------------------|--------------------------------------------------------------------------------|
| Coal                  | 0.7559                                                                         |
| Petroleum             | 0.5857                                                                         |
| Natural Gas           | 0.4483                                                                         |
| Water/Nuclear Power   | 0                                                                              |
3. Results

3.1. Introduction of Shanghai

Shanghai as one of the four municipalities in China and as one of the first 14 open Chinese ports, it is the center of economy, finance, trade, and shipping in China. Recently, revolutionary policies such as replacing business taxes with value added, tax free trading have been implemented in Shanghai. The implementation of free trading indicates that Shanghai is becoming a new test ground for upcoming reforms and “opening-up” acts, and will represent China in global competitions. Thus, in the new round of city comprehensive planning, Shanghai is set to become the most globally competitive and influential city with global resource allocation capabilities in 2040. This requires Shanghai to be developed as a center of global transportation and allocation, with critical influence over the price of global production factors, and critical attraction to global business and investments. Thus, Shanghai can eventually become a global pivot, similar to New York, London, and Tokyo. To become a global pivot, Shanghai must not only catch up to the highest pace of ecological development in the global scheme but must also be able to attract and retain excellent companies and individuals. To meet such requirements, the social state and ecological quality of the city itself are also crucial. In the 13th 5-year Plan of Environmental Protection and Ecological Construction for Shanghai, ecofriendly development and environmental quality improvement were emphasized as priorities, targeting a globalized livable standard. Therefore, low carbon emissions and pollution control are also a critical part of the tactical plan for Shanghai to become a global pivot. Accordingly, whether a city is livable has become an indication of the city’s soft power in global competitions. Furthermore, Shanghai is a listed nexus in the Belt and Road Initiative, but the key functions of global transportation still need to be developed. It still faces the challenges in regard to global airline business rules regarding low carbon emissions adaption, transportation intensification, transportation system energy consumption, and carbon emissions optimization. Thus, selecting Shanghai as the case for research on the megacity CBI system is very practical.

3.2. Index Weight

Based on the 23 indexes included in the CBI system for megacities, and by collecting and processing data for Shanghai from 2005 to 2018, the weight of each index was determined using the entropy method. The results are given in Table 4. In the drive level, the weight of the regional GDP (0.0649) which counts for the total is slightly lower than, but almost the same as, the regional GDP per person (0.068), which counts for the intensity. However, in the pressure level, the weight of the index that counts for the total, i.e., the energy consumption weight (0.0409), is higher than the weights of the indexes that count for the intensity, which are the weight of the energy consumption per 10k GDP (0.0388) and the weight of the energy consumption per person (0.0146). In the state level, the weight of the carbon emission index (0.0298) is lower than the weight of the carbon emission per 10k GDP, but is higher than the weight of carbon emissions per person (0.0259). This indicates that during the 15 years from 2005 to 2018, the regional GDP growth in Shanghai was approximately the same as the regional GDP growth per person. However, it also shows that carrying the benefits from regional GDP growth to individuals, which means improving the quality of life for individuals, is still a significant challenge. As for the energy consumption and carbon emissions, the gross change (mostly increasing) is higher than the change per person and per 10k GDP (mostly decreasing), indicating that China has been emphasizing lowering the intensity rather than controlling the total amount of emissions for a long time. This has resulted in fast growth in regard to the total emissions, while also achieving emission intensity reduction goals.
Table 4. Weights of indicators in co-benefits indicator system for Shanghai.

| Framework Level | Index | Weight |
|-----------------|-------|--------|
| Drive (D)       | Regional GDP | 0.0649 |
|                 | Average regional GDP per person | 0.0680 |
|                 | Weight of first industry production in GDP | 0.0341 |
|                 | Weight of second industry production in GDP | 0.0380 |
|                 | Weight of third industry production in GDP | 0.104 |
|                 | Residential population | 0.0639 |
| Pressure (P)    | Amount of energy consumption | 0.0409 |
|                 | Average energy consumption per person | 0.0146 |
|                 | Energy consumption per unit GDP | 0.0388 |
|                 | Energy consumption of industry added value | 0.0298 |
| State (S)       | PM$_2.5$ average annual concentration | 0.0442 |
|                 | PM$_10$ average annual concentration | 0.0534 |
|                 | SO$_2$ average annual concentration | 0.0380 |
|                 | NO$_2$ average annual concentration | 0.0201 |
|                 | Carbon emission | 0.0298 |
|                 | Average carbon emission per person | 0.0259 |
|                 | Carbon emission per 10k GDP | 0.0322 |
| Impact (I)      | Frequency of acid rain | 0.0547 |
|                 | Average regional dust settling | 0.0377 |
|                 | Average annual temperature | 0.0075 |
| React (R)       | Flexibility index of energy resource | 0.0405 |
|                 | Average public green land per person | 0.0730 |
|                 | Investment in eco-protection | 0.0407 |

Overall, the weight of the tertiary industry production proportion in the GDP was the highest, with a value of 0.104. This is closely related to government promotional policies. Its GDP contribution is on a growing trend, and increased by 35.7%, from 51.51% in 2005 to 69.9% in 2018. The weight of the annual average temperature is the smallest, with a value of 0.0075. It was not emphasized, as global warming only becomes significant when the time span is much longer. In such a short time span (14 years), the change in the annual average temperature is relatively less significant. The information entropy was relatively high, whereas the weight was slow. However, it may become more significant in the future, as global warming becomes increasingly severe.

3.3. Co-Benefit Index

The CBI for each year during the 14 years of the research time span (2005 to 2018) was further calculated based on the weight calculations and is shown in Table 5 and Figure 2. The CBI was on a growing trend during the 14 years and increased from 0.375 in 2005 to 1.365 in 2018 (a 264% increase). This indicates that the efforts taken in Shanghai and their effects were positive overall. With the exception of 2012–2013 and 2014–2015, the CBI values grew in all other years, with an average growth rate of 18.86%.
Table 5. The co-benefits index (CBI) of Shanghai from 2005 to 2018.

| Year | CBI     | Annual Percentage Increase |
|------|---------|-----------------------------|
| 2005 | 0.375   | \                           |
| 2006 | 0.482   | 28.5%                       |
| 2007 | 0.524   | 8.7%                        |
| 2008 | 0.544   | 3.8%                        |
| 2009 | 0.673   | 23.7%                       |
| 2010 | 0.734   | 9.1%                        |
| 2011 | 0.772   | 5.2%                        |
| 2012 | 0.913   | 18.3%                       |
| 2013 | 0.897   | −1.8%                       |
| 2014 | 1.089   | 21.4%                       |
| 2015 | 1.072   | −1.6%                       |
| 2016 | 1.200   | 11.9%                       |
| 2017 | 1.266   | 5.5%                        |
| 2018 | 1.365   | 13.8%                       |

Figure 2. The co-benefits index (CBI) of Shanghai from 2005 to 2018.

The CBI values were on a decreasing trend in 2012–2013 and 2014–2015, with a high increase on the previous year (2011–2012 and 2013–2014). This is possibly because the government did not facilitate as many initiations as in the beginning years of the five-year plan. For many cities in China, the five-year plan is a long-term goal, and local governments tend to slow down the progression on the following year if the goal for the previous year was achieved or was overly complete, to thereby focus on goals in other fields. Thus, the CBI suffered a slight decrease in carbon emission reduction and air pollution controls in 2012–2013 and 2014–2015. Owing to limitations in obtaining data, this conclusion cannot be confirmed to repeatedly appear at the end of each five-year plan period. This research can be further developed by including data from the next five-year plan and adding analysis based thereon.

3.4. Evaluation

Based on the analysis of CBI values of energy consumption and carbon emission at the pressure and state levels in the co-benefit system for ecological development in Shanghai, and knowing that the measures in controlling total emissions were less effective than controlling per 10k GDP emissions during the research time span, several suggestions can be formulated. A requirement for total emissions should be included and emphasized in policy marketing. In fact, this suggestion has already been addressed and employed in the newest policy. The total energy consumption was listed as a control
index in the Shanghai energy conservation and climate change act of the 12th Five-Year Plan [46], but no specific target was provided. It was later specified in the Shanghai 2018 conservation Plan in the context of emissions reduction and key work planning for the climate change act [47]. The total energy consumption, carbon emissions increase, and coal consumption were listed in detail as control targets, and were limited to 2.4 million, 5.15 million, and 4.4 million standard coal equivalents, respectively. Additionally, the specific year of the peak total carbon emissions was required to be clarified in the 13th Five-Year Plan.

The ranking of each index in the ecological development CBI system is listed in Table 6. The index for the tertiary industry production proportion of the GDP held the highest weight, indicating that it is the most significant index for co-benefit development in Shanghai. Thus, the most effective way to boost the comprehensive CBI of Shanghai is to further promote industry structure transformations and upgrades, more specifically for tertiary industries, e.g., service and high technology industries. Additionally, the low energy costs of tertiary industries can reduce fossil fuel consumption and increase CBI from the root.

Table 6. Weights of indicators from high to low in CBI system in Shanghai.

| Index                                                      | Weight |
|------------------------------------------------------------|--------|
| Weight of tertiary industry production proportion in GDP    | 0.104  |
| Average public green land per person                        | 0.073  |
| Residential population                                      | 0.0693 |
| Regional GDP per person                                     | 0.068  |
| Regional GDP                                               | 0.0649 |
| Frequency of acid rain                                      | 0.0547 |
| PM$_{10}$ average annual concentration                      | 0.0534 |
| PM$_{2.5}$ average annual concentration                     | 0.0442 |
| Amount of energy consumption                                | 0.0409 |
| Investment in eco-protection                                | 0.0407 |
| Flexibility index of energy resource                        | 0.0405 |
| Energy consumption per unit GDP                              | 0.0388 |
| Weight of secondary industry production proportion in GDP    | 0.0388 |
| SO$_2$ average annual concentration                          | 0.038  |
| Average regional dust settling                               | 0.038  |
| Weight of first industry production proportion in GDP        | 0.0377 |
| Carbon emission per 10k GDP                                 | 0.0341 |
| Energy consumption of industry added value                  | 0.0322 |
| Carbon emission                                             | 0.0328 |
| Average carbon emission per person                           | 0.0298 |
| NO$_2$ average annual concentration                          | 0.0295 |
| Average energy consumption per person                        | 0.0201 |
| Average annual temperature                                  | 0.0146 |

In the pollution management field, the indexes for investment in eco-protection was the most heavily weighted index, and had major impacts on the final CBI of the city. As shown in Figure 3, the change trends for both the investment in the eco-protection index and CBI from 2006 to 2018 were identical, confirming that the annual investment in eco-protection had a significant impact on the CBI of Shanghai. Further enhancement of the investment can be suggested. Roughly, it can be estimated that the investment in eco-protection will be further increased by 440 billion Yuan or 37.5% in the period of the 13th Five-Year Plan, as compared to the 12th Five-Year Plan. The CBI of Shanghai will be further boosted once the 13th Five-Year Plan is implemented.

Measures aiming at managing acid rain could be beneficial to the CBI of Shanghai. In 2014, the acid rain frequency was as high as 72.4%, i.e., significantly more frequent than in 2005 (40%). In 2018, the frequency dramatically dropped to 53.8% but remained higher than in the first year. The formulation of acid rain is caused by multiple factors, such as massive emissions of SO$_2$ and NO$_2$, regional transport, and climate effects [48]. As Shanghai is within one of the three top acid rain regions,
and in consideration of the importance of regional transport in the acid rain formulation, measures that lower the emissions of SO$_2$ and NO$_2$ are suggested. Regional coordinated acid rain pollution reduction measures are also suggested.

Table 6. Weights of indicators from high to low in CBI system in Shanghai.

| Index                                           | Weight  |
|-------------------------------------------------|---------|
| Weight of tertiary industry production proportion in GDP | 0.104   |
| Average public green land per person             | 0.073   |
| Residential population                           | 0.0693  |
| Regional GDP per person                         | 0.068   |
| Regional GDP                                    | 0.0649  |
| Frequency of acid rain                           | 0.0547  |
| PM$_{10}$ average annual concentration           | 0.0534  |
| PM$_{2.5}$ average annual concentration          | 0.0442  |
| Amount of energy consumption                     | 0.0409  |
| Investment in eco-protection                     | 0.0407  |
| Flexibility index of energy resource             | 0.0405  |
| Energy consumption per unit GDP                 | 0.0388  |
| Weight of secondary industry production proportion in GDP | 0.038   |
| SO$_2$ average annual concentration              | 0.038   |
| Average regional dust settling                   | 0.0377  |
| Weight of first industry production proportion in GDP | 0.0341   |
| Carbon emission per 10k GDP                     | 0.0322  |
| Energy consumption of industry added value       | 0.0298  |
| Carbon emission                                  | 0.0298  |
| Average carbon emission per person               | 0.0259  |
| NO$_2$ average annual concentration              | 0.0201  |
| Average energy consumption per person            | 0.0146  |
| Average annual temperature                       | 0.0075  |

4. Discussion and Conclusions

4.1. Limitations

4.1.1. Applicable Conditions

This research study on CBI system targeted megacities with more than 10 million residents, as megacities are relatively more important in national economic development, and are facing more severe and serious consequences. It was not meant to be suitable for all cities, as the determinations of the positivity and negativity of some indexes were based on the development states of megacities. For example, the index of total energy consumption is negative for megacities, as it must be controlled urgently, but the same does not hold for cities with limited development and size. The positivity and negativity cannot be solely judged as negative for all states of city development.

4.1.2. Annual Average Concentration of PM$_{2.5}$ as an Index

The haze pollution phenomenon is one of the most common and challenging air pollution phenomena in megacities in China. Initially, the annual average concentration of PM$_{2.5}$ was included in the megacity ecodevelopment CBI system. However, China only started to publish PM$_{2.5}$ data in 2012. Thus, only seven years of data (from 2012 to 2018) were available, which was insufficient for conducting the assessment. Excessive contingency and uncertainty would be introduced if conducting the assessment; thus, the index was not discussed. Nevertheless, more data will become available in the future, so that the annual average concentration of PM$_{2.5}$ can be assessed and included as an index in the megacity ecodevelopment CBI system, thereby lowering the contingency and uncertainty.

4.1.3. Average Regional Dust Settling as an Index

According to the 2018 Shanghai Ecological and Environmental Bulletin, the conventional manual monitoring on area dust fall was replaced by online dust monitoring on roads in Shanghai in 2018 in order to further improve the accuracy and timeliness of the data monitored relating to coarse particles. Then we use the index of average concentration of road dust particulate matter in Shanghai to replace the index of average regional dust settling in 2018. Online dust monitoring is more accurate and less
error than manual monitoring. The value of index of average concentration of road dust particulate matter in Shanghai will be more scientific in the future. But in this article, we will still use the index of average regional dust settling.

4.2. Suggestions

4.2.1. Enhancing Management of Total Energy Consumption and Carbon Emissions

We will further strengthen the “dual aggregation” control over energy consumption and carbon emissions, and move faster to achieve zero growth in both areas firstly. Then we also should strengthen management to reduce the usage of high carbon energy sources such as coal and oil, and make coordinated developments of energy conservation and low carbon and air pollution management. Governments have to fully implement the benchmarking at the international advanced level, persist to improve efficiency of energy utilization, and reduce the intensity of carbon emissions. Finally, we shall put effort into promoting technological innovation in energy conservation and low carbon, and drive key technological breakthroughs and industrial development of energy conservation and low carbon by relying on major projects of energy conservation and low carbon.

4.2.2. Promoting Industry Structure Transformations and the Development of Tertiary Industry

Preoccupied with economic growth rate, the extensive economic development model and the thinking on regarding industry as important and making light of the service industry is still the main ideological root which restricts the adjustment of economic structure and the optimization of industrial structure. With pressures of energy resources and environment in China, the mode of economic development relying on increasing material resources input is unsustainable. Extensive economic growth model has been obviously unable to adapt the requirements of future economy and social development. Therefore, it is necessary to establish a comprehensive, coordinated and sustainable economic development model to achieve the unification of speed, structure quality and benefit, and the coordination of economic development and population, resources and environment.

4.2.3. Increasing Investments in Eco-Protection and Decreasing the Gap between the Actual Ecological Quality of the City and the Residential Expectations

In the construction and operation of environmental protection infrastructure, the majority of cities in China at present are severely underfunded. Without bringing in mechanisms of marketization and industrialization, the construction and operation management of facilities of pollution control severely impeded the development of cities’ infrastructure construction of environmental protection and worsened the effect of pollution control in China. With the continuous improvement of people’s living standards, the requirements of ecological environmental quality have also correspondingly increased. However, the reality of serious urban environmental pollution has formed a certain degree of contrast with people’s increasing requirements of improving environmental quality. Based on the comprehensive analysis of the condition and development trend of urbanization, the infrastructure construction of urban environmental protection in China has lagged behind the development of urbanization for a long time, has not been synchronously developed with urban construction, and cannot meet the needs of sustainable development of urban economy and society. Therefore, it is necessary to increase the investment in urban environmental protection and narrow the gap between the urban actual environmental quality and the expected environmental quality of urban residents.

4.2.4. Cowork Regionally to Control the Pollution of Acid Rain

We will formulate strict standards for the quality of the atmospheric environment to improve the pollutant discharge permit system and limit the total SO2 emissions according to regional environmental capacity. We should adjust industrial structure and transform heavily polluting enterprises by eliminating backward processes and obsolete equipment. At the same time, we should
improve coal burning technology to reduce the emissions of SO\textsubscript{2} and NO\textsubscript{X}. Increasing the proportion of energy sources that are pollution-free or less polluting will be the best way. The development of clean energy that can replace coal burning, such as solar energy, nuclear energy, hydropower, wind energy, geothermal energy, natural gas and other clean energy, will make a great contribution to reducing SO\textsubscript{2} emissions and preventing acid rain.

4.3. Expectations

4.3.1. Cross Comparison of Different Cities Under the Same Index System

The method of the megacity CBI system was applied to Shanghai. We will select other megacities in China, such as Beijing, Tianjin, Guangzhou and so on, to make a cross comparison in order to find out common characteristics in future. For example, the ranking of the weights for indexes in each framework level of different cities is to determine whether the effects of each factor are approximately the same for the selected cities, so as to provide theoretical basis for the subsequent cross comparisons of the different megacities under the same co-benefit index system. Meanwhile, by keeping the relative magnitude of each index in the system constant, the weight for each index of the CBI system can be re-calculated. For example, based on a period of data of several megacities, and by taking the average of each CBI value for all cities, a normalized comprehensive CPI can be obtained for each city.

4.3.2. Generalized Co-Benefits Index (CBI) System

The CBI system developed in this research is specialized, and only assesses the co-benefits of measures for reducing carbon emissions and controlling air pollution. A generalized CBI system should further assess more economic and social factors [49], such as public health improvements. For future research, additional factors including social co-benefits (e.g., residential health) and other aspects of pollution management in cities (e.g., city water body pollution management, city solid was management) can be included in the CBI system for a more comprehensive assessment of a city’s economy, social, and ecology development.

4.3.3. Co-Benefit Monetization

Comprehensive CBI is an indicator that represents a city’s economic, social, and ecological development state, and can be beneficial for policy-makers in understanding the economic benefits of implementing new policies, if the cost and effect can be presented as cost and benefit. Specifically, research on co-benefit monetization can be concentrated in key departments for city energy conservation and emissions reduction, such as those for industry, transportation, and construction. A cost–benefit analysis of the effects of relative policies can provide a more direct and clearer display of the co-benefits. Furthermore, with the aid of scenario analysis and model predictions, the analysis and prediction of co-benefits can provide a reliable scientific reference for future policymaking in regard to city sustainability.

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References

1. Science, L. Global Warming: News, Facts, Causes & Effects. Ed. Available online: http://www.livescience.com/topics/global-warming (accessed on 6 November 2019).
2. Tiao, G.C.; Box, G.E.P.; Hamming, W.J. Analysis of Los Angeles Photochemical Smog Data: A Statistical Overview. J. Air Pollut. Control Assoc. 1975, 25, 260–268. [CrossRef]
3. Wang, G.; Zhang, R.; Gomez, M.E.; Yang, L.; Zamora, M.L.; Hu, M.; Lin, Y.; Peng, J.; Guo, S.; Meng, J.; et al. Persistent sulfate formation from London Fog to Chinese haze. Proc. Natl. Acad. Sci. USA 2016, 113, 13630–13635. [CrossRef]

4. Núñez-Cacho, P.; Molina-Moreno, V.; Corpas-Iglesias, F.A.; Cortés-García, F.J. Family Businesses Transitioning to a Circular Economy Model: The Case of “Mercadona”. Sustainability 2018, 10, 538. [CrossRef]

5. Ryan, M.; Antoniou, J.; Brooks, L.; Jiya, T.; Macnish, K.; Stahl, B. The Ethical Balance of Using Smart Information Systems for Promoting the United Nations’ Sustainable Development Goals. Sustainability 2020, 12, 4826. [CrossRef]

6. Keitsch, M. Structuring Ethical Interpretations of the Sustainable Development Goals—Concepts, Implications and Progress. Sustainability 2018, 10, 829. [CrossRef]

7. Scovronick, N.; Budolfson, M.; Dennig, F.; Errickson, F.; Fleurbaey, M.; Peng, W.; Socolow, R.H.; Spears, D.; Wagner, F. The impact of human health co-benefits on evaluations of global climate policy. Nat. Commun. 2019, 10, 2095. [CrossRef] [PubMed]

8. Wagner, F.; Amann, M.; Borken-Kleefeld, J.; Cofala, J.; Höglund-Isaksson, L.; Purohit, P.; Rafaj, P.; Schöpp, W.; Winiwarter, W. Sectoral marginal abatement cost curves: Implications for mitigation pledges and air pollution co-benefits for Annex I countries. Sustain. Sci. 2012, 7, 169–184. [CrossRef]

9. Chen, H.; Wang, Z.; Xu, S.; Zhao, Y.; Cheng, Q.; Zhang, B. Energy demand, emission reduction and health co-benefits evaluated in transitional China in a 2 °C warming world. J. Clean. Prod. 2020, 264, 121773. [CrossRef]

10. Jiang, L.; Xue, B.; Ma, Z.; Yu, L.; Huang, B.; Chen, X. A life-cycle based co-benefits analysis of biomass pellet production in China. Renew. Energy 2020, 154, 445–452. [CrossRef]

11. Alimujiang, A.; Jiang, P.; Dong, H.; Hu, B. Synergy and co-benefits of reducing CO2 and air pollutant emissions by promoting new energy vehicles: A case of Shanghai. Acta Sci. Circumstantiae 2020, 5, 1873–1883.

12. Mao, X.; Xing, Y.; Hu, T.; Zeng, A.; Liu, S. An environmental-economic analysis of carbon, sulfur and nitrogen co-reduction path for China’s power industry. China Environ. Sci. 2012, 32, 748–756.

13. Ding, M.A.; Chen, W.Y. Analysis of the co-benefit of emission reduction measures in China’s iron and steel industry. China Environ. Sci. 2015, 1, 198–303. [CrossRef] [PubMed]

14. Sun, X.; Jiang, P.; Gao, S.; Zheng, J.; Zhu, Y.; Zhang, M. Environmental Sustainable Development with Co-benefits Approach in Guangxi Province. J. Fudan Univ. (Nat. Sci.) 2016, 55, 173–182.

15. Nikiforiadis, A.; Chrysostomou, K.; Aifadopoulou, G. Exploring Travelers’ Characteristics Affecting their Intention to Shift to Bike-Sharing Systems due to a Sophisticated Mobile App. Algorithms 2019, 12, 264. [CrossRef]

16. Ruiz-Guerra, I.; Molina-Moreno, V.; Cortes-Garcia, F.J.; Nunez-Cacho, P. Prediction of the impact on air quality of the cities receiving cruise tourism: The case of the Port of Barcelona. Heliyon 2019, 5, e01280. [CrossRef]

17. Svarstad, H.; Petersen, L.K.; Rothman, D.; Siepel, H.; Wätzold, F. Discursive biases of the environmental research framework DPSIR. Land Use Policy 2008, 25, 116–125. [CrossRef]

18. Zhang, H.; Zhou, J. Evaluation of China’s provincial rural financial ecological environment based on DPSIR model. Jiangsu Agric. Sci. 2018, 46, 319–323.

19. Zhang, L.; Wang, W.; Deng, Z.; Zhao, Y. On the evaluation system of the environmental business behavior based on the DPSIR model. J. Saf. Environ. 2018, 18, 342–348.

20. Gari, S.R.; Newton, A.; Icely, J.D. A review of the application and evolution of the DPSIR framework with an emphasis on coastal social-ecological systems. Ocean Coast. Manag. 2015, 103, 63–77. [CrossRef]

21. Zhang, L.; Li, N.; Qin, Y.; Zhang, J.; Wang, X. The low-carbon city evaluation and its spatial differentiation based on the DPSIR. World Reg. Stud. 2019, 28, 85–94.

22. Qiao, J. Application of Improved Entropy Method in Henan Sustainable Development Evaluation. Resour. Sci. 2004, 26, 113–119.

23. Wu, Y.; Zhong, J. Study on Building the Assessment System on Innovative Cities Based on Entropy Method. Sci. Technol. Manag. Res. 2011, 18, 13–15.

24. Liu, Q.; Zeng, H. Evaluation of Circular Economy Development Based on Entropy Method—A case study of Tianshui City in Gansu Province. Territ. Nat. Resour. Study 2017, 2, 25–28.
25. Wang, K.; Guo, X.; Li, M. Performance Evaluation of Ecological Civilization of Urban Agglomeration in Greater Bay Area of Yangtze River Delta Based on the Conjoint Analysis of Factor Analysis and Entropy Method. *Ecol. Econ.* **2020**, *4*, 213–218.

26. Liu, Y.; Liu, C.L.; Zhang, Y. Research on Sustainable Utilization of Land Resources in Quanzhou City Based on Entropy Method. *J. Suzhou Univ.* **2019**, *34*, 75–80.

27. Chen, X. Dynamic Evaluation of Sustainable Land Use Based on Entropy Method—A Case Study of Jiangxi Area. *Lioning Agric. Sci.* **2017**, *1*, 37–42.

28. Zhou, X.; Tang, X.; Li, M. Evaluation on the Urban Land Use Intensity and its Spatial Difference Based on Improved Entropy Method and Spatial Autocorrelation—A Case Study of Jiangxi Province. *J. Fujian Norm. Univ. (Nat. Sci. Ed.)* **2015**, *31*, 88–97.

29. Ma, Y.-M.; Wu, Y.-M.; Wu, B.-J. Comprehensive Evaluation of Sustainable Urban Development of Yangtze River Delta Based on Entropy Method and Quadrant Method. *Econ. Geogr.* **2015**, *6*, 47–53.

30. Lu, C.; Wen, F.; Yuan, X.; Qin, Y. Research on risk identification of urbanization based on the entropy method in henan province. *Chin. J. Agric. Resour. Reg. Plan.* **2018**, *39*, 142–147.

31. Liu, J.; Huiran, C.; Xie, Z.; Liu, B. A Study on the Urbanization Quality Evaluation of Prefecture-level Cities in Hebei Province Based on Entropy Method. *Math. Pract. Theory* **2020**, *2*, 73–81.

32. Guo, X. Application of improved entropy method in evaluation of economic result. *Syst. Eng. Theory Pract.* **1998**, *12*, 99–103.

33. Wei, J.; Luo, W. Evaluation of Sustainable Ecological Development in Chengdu City Based on DPSIR Model. *Environ. Sci. Manag.* **2013**, *2*, 184–187.

34. Huang, Z.; Li, G.; Li, Y.; Chang, Y. Evaluation and Analysis of Sustainable Development in Beijing Based on DPSIR Model. *Urban Dev. Stud.* **2016**, *23*, 20–24.

35. Liu, X.; Liu, H.; Chen, J.; Liu, T.; Deng, Z. Evaluating the sustainability of marine industrial parks based on the DPSIR framework. *J. Clean. Prod.* **2018**, *188*, 158–170. [CrossRef]

36. Qiao, X.; Yang, Y.; Yang, Y.; Feng, D. Applying DPSIR Model and Theil Coefficient to Assess Sustainable Development in Henan Province. *Aral Res. Dev.* **2017**, *36*, 18–22.

37. Zhou, Y.; Wang, J.; Gao, J.; Jialing, R. Evaluation and Obstacle Factor Diagnoses of Low Carbon Transport Development Based on DPSIR: A Case Study of Beijing. *Ecol. Econ.* **2020**, *4*, 13–18.

38. Wei, Y.; Zhu, X.; Li, Y.; Yao, T.; Tao, Y. Influential factors of national and regional CO2 emission in China based on combined model of DPSIR and PLS-SEM. *J. Clean. Prod.* **2019**, *212*, 698–712. [CrossRef]

39. Salguero-Puerta, L.; Leyva-Diaz, J.C.; Cortes-Garcia, F.J.; Molina-Moreno, V. Sustainability Indicators Concerning Waste Management for Implementation of the Circular Economy Model on the University of Lome (Togo) Campus. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2234. [CrossRef]

40. Gu, J.; Hu, W.; Tian, S. Evaluation of Ecological Carrying Capacity and Diagnosis of Obstacle Factors in Jiangsu Province Based on DPSIR-TOPSIS Model. *Bull. Soil Water Conserv.* **2019**, *39*, 246–252.

41. Spanò, M.; Gentile, F.; Davies, C.; Laforêtzza, R. The DPSIR framework in support of green infrastructure planning: A case study in Southern Italy. *Land Use Policy* **2017**, *61*, 242–250. [CrossRef]

42. National BureauofStatistics. *ChinaStatistics Yearbook*; China Statistics Press: Beijing, China, 2019.

43. Albrecht, J.; François, D.; Schoors, K. A Shapley decomposition of carbon emissions without residuals. *Energy Policy* **2002**, *30*, 727–736. [CrossRef]

44. Xu, G.; Liu, Z.; Jiang, Z. Decomposition Model and Empirical Study of Carbon Emissions for China, 1995–2004. *China Popul. Resour. Environ.* **2006**, *16*, 158–161.

45. IPCC. 2006 *IPCC Guidelines for National Greenhouse Gas Inventories: Energy*; Institute for Global Environmental Strategies: Hayama, Japan, 2006.

46. Shanghai Municipal Development & Reform Commission. The 12th Five Year Plan of Energy Conservation and Climate Change in Shanghai. Available online: http://www.shanghai.gov.cn/nw2/nw2314/nw2319/nw10800/nw11407/nw29273/u26aw31222.html (accessed on 9 March 2012).

47. Shanghai Municipal Development & Reform Commission. Key Work Arrangements of Energy Conservation and Emission Reduction in Shanghai in 2018. Available online: http://www.shanghai.gov.cn/nw2/nw2314/nw2319/nw12344/u26aw56092.html?date=2018-06-04 (accessed on 4 June 2018).
48. Wu, C.; Dai, J.; Chen, Q.S.A.; Xie, Q. Visualization analysis of the research status and emerging trends of the acid rain application. *J. Saf. Environ.* 2019, 19, 344–353.

49. Cai, J.; Gao, S.; Sun, X.; Jiang, P.; Zheng, J.; Zhang, M. A review of studies on the co-benefits of environmental, economic and social development. *China Popul. Resour. Environ.* 2016, 26, 35–38.

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