

GREEN INDUSTRY PROGRESS (GIPro) INDEX FOR 18 CHINESE PROVINCES



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List of Acronyms

COD:	Industrial Chemical Oxygen Demand Effluent Intensity
ENERGY:	Industrial Energy Consumption Intensity
GEMP:	Employees in Less Energy Intensive Sectors as Percent of Total Industrial Employees
GEP:	Green Economy Progress
GIPer:	Green Industry Performance
GIPro:	Green Industry Progress
GIVA:	Industry Value Added of Less Energy Intensive Sectors as Percent of Total Industry Value Added
HWASTE:	Industrial Hazardous Waste Generation Intensity
IVA:	Industry Value Added
ILO:	International Labour Organization
OECD	Organisation for Economic Co-operation and Development
PAGE:	Partnership for Action on Green Economy
UNIDO:	United Nations Industrial Development Organizations
UNDP:	United Nations Development Programme
UNITAR:	United Nations Institute for Training and Research
SO ₂ :	Industrial Sulphur Dioxide Emission Intensity
WATER:	Industrial Water Withdrawal Intensity

Executive Summary

The Partnership for Action on Green Economy (PAGE) published A Stocktaking Report on the Transition to a Green Economy in China's Jiangsu Province (PAGE, 2016). As a follow-up to the Report, UN Environment initiated a project to construct a Green Economy Progress (GEP) index for Jiangsu Province. At the same time, UNIDO launched a project to construct a Green Industry Progress (GIPro) index using data from 18 highly industrialized Chinese provinces, including Jiangsu, as a sectorial focused index, which would complement the ongoing PAGE development of a provincial Green Economy Progress (GEP) index. A “progress” composite index like GEP concentrates on trend changes with respect to a set of relevant targets and critical thresholds. It allows for differences not only in the level of outcomes, but also in the specific rates of progress in meeting targets, which are based on the best performance of provinces/states within a country. The methodology helps countries' policymakers to understand policy relevance and set policy priorities at the provincial and country level.

Because there is no absolute measure of progress for green industrialization at the provincial level, an application of the GIPro methodology uses provincial data to compare relative progress over the period 2006-2015. A multidimensional perspective on progress is created by combining seven indicators into a GIPro index. These indicators are green industry value added, green industrial employment, energy intensity, water intensity, chemical oxygen demand intensity, sulphur dioxide intensity and hazardous waste intensity. Progress for any indicator is simply the ratio between actual and desired changes.

The GIPro index shows that 14 out of 18 provinces achieved overall progress between 2006 and 2015 in their transition towards green industrialization. When considering indicators on an individual basis, on average, progress is found to be most significant in reducing energy intensity, water intensity, chemical oxygen demand intensity and sulphur dioxide intensity in the 18 provinces. However, on average, provinces did not progress as much in areas of green industry value added, green industrial employment or hazardous waste intensity. Many provinces even experienced a regress for those indicators.

The progress in each indicator identifies the impact of each indicator on a province's overall ranking among the 18 provinces. This report offers policy recommendations pinpointing the indicator or indicators for each province that need to improve in order to enhance its overall green industrialization progress.

Green Industry Progress (GIPro) Index

1. Background

At the Sustainable Development Summit on the 25th of September 2015, UN Member States adopted the 2030 Agenda for Sustainable Development, including a set of Sustainable Development Goals (SDGs), otherwise known as the Global Goals. The SDGs are a new, universal set of goals, targets and indicators that UN Member States are expected to use to frame their agendas and policies over the next 15 years.

The United Nations Industrial Development Organization (UNIDO), a specialized UN agency, promotes industrial development for poverty reduction, inclusive globalization and environmental sustainability. The mandate of UNIDO, as described in the Lima Declaration adopted at the fifteenth session of the UNIDO General Conference in 2013, is to promote and accelerate inclusive and sustainable industrial development (ISID) to achieve shared prosperity and environmental sustainability around the world. The concept of ISID is included in the UN SDG Goal 9: build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

The Partnership for Action on Green Economy (PAGE) was officially launched by the United Nations Environment Programme (UN Environment), the International Labour Organization (ILO), the United Nations Industrial Development Organization (UNIDO) and the United Nations Institute for Training and Research (UNITAR) at UN Environment's Governing Council in 2013 as the United Nation's direct response to the Rio+20 Conference. UNDP joined the Partnership in 2014, further increasing the Partnership's capacity to fulfill its mandate. The Partnership calls on the international community to provide assistance to countries interested in developing, adopting, and implementing inclusive green economy policies and strategies for achieving sustainable development and poverty eradication.

UN Environment is supporting PAGE by creating tools and metrics that help to track progress in green economy and sustainable development. It developed a Green Economy Progress Measurement Framework that facilitates a cross-country comparison of countries' efforts to transition to greener and more inclusive economies (UNEP, 2015). There are a number of studies that assess green economy progress at the country level following the framework, but there is no measure of progress for green industrialization at the country level.

China, as the second largest global economy, aims to upgrade its industry in a sustainable and harmonious manner. In the National 13th Five-Year Plan, China announced its plan to comprehensively advance innovative, coordinated, green, open and shared development in order to create a moderately prosperous society. 'Green' is one of the five development

philosophies in the Plan. China aims to create a green manufacturing system through green manufacturing projects and green product lifecycle management. It is supporting the development of green service providers, expanding the use of energy efficient and environmentally friendly products and encouraging innovations in technology, equipment, and green service models. Construction of a Green Industry Progress (GIPro) index using the GEP methodology is one approach to assessing China's progress in achieving green industrialization as called for in its Five-Year Plan.

1.1 Composite Indexes

Ensuring effective inclusive green industry policymaking requires a robust set of indicators to identify major issues, formulate appropriate policy responses and assess the potential policy impacts. Composite indexes are useful in this process because they summarize complex, multi-dimensional policy-relevant data into a single indicator. They facilitate the interpretation of many separate indicators by reducing the set of indicators without losing the underlying information. For composite indexes to facilitate interpretation, it is critical to have a sufficient number of indicators so that the multidimensionality is captured, but limited in number for ease of interpretation. To understand a complex phenomenon like green industrialization, composite indexes are best suited to capture its multi-dimensional nature and synthesize the information captured by the aggregated indicators (OECD, 2008).

In some cases, researchers and policymakers are interested in evaluating the performance of countries/regions/individuals in terms of a specific set of outcomes. For this type of composite index, the focus of the analysis is on "performance." Examples of performance composite indexes are the UNDP Human Development Index (HDI) and the UNIDO Competitive Industrial Performance Index (CIP). The HDI captures the capability approach that sees human life as a set of 'doings and beings' or 'functionings'. In this approach, functioning is the achievement of a person: what he or she manages to do or to be, while a capability reflects the various combinations of 'functionings' he or she can achieve (UNDP, 2016). The CIP index is a composite index that captures the competitiveness of national industries and provides a prospective means for international comparison. Industrial competitiveness, which is not possible to estimate by one single indicator, is calculated as a non-linear combination of eight component indicators grouped into three dimensions (UNIDO, 2017). These types of performance composite indexes focus on outcome variables, with the understanding that there are a variety of policy avenues that can be taken to achieve a desired outcome.

"Progress" composite indexes, like the UN Environment Green Economy Progress (GEP) index, in addition to the flexibility of the performance composite indexes as discussed in previous paragraph, concentrate on trend changes with respect to a set of relevant targets

and critical thresholds. They allow for differences not only in the level of outcomes, but also in the specific rates of progress in meeting targets, which are based on best performance of provinces or states.

1.2 Green Economy Progress Measurement Framework

We follow the Green Economy Progress (GEP) measurement framework to construct a GIPro index. The GEP measurement framework estimates the progress in achieving the transition to an inclusive green economy at the national and global levels. The framework measures the transition to an economy that produces environmentally friendly goods and services, creates economic opportunities, improves societal well-being, and adds new jobs, while staying within our planet's resource capacity (PAGE, 2017a).

The GEP measurement framework includes a composite GEP index, as well as a “dashboard” of environmental sustainability indicators. The GEP Measurement Framework incorporates a set of green economy indicators to measure progress against set targets. Progress towards a green economy is measured for each indicator, and is aggregated into a composite index across several parameters for each country. This pins down the progress each country has made and allows a comparison of progress within the peer groups for the particular indicators. (UNIDO defined four development groups which together can be considered as a peer group for country level comparison: industrialized countries, emerging industrialized economies, other developing economies and least developed countries.) The weighting system of the GEP framework allows for making meaningful comparisons across countries and within a country across indicators (PAGE, 2017b).

2. GIPro Index: Phase One

Both the Chinese government and PAGE are aware that assessing progress towards a green economy can play a significant role in helping national and local governments to explore new green development paths. In 2016, PAGE published A Stocktaking Report on the Transition to a Green Economy in China's Jiangsu Province (PAGE, 2016).

As a follow-up to the Stocktaking Report, UN Environment initiated a project to construct a GEP index for Jiangsu Province. At the same time, UNIDO launched a project to construct a Green Industry Progress (GIPro) index as a sector-focused index, which would complement the ongoing PAGE development of a GEP index. One of the most important advantages of this methodology is benchmarking analysis. Because there is no absolute measure of progress for green industrialization at the provincial level, an application of the GIPro methodology uses data for several provinces including Jiangsu to compare relative progress.

UNIDO undertook a Phase One assessment to test the GIPro methodology. The test includes eight provinces and nine indicators. The nine indicators are taken from the economic, social and environmental dimensions of sustainable development. The indicators for this phase are: industry value added per capita, employees in manufacturing as percentage of total employees, industrial energy consumption intensity, industrial water withdrawal intensity, industrial hazardous waste generation intensity, industrial chemical oxygen demand effluent intensity, industrial carbon dioxide emission intensity, industrial sulphur dioxide emission intensity and industrial total suspended particulate emission intensity. The GIPro index ranks Jiangsu sixth out of eight provinces/cities (Table 1). Note that this is a ranking of greening industry progress rather than a measure of current performance. Ranking sixth out of eight provinces does not mean that Jiangsu has a “bad” performance in terms of greening industrialization, just that other provinces/cities made greater progress in green industrialization than Jiangsu during the period from 2006 to 2015.

Table 1 Phase One: GIPro index for eight provinces/cities in China

Region	GIPro Index	Ranking
SICHUAN	0.90	1
SHANDONG	0.81	2
JILIN	0.71	3
GUANGDONG	0.59	4
TIANJIN	0.51	5
JIANGSU	0.47	6
NINGXIA	0.44	7
BEIJING	0.42	8

The Phase Two GIPro index ranks the progress of 18 provinces based on seven indicators (Table 2). The new economic (GIVA) and social (GEMP) indicators are now more representative of green industrialization because they reflect a shift to green manufacturing and employment rather than to MVA per capita and overall manufacturing employment. The carbon dioxide indicator is no longer included because there are no official estimates of these emissions at the provincial level; the estimate of these emissions in the Phase One report is based on energy use. Total Suspended Solids emissions are also excluded because the Sulphur Dioxide emission variable is seen as sufficient characterization of air pollution.

Table 2 Changes in indicators between Phase One and Two

Category	Phase One Indicators	Interpretation	Phase Two Indicators	Interpretation	Explanation
Economy	MVAPC	MVA per Capita	GIVA	Industry Value Added of Less Energy Intensive Sectors as Percentage of Total Industry Value Added ¹	Replaced by new variable
Social	EMP	Employees in manufacturing as % of total employees.	GEMP	Employees in Less Energy Intensive Sectors as Percentage of Total Industrial Employees	Replaced by new variable
Environment	WATERINT	Industrial water withdrawal intensity	WATER	Industrial water withdrawal intensity	
	ENERGYINT	Industrial energy consumption intensity	ENERGY	Industrial energy consumption intensity	
	COD	Industrial COD effluent intensity	COD	Industrial Chemical Oxygen Demand Effluent Intensity	
	SO ₂	Industrial SO ₂ emission intensity	SO ₂	Industrial Sulphur Dioxide Emission Intensity	
	HWASTE	Industrial hazardous waste generation intensity	HWASTE	Industrial hazardous waste generation intensity	
	CO ₂	Industrial CO ₂ emission intensity			Removed
	TSP	Industrial total suspended particulate emission intensity			Removed

Indicators in the GIPro index assess provinces' relative progress by comparing individual provinces with the best performing ones. In doing so, the GIPro index gives decision-makers access to data organized in ways that are easy to understand and policy-relevant. The objective is to encourage provincial authorities to review the effectiveness of indicator-specific policies that promote green industrialization.

3. GIPro methodology

The GIPro index follows the GEP index methodology (PAGE 2017a). It combines two types of indicators, goods and bads. For good indicators, like GIVA, a larger value is better. For the bad indicators, like energy intensity, a smaller value is better. Progress on a single indicator corresponds to the ratio of the actual and desired increments (in the case of goods) or reductions (in the case of bads) and is estimated as follows:

¹"Industrial Green Development Plan (2016-2020)" from the Ministry of Industry and Information Technology "aims to optimize the industrial structure that accelerates the development of advanced manufacturing and strategic emerging industries with low energy consumption and less pollution and promotes the transformation to service-oriented manufacturing".

$$Progress = \begin{cases} \frac{p_{goods}(y^1, y^0)}{s_{goods}(y^*, y^0)} = \frac{dy}{dy^*} = \frac{y^1 - y^0}{y^* - y^0} \\ \frac{p_{bads}(y^1, y^0)}{s_{bads}(y^*, y^0)} = \frac{d(-y)}{d(-y^*)} = \frac{y^0 - y^1}{y^0 - y^*} \end{cases} \quad (1)$$

In equation (1), y^0 is the initial value of indicator, y^1 is the final value of indicator and y^* is the target value.

3.1 Target and threshold

For each indicator, its initial and final values are known. In order to calculate the progress of equation (1), the target should be determined. Following the GEP index methodology (PAGE 2017b), the target (y^*) is defined as the following expression (2):

$$\begin{aligned} y^* &= \max\{t, \lambda y^0\}, \lambda > 1 \quad (goods) \\ y^* &= \min\{t, \beta y^0\}, \beta < 1 \quad (bads) \end{aligned} \quad (2)$$

In equation (2), t represents the threshold for “good” indicators; the value of the threshold is set at the 25th percentile of the sample distribution at the starting year. For the “bad” indicators, it is set at the 75th percentile of the initial year distribution. λ (lambda) represents the ratio between the final (y^1) and initial (y^0) values for each indicator for the sample 90th percentile of the distribution for good indicators; β (beta) represents the ratio between the final y^1 and initial y^0 value for each indicator for the 10th percentile of the distribution for bad indicators. Notice that if the target falls below the threshold for goods or above the threshold for bads, the target value (y^*) is set to be the threshold value.

Once the target is formulated, the progress on any particular indicator (from equation 1) is obtained as follows:

$$Progress = \begin{cases} \frac{dy}{dy^*} = \frac{y^1 - y^0}{\max\{t, \lambda y^0\} - y^0}, & \lambda > 1 \\ \frac{d(-y)}{d(-y^*)} = \frac{y^0 - y^1}{y^0 - \min\{t, \beta y^0\}}, & \beta < 1 \end{cases} \quad (3)$$

In equation (3), the index can also be negative in some situations. For the good indicators, if the final value is lower than the initial value, the GIPro index is negative. For the bad indicators, if the final value is higher than the initial value, progress is negative. The index takes on a value above or below one, depending on whether actual progress is above or below the target.

3.2 Weighting System

As there are seven indicators within the three dimensions of the GIPro index, a weighting scheme needs to be calculated for a comprehensive index. In this method, there are two

steps: the first step is to develop the single indicator's weight, called weight 1, and the second step is to develop weights among the indicators, called weight 2.

Weight 1: Initial position relative to the threshold per indicator

For each indicator, the corresponding weight is set as the ratio between the initial value and threshold as expressed in (4). For goods, the smaller the y_j^0 , the larger the weight. For bads, the larger the y_j^0 , the larger the weight .

$$\hat{\pi}_j = \begin{cases} \frac{t_j}{y_j^0}, & \text{if } j \in G \\ \frac{y_j^0}{t_j}, & \text{if } j \in B \end{cases} \quad (4)$$

Where j refers to a particular indicator; G is the set of good indicators; B is the set of bad indicators.

Weight 2: Relative progress among indicators

The second step is to normalize (or re-weight) the $\hat{\pi}_j$ to obtain the weight 2 (π_j), which determines the relative progress in one indicator vis-à-vis the others. Normalized weights are then defined by the following formula 5. This re-weight is used to aggregate the index following formula 6:

$$\pi_j = \frac{\hat{\pi}_j}{\sum_{j \in J} \hat{\pi}_j}, \quad \sum_{j \in J} \pi_j = 1 \quad (5)$$

$$GIPro = \sum_{j \in G} \pi_j \frac{dy_j}{dy_j^*} + \sum_{j \in B} \pi_j \frac{d(-y_j)}{d(-y_j^*)} \quad (6)$$

4. A simple example to illustrate the calculation of GIPro index

Two indicators, GIVA (a good) and ENERGY (a bad) for one province, are calculated below to illustrate the estimation process for the GIPro index. Tianjin province data are shown in columns 2 and 3 of Table 3.

4.1 The target and threshold for GIVA (goods):

Based on the 2006 (initial) and 2015 (final) year values, the change between the 2006 and 2015 values of GIVA is shown in the fourth column of Table 3 and the change for Tianjin is the difference $58.89 - 68.84 = -9.95$. The ch ratio (change ratio), the final (y^1) value divided by the initial value y^0 , is shown in the fifth column as the ch ratio for Tianjin = $58.89/68.84 = 0.85$.

The target ch_ratio (λ) is the 90th percentile of the ch_ratio distribution, which is 1.20.

The threshold t is the 25th percentile of the initial distribution, which is 56.64.

Therefore, the GIVA target y^* for Tianjin based on equation (2) is $\max(56.64, 1.20 \times 68.84) = 82.71$.

$$y^* = \max\{t, \lambda y^0\}, \lambda > 1 \quad (\text{goods})$$

The progress for each indicator, based on equation (3), is shown in the last column. GIVA progress for Tianjin (negative progress) = $(58.89 - 68.84) / (82.71 - 68.84) = -0.72$.

$$\text{Progress} = \frac{dy}{dy^*} = \frac{y^1 - y^0}{\max\{t, \lambda y^0\} - y^0}, \quad \lambda > 1 \quad (3)$$

Table 3 GIVA and ENERGY calculations

Province	2006 (y^0)	2015 (y^1)	change ($y^1 - y^0$)	ch_ratio	target ch ratio (λ)	t	y^*	GIVA progress
Tianjin	68.84	58.89	-9.95	0.85	1.20	56.64	82.71	-0.72
Province	2006 (y^0)	2015 (y^1)	change ($y^0 - y^1$)	ch_ratio	target ch ratio (β)	t	y^*	ENERGY progress
Tianjin	0.45	0.38	0.07	0.85	0.43	1.08	0.19	0.26

4.2 The target and threshold for ENERGY (bads):

Based on the initial 2006 and final 2015 energy intensity values, there is a change value of 0.07 and a ch_ratio of 0.85 (Table 3). The target ch_ratio (β) is the 10th percentile of the ch_ratio distribution, which is 0.43. The threshold t is the 75th percentile of the initial distribution, which is 1.08. Therefore, the ENERGY target y^* for Tianjin based on equation (2) is $\min(1.08, 0.43 \times 0.45) = 0.19$.

$$y^* = \min\{t, \beta y^0\}, \beta < 1 \quad (\text{bads}) \quad (2)$$

The ENERGY progress for Tianjin province based on equation (3) is $(0.45 - 0.38) / (0.45 - 0.26) = 0.26$.

$$\text{Progress} = \frac{d(-y)}{d(-y^*)} = \frac{y^0 - y^1}{y^0 - \min\{t, \beta y^0\}}, \quad \beta < 1 \quad (3)$$

4.3 Weight system for the composite index

Weight 1 ($\hat{\pi}$)

The first step is to set the initial weight ($\hat{\pi}$) for each indicator between the initial 2006 value and the threshold as equation (4).

For goods, weight 1 ($\hat{\pi}$) is set as the ratio of the threshold to the initial value; the corresponding results are shown in the 3rd column of Table 4. Using the GIVA of Tianjin as an example, the GIVA Weight 1 (Tianjin) = $56.64 / 68.84 = 0.82$.

$$\hat{\pi}_j = \frac{t_j}{y_j^0}, \text{ if } j \in G \quad (4)$$

For bads, weight 1 ($\hat{\pi}$) is set as the ratio of the initial value to threshold, the corresponding results are shown in the 6th column of Table 4. Using the ENERGY of Tianjin as an example, the ENERGY Weight 1 (Tianjin) = 0.45/1.08 = 0.42

$$\hat{\pi}_j = \frac{y_j^0}{t_j}, \text{ if } j \in B \quad (4)$$

Table 4 Progress and weights for GIVA and ENERGY

Provinces	GIVA progress	GIVA weight 1	GIVA weight 2	ENERGY progress	ENERGY weight 1	ENERGY weight 2
Tianjin	-0.72	0.82	0.23	0.26	0.42	0.12
Hebei	-0.31	0.85	0.17	0.45	1.03	0.20
Shanxi	1.06	0.96	0.16	0.08	1.60	0.26
Inner Mongolia	0.46	1.43	0.15	0.78	1.39	0.14
Liaoning	1.04	1.03	0.19	0.46	0.64	0.12
Jilin	-0.25	0.84	0.11	1.30	0.70	0.10
Jiangsu	-0.50	0.77	0.17	0.46	0.48	0.11
Zhejiang	-0.46	1.01	0.24	0.54	0.50	0.12
Anhui	0.10	0.80	0.14	0.95	0.86	0.15
Fujian	-0.12	0.72	0.18	0.58	0.52	0.13
Jiangxi	-0.63	0.82	0.15	0.70	0.62	0.11
Shandong	-0.21	0.81	0.21	0.08	0.45	0.12
Henan	-1.51	0.75	0.18	0.70	0.75	0.17
Guangdong	0.03	0.72	0.20	0.47	0.15	0.04
Sichuan	0.10	0.85	0.13	1.13	0.92	0.14
Shaanxi	-0.49	0.72	0.16	0.33	0.53	0.12
Qinghai	-0.63	1.36	0.04	0.31	1.94	0.05
Ningxia	0.00	1.19	0.09	0.77	2.62	0.20

Weight 2 (π)

The second step is to re-weigh the initial weight to obtain weight 2 (π), which reflects the relative progress among indicators, by equation (5).

$$\pi_j = \frac{\hat{\pi}_j}{\sum_{j \in J} \hat{\pi}_j}, \quad \sum_{j \in J} \pi_j = 1 \quad (5)$$

GIVA weight 2 for Tianjin = GIVA weight 1 / (GIVA weight 1 + GEMP weight 1 + ENERGY weight 1 + HWASTE weight 1 + COD weight 1 + SO₂ weight 1)

So GIVA weight 2 for Tianjin = 0.82 / (0.82+0.83+0.42+0.49+0.61+0.18+0.27) = 0.23.

Similarly, ENERGY weight 2 for Tianjin =
 $0.417 / (0.823 + 0.827 + 0.417 + 0.485 + 0.612 + 0.183 + 0.274) = 0.115$.

The calculation of weight 2 estimates for all indicators and provinces is shown in Annex Table 1.

4.4 GIPro index

Based on the analysis above, the composite GIPro index is obtained by equation (6).

$$GIPro = \sum_{j \in G} \pi_j \frac{dy_j}{dy_j^*} + \sum_{j \in B} \pi_j \frac{d(-y_j)}{d(-y_j^*)} \quad (6)$$

Using Tianjin as an example:

$$\begin{aligned} & \text{GIPro (Tianjin)} \\ &= (\text{GIVA progress} * \text{GIVA weight 2}) + (\text{GEMP progress} * \text{GEMP weight 2}) + (\text{ENERGY} \\ & \text{progress} * \text{ENERGY weight 2}) + (\text{HWASTE progress} * \text{HWASTE weight 2}) + (\text{COD} \\ & \text{progress} * \text{COD weight 2}) + (\text{SO}_2 \text{ progress} * \text{SO}_2 \text{ weight 2}). \\ &= 0.23 * (-0.72) + 0.29 * (-0.04) + 0.12 * 0.26 + 0.13 * 0.80 + 0.17 * 2.35 + 0.05 * 0.79 + 0.08 * 0.97 \\ &= 0.48. \end{aligned}$$

5. GIPro Index for 18 Chinese provinces: Phase Two

5.1 18 provinces

There are 31 provinces in mainland China that are at different stages of industrialization (Annex Table 2). The calculation of the GIPro index is limited to the provinces where the average IVA (Industry Value Added) during the period 2006 to 2015 is more than 40% of GDP. Under this criterion, 20 provinces remain in the dataset. Two provinces, Chongqing and Heilongjiang, are excluded from the analysis because the percentage of IVA decreased continually from 2006 to 2015 and the rate will probably continue decreasing in the future. Hubei province is excluded because of insufficient data. Ningxia province, with an average percentage of only 38% of IVA in GDP, is included because of the high percentage of energy intensive industry in IVA. Consequently, the dataset includes 18 provinces — Anhui, Fujian, Guangdong, Henan, Hebei, Inner Mongolia, Jiangsu, Jiangxi, Jilin, Liaoning, Ningxia, Qinghai, Shaanxi, Shandong, Shanxi, Sichuan, Tianjin, and Zhejiang.

5.2 Indicator Selection

This report includes seven indicators that address the three dimensions of sustainable development. The economic indicator is GIVA. The social indicator is GEMP. The

environmental indicators are a combination of resource use indicators (ENERGY and WATER) and pollution indicators (COD, HWASTE and SO₂).

5.3 Time

This report uses data for the 18 provinces for the period of 2006 to 2015.

5.4 Data description

This report takes data from several Chinese sources that are listed in Table 5

Table 5 Data description of the indicators

Indicator	Description	Unit	Data Source
GIVA	Industry Value Added of Less energy intensive sectors ² as a percentage of total Industry Value Added	Percentage	National Bureau of Statistics (NBS); Provincial/Municipal statistics authority
GEMP	The number of employees in less energy intensive sectors as a percentage of total industrial employees	Percentage	Provincial/Municipal statistics authority
ENERGY	Industrial Energy Consumption Intensity	Ton of oil equivalent (TOE)/1000 USD	Provincial/Municipal statistics authority
WATER	Industrial Water Withdrawal Intensity	m ³ /1000USD	National/Provincial Water Resources authorities
COD	Industrial Chemical Oxygen Demand Effluent Intensity	kg/1000USD	National/Provincial Environmental Protection authorities
SO ₂	Industrial Sulphur Dioxide Emission Intensity	kg/1000USD	National/Provincial Environmental Protection authorities

² The less energy intensive sectors are all industry sectors excluding the six high energy intensive sectors, classified as such in the "2010 National Economic and Social Development Statistics Report". These six are chemical raw materials and chemical products manufacturing; non-metallic mineral products industry; ferrous metal smelting and rolling processing industry; non-ferrous metal smelting and rolling processing industry; petroleum processing coking and nuclear fuel processing industry; and electricity and heat production and supply industry.

HWASTE ³	Industrial Hazardous Waste Generation Intensity	kg/1000USD	National/Provincial Environmental Protection authorities
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6. Individual and collective indicator progress⁴

This section presents the results of green industrialization progress for each indicator and collectively for all indicators. Progress on a single indicator is compared across provinces by simply comparing the progress values of one province with another, keeping in mind that different provinces may have a different target, which means that the index compares relative realization against the common aspects given by the 18-province threshold.

6.1. Progress on GIVA

Figure 1 and Annex Table 3 show the following findings for the GIVA indicator:

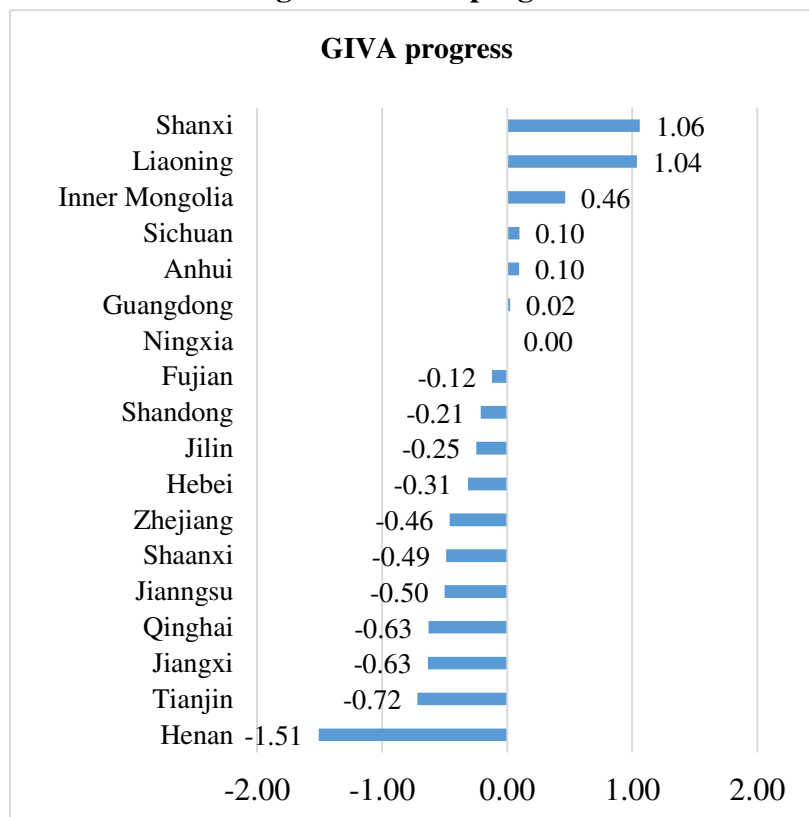
- (1) Among the 18 provinces, Shanxi performs best over the period 2006 to 2015.
- (2) The GIVA progress of two provinces (Shanxi and Liaoning) is greater than 1 (1.06, 1.04), which means that the progress of these two provinces exceeds their target values.
- (3) The GIVA indicators of seven provinces are positive or zero (Shanxi, Liaoning, Inner Mongolia, Sichuan, Anhui, Guangdong and Ningxia), which means these provinces progressed or stayed the same in greening their industrial output. The GIVA indicator is negative for the other 11 provinces, which shows that their performance deteriorated over the period 2006-2015.

³ ENERGY, WATER, HWASTE, COD, and SO₂ are all intensity measures in their respective units divided by IVA.

⁴There are no target values greater than one in the Phase One report because the number of provinces included is less than 10. The target progress value for more than 10 provinces, 18 in Phase Two, is formulated by multiplying its initial value of the λ of the 10 per cent best performing countries. For a "good", λ represents the ratio between the final (y_1) and initial (y_0) values for each indicator for the 90th percentile of the distribution. In this case, some provinces could progress more than the target value. However, when the number of the provinces is less than or equal to 10, then the target value (90th percentile) would be the largest one. No province's actual progress ratio would be larger than the target.

(4) The average progress of the 18 provinces on the GIVA indicator is negative (-0.17). This result indicates that collectively the 18 provinces have not progressed in shifting their industrial structure away from energy intensive sectors. Possible explanations for the limited progress are the need for better integration of capital-intensive manufacturing with the productive service sector in Eastern China and greater internal optimization of the industrial sector in other regions, especially in Western China (Fu et. al., 2018).

Figure 1. GIVA progress



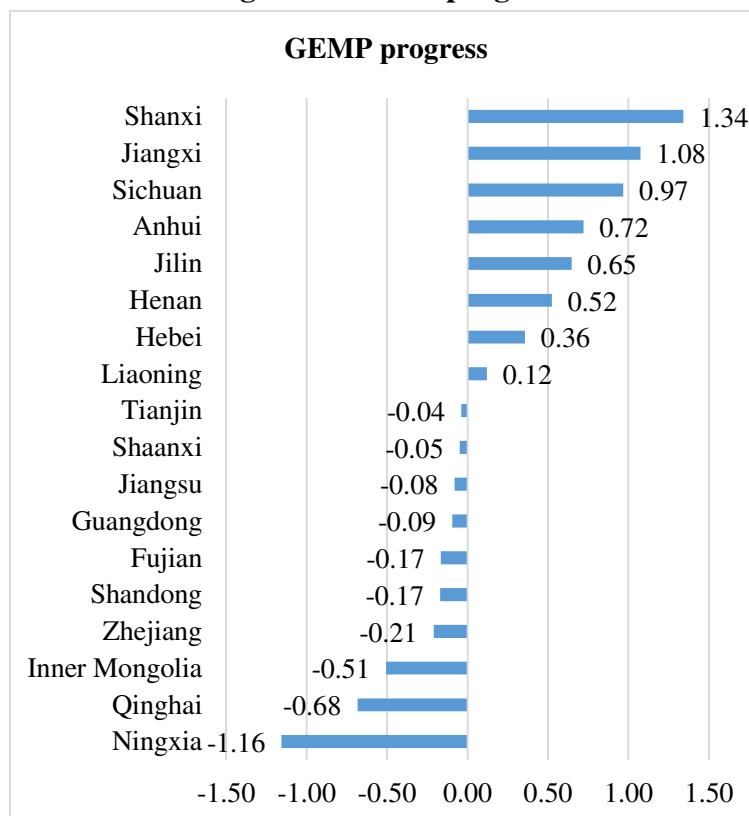
6.2. Progress on GEMP

Figure 2 and Annex Table 4 show the following findings for the GEMP indicator:

- (1) Shanxi performs best among the 18 provinces.
- (2) The progress of two provinces (Shanxi and Jiangxi) is greater than 1, which means that the progress of these two provinces exceeds their target values.
- (3) The GEMP indicator for eight provinces (Shanxi, Jiangxi, Sichuan, Anhui, Jilin, Henan, Hebei and Liaoning) are positive, which means that these provinces increased green employment over the period 2006 to 2015. In contrast, the progress of 10 provinces for the indicator is negative, which means that their performance deteriorated over the period.

- (4) The average progress of the 18 provinces on the GEMP indicator is slightly positive, 0.14.

Figure 2. GEMP progress

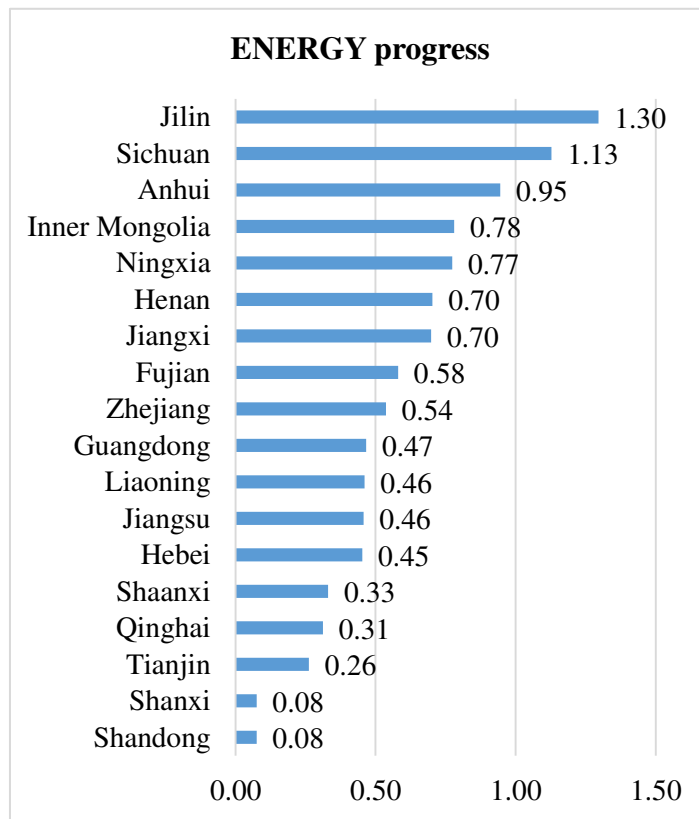


6.3. Progress on ENERGY

Figure 3 and Annex Table 5 show the following findings for the ENERGY indicator:

- (1) Jilin performs best among the 18 provinces.
- (2) The progress of two provinces (Jilin and Sichuan) is greater than 1, which means that the progress of these two provinces exceeds their target values.
- (3) All provinces perform positively on the ENERGY indicator, which means that all 18 provinces reduced their energy intensity over the period 2006 to 2015.
- (4) The average progress of the 18 provinces on the ENERGY indicator is 0.57.

Figure 3. ENERGY progress

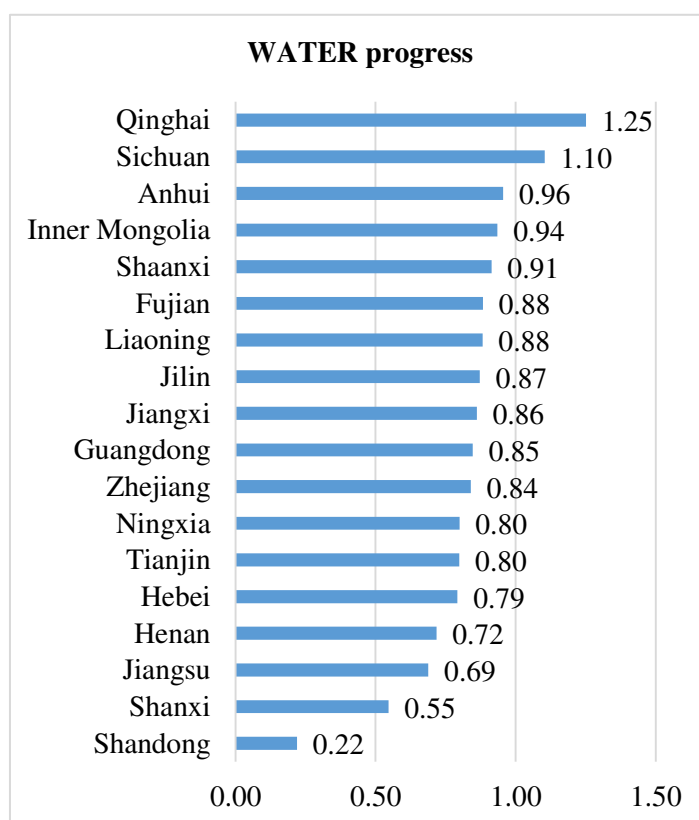


6.4. Progress on WATER

Figure 4 and Annex Table 6 show the findings for the WATER indicator:

- (1) Qinghai performs best among the 18 provinces.
- (2) The progress of Qinghai and Sichuan provinces is greater than 1, which means that the progress of these two provinces exceeds their target values.
- (3) All provinces perform positively on the WATER indicator, which means all 18 provinces reduced their water intensity over the period 2006 to 2015.
- (4) The average progress of the 18 provinces on the WATER indicator is 0.83.

Figure 4. WATER progress



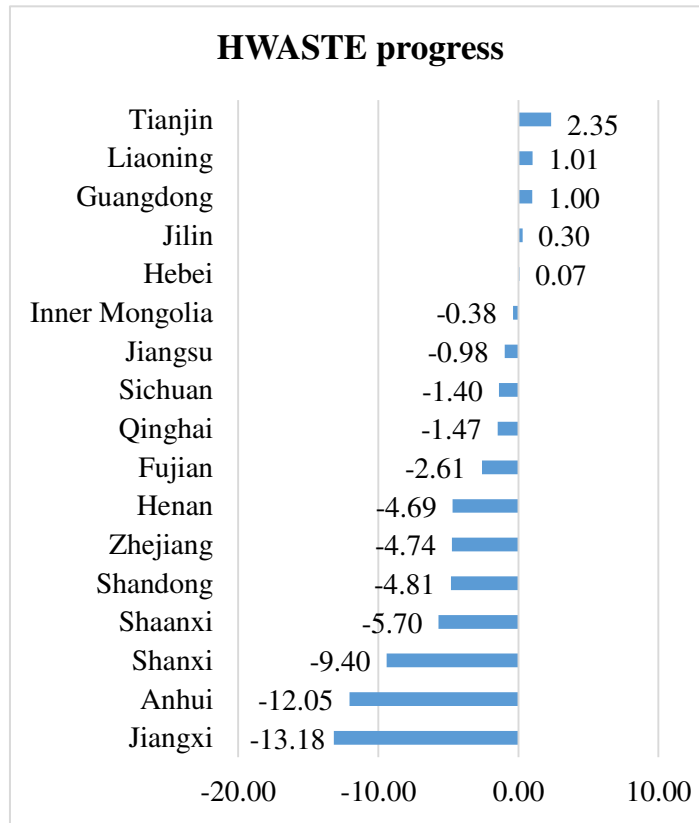
6.5. Progress on HWASTE

Figure 5 and Annex Table 7 show the findings for the HWASTE indicator:

- (1) Tianjin performs best among the 18 provinces.
- (2) The progress of two provinces, Tianjin and Liaoning, is greater than 1, which means they exceed their target values.
- (3) There are five provinces (Tianjin, Liaoning, Guangdong, Jilin and Hebei) where HWASTE indicators are positive, which means hazardous waste intensity decreased over the period 2006 to 2015. The progress of the other 13 provinces is negative over the period.
- (4) Among the 18 provinces, Ningxia has the worst performance with a value of -316.48, based on official statistics. The HWASTE intensity of Ningxia in 2015 is not much different from other provinces, but its intensity in 2006 is questionably low, which results in negative progress.⁵
- (5) The average progress of all the 18 provinces on the HWASTE indicator is negative (-20.73).

⁵ The final impact of negative progress for HWASTE on the overall province performance (GIPro index) is limited precisely because of Ningxia's favorable initial condition (Low initial intensity in 2006).

Figure 5. HWASTE progress⁶



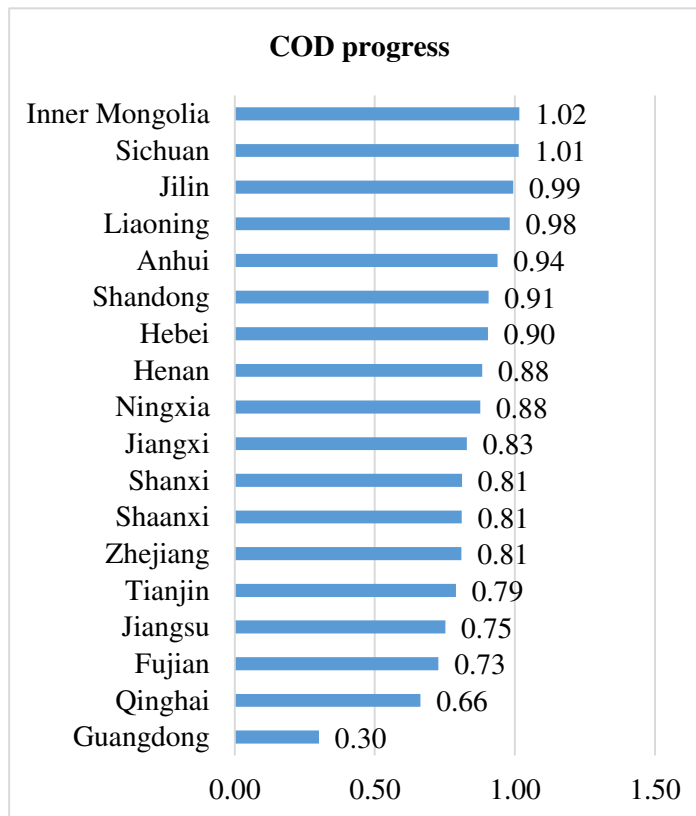
6.6. Progress on COD

Figure 6 and Annex Table 8 show the findings for the COD indicator:

- (1) Inner Mongolia performs best among the 18 provinces.
- (2) The progress of two provinces, Inner Mongolia and Sichuan, is greater than 1, which means that the progress of these two provinces exceeds their target values.
- (3) All provinces perform positively on COD, which means that for all 18 provinces COD intensity decreased over the period 2006 to 2015.
- (4) The average progress of the 18 provinces on the COD indicator is 0.83, which is better than all other indicators except SO₂.

⁶ The progress value for the Ningxia province (-316.481) is excluded because it distorts the figure. However, it is included in the annex Table 7.

Figure 6. COD progress

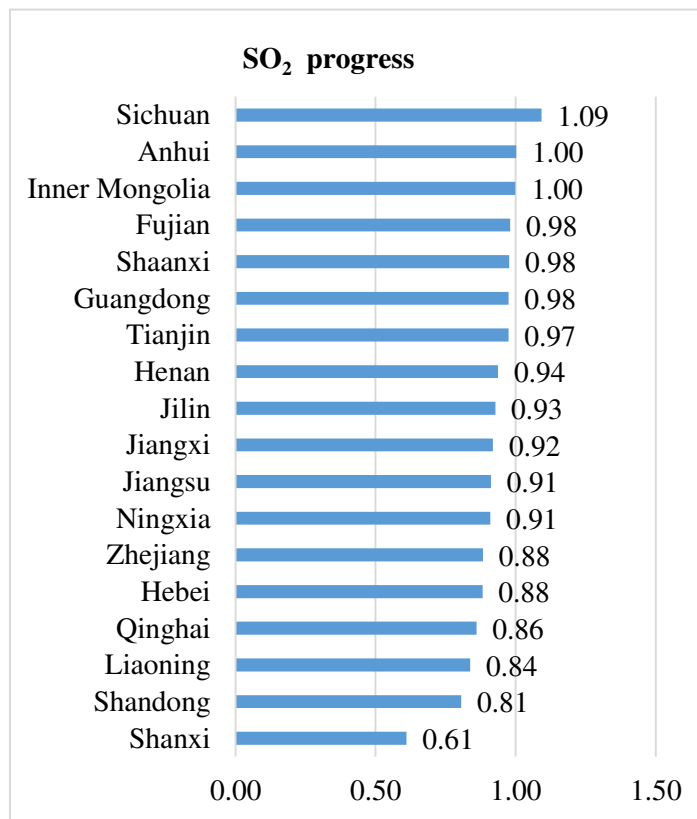


6.7. Progress on SO₂

Figure 7 and Annex Table 9 show the findings for the SO₂ indicator:

- (1) Sichuan performs best among the 18 provinces.
- (2) The progress of two provinces (Sichuan and Anhui) is greater than 1, which means that the progress of these two provinces exceeds the target value.
- (3) All provinces performed positively on SO₂, which means that SO₂ intensity decreased over the period 2006 to 2015.
- (4) The average progress of the 18 provinces on indicator SO₂ is 0.92.

Figure 7. SO₂ progress



6.8. Result of GIPro Index

Figure 8 shows the GIPro index results for the 18 provinces:

- (1) Liaoning progresses the most among the 18 provinces.
- (2) Thirteen provinces have positive GIPro values. The other five provinces (namely Jiangxi, Shaanxi, Zhejiang, Qinghai and Shandong) have negative GIPro values.

Figure 9 is a mapping of the GIPro index findings. The darker the green area, the higher the progress on green industrialization.

Figure 8. GIPro index

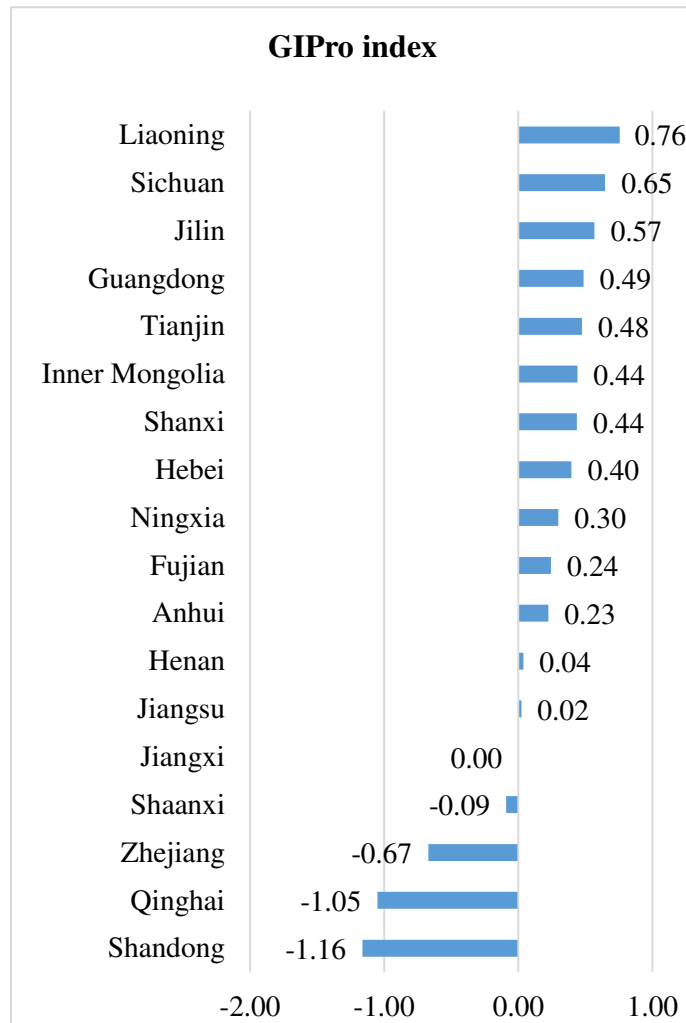


Figure 9. Map of Green Industry Progress (GIPro)



Map based on Longitude (generated) and Latitude (generated). Color shows sum of Rank. The marks are labeled by Provinces. Details are shown for Country..



Source: figure created by the author based on GIPro index value

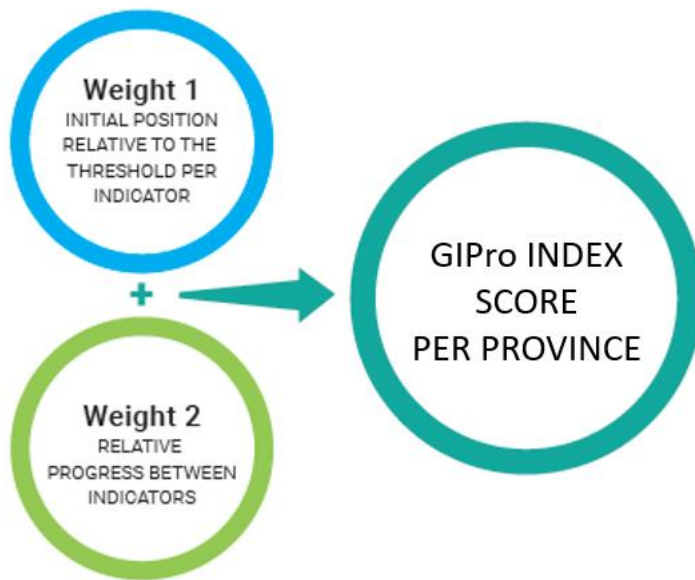
7. GIPro methodology for identifying policy priorities

This section describes how the indicators chosen for the GIPro index can be used to assign priorities to policy recommendations. The weighting system of the methodology is used as a normative guideline to craft policy recommendations. However, the higher ranking of a province does not mean that it has made progress in terms of green industrialization but rather that other provinces/cities made less progress in green industrialization during the given period. A positive index value indicates progress and a negative value indicates regress (negative progress).

As described in section 4.3, GIPro methodology adopts a double weighting system (figure 10) where weight 1 is the ratio between the threshold and the initial level of the seven indicators. This formulation assigns a greater weight to those indicators in which provinces are in a disadvantaged position in the initial year with respect to the threshold. The higher the weight, the more disadvantaged the initial position of a particular province is with respect to the threshold. For example, the weight 1 of Tianjin for hazardous waste (0.612) is much higher than the weight 1 of Ningxia (0.013) for the same indicator. In other words, Tianjin is further away from the hazardous waste threshold than Ningxia (Box 1). Therefore, progress on reducing hazardous waste is a more important policy priority for the province of Tianjin than for Ningxia.

The normalized weight 2 is computed by dividing each weight 1 by the sum of all the weight 1s within the province (sum of all weights equal to 1). This re-weight reflects the relative importance of one indicator over the others. In addition, it enables a comparison of the results across provinces and across indicators within provinces. It can be interpreted that a higher normalized weight of an indicator for a province means that particular indicator needs to get priority in policy implementation. In other words, this weight is providing information to provinces about where to put priorities and whether the progress is happening in the area where it is needed most. Box 1 illustrates how the weighting system informs two provinces about policy priorities for two parameters.

Figure 10. The weighting system in GIPro Index



Source: (PAGE, 2017b).

Box 1 How weighting mechanism of GIPro leads policy formulation

Table a. Weight 1 and weight 2 for the provinces Tianjin and Ningxia

	Tianjin		Ningxia	
	HWASTE	COD	HWASTE	COD
Weight 1	0.612	0.183	0.013	4.216
Weight 2	0.169	0.051	0.001	0.327

A double Weighting System is used to determine:

Weight 1: initial year position of province relative to the 18-province threshold as it can be seen in the following table b.

Weight 2: relative importance of one indicator with respect to others in a given province

Table b. Initial year and threshold value for the provinces Tianjin and Ningxia

	Tianjin		Ningxia	
	HWASTE	COD	HWASTE	COD
Initial year	3.47	0.88	0.07	20.18
Threshold	5.68	4.79	5.68	4.79

To understand the power of the double weighting system, let us look at the weights used for Tianjin and Ningxia Provinces between 2006 and 2015. These weights are part of the unique equation used to calculate progress on the GIPro index indicators for each province. Weight 1 is positive for both provinces, which tells us that they are on the “wrong” side of the threshold for HWASTE and COD and progress could be made by moving towards the “right” side (reducing HWASTE and COD)⁷. A higher weight for Tianjin than Ningxia for HWASTE means that any reduction in HWASTE that Tianjin is able to make, will count as greater progress than a reduction made by Ningxia.

Expanding on the inter-province analysis of Weight 1, Weight 2 takes into consideration the relative importance of progress among indicators for each province – intra-province analysis. In this case, Ningxia experiences greater problems with COD than HWASTE (indicated by a higher weight, 0.327, compared to 0.001), indicating that for Ningxia, progress on COD is of greater priority than progress on HWASTE. Whereas progress on HWASTE is of higher relative priority for Tianjin (0.169), progress on COD is of higher relative priority for Ningxia (0.327).

These weights are important components of the unique GIPro Index methodology for multidimensional comparison. They allow provincial governments to compare progress on green industry indicators with that of their counterparts, as well as establish policies based on areas of highest concern.

8. Policy recommendations for the 18 provinces

In section 8, we present how the weighting mechanism of GIPro addresses policy relevance and helps in setting policy priorities. With this technique we are able to display the overall picture of advancement made by each province and compare the efforts of provinces across indicators and across provinces for each indicator. It allows us to determine if progress is occurring in the areas where it is most needed. The normalized weight (weight 2) takes into consideration the relative importance of progress among indicators for each province – intra-province analysis. The higher the weight of an indicator means that a province experiences a greater problem with that indicator. In other words, policymakers need to set priorities on the indicators that have a higher weight. This section draws policy recommendations based on the top three priority indicators selected according to the relative value of normalized weights which are listed in Table 6.

Table 6 Top three policy priorities for each province

Provinces	GIVA	GEMP	ENERGY	WATER	HWASTE	COD	SO2	Top three priority indicators
Liaoning	0.192	0.178	0.120	0.053	0.195	0.134	0.128	HWASTE, GEMP, GIVA
Sichuan	0.127	0.149	0.138	0.165	0.117	0.161	0.143	WATER, COD, GEMP
Jilin	0.114	0.122	0.095	0.076	0.366	0.154	0.073	HWASTE, COD, GEMP
Guangdong	0.197	0.202	0.041	0.145	0.269	0.072	0.073	HWASTE, GEMP, GIVA
Tianjin	0.227	0.228	0.115	0.134	0.169	0.051	0.076	GEMP, GIVA, HWASTE
Inner Mongolia	0.146	0.112	0.143	0.041	0.203	0.169	0.187	HWASTE, COD, SO ₂
Shanxi	0.158	0.171	0.263	0.050	0.025	0.126	0.208	ENERGY, SO ₂ , GEMP
Hebei	0.168	0.204	0.202	0.046	0.109	0.144	0.127	GEMP, ENERGY, GIVA
Ningxia	0.092	0.078	0.204	0.046	0.001	0.327	0.252	COD, SO ₂ , ENERGY
Fujian	0.18	0.198	0.131	0.255	0.059	0.083	0.093	WATER, GEMP, GIVA

Anhui	0.137	0.147	0.148	0.297	0.045	0.122	0.104	WATER, ENERGY, GEMP
Henan	0.175	0.216	0.174	0.091	0.056	0.138	0.151	GEMP, GIVA, ENERGY
Jiangsu	0.173	0.178	0.109	0.218	0.189	0.066	0.067	WATER, HWASTE, GEMP
Jiangxi	0.150	0.183	0.113	0.237	0.047	0.125	0.146	WATER, GEMP, GIVA
Shaanxi	0.159	0.196	0.116	0.068	0.079	0.159	0.224	SO2, GEMP, COD
Zhejiang	0.241	0.176	0.118	0.062	0.175	0.135	0.093	GIVA, GEMP, HWASTE
Qinghai	0.038	0.036	0.054	0.036	0.759	0.042	0.034	HWASTE, ENERGY, COD
Shandong	0.209	0.202	0.116	0.021	0.262	0.086	0.103	HWASTE, GIVA, GEMP

1. Liaoning needs to focus on hazardous waste management (0.195) and shifting to green industry value added (0.192) and green industrial employment (0.178) compared to other indicators because of the higher indicator weights. Water management in industry is the least important policy concern because the indicator weight is quite low.
2. Sichuan needs to focus on water use, chemical oxygen demand and shifting to green industrial employment compared to other environmental concerns. While the province needs to pay greater attention to these three indicators, it should not neglect the other indicators that are important for green industrialization.
3. Jilin needs to focus on hazardous waste management, chemical oxygen demand and shifting to green industrial employment compared to other environmental problems. It needs to prioritize hazardous waste management more than the other two environmental concerns because the weight for this indicator is much higher than for the other two indicators.
4. Guangdong needs to focus on hazardous waste management and on shifting to green industry value added and green industrial employment. Among these three

environmental concerns, the greatest emphasis should be on hazardous waste management.

5. Inner Mongolia needs to focus on hazardous waste management, sulphur dioxide and chemical oxygen demand. The weight for hazardous waste is higher than for the other two, which means the province needs to prioritize the management of this to enhance its overall green industrialization progress.
6. Tianjin needs to focus on shifting to green industrial employment, green industry value added and hazardous waste management.
7. Shanxi needs to focus on energy management. In addition, reducing sulphur dioxide and shifting to green employment are seen as more significant than other environmental concerns.
8. Hebei needs to focus primarily on shifting to green industrial employment and energy use and secondly on shifting to green industry value added.
9. Ningxia needs to focus primarily on reducing chemical oxygen and sulphur dioxide demand and secondly on energy management. For this province, improving hazardous waste management is of lesser importance.
10. Fujian needs to focus on water use and shifting to green employment and green value added. Improving the management of these three parameters is important for green industrialization.
11. Anhui needs to focus on water and energy use and shifting to green industrial employment.
12. Henan needs to focus on shifting to green industrial employment and green industry value added and energy use. Improving the management of these three concerns would improve its GIPro ranking.
13. Jiangsu needs to focus on water use, hazardous waste management and shifting to green industrial employment.
14. Jiangxi needs to focus on water use, shifting to green industrial employment and green industry value added. It needs to improve its performance in these three aspects of greening to improve its ranking.

15. Shaanxi needs to first focus on reducing sulphur dioxide emissions and shifting to green industrial employment and secondarily on reducing chemical oxygen demand and shifting to green industry value added.
16. Zhejiang needs to focus on shifting to green industry value added. Lesser policy priorities are shifting to green industrial employment and hazardous waste management.
17. Qinghai needs to focus on hazardous waste management. Progress on hazardous waste management is most important because its indicator alone has a weight of 0.750, whereas the second highest weight is for energy intensity (0.054), which is 13 times lower than for hazardous waste intensity.
18. Shandong needs to focus on hazardous waste management and shifting to green industry value added and green industrial employment.

9. Sensitivity tests

9.1. Sensitivity tests

We also investigate how the green ranking of provinces changes with alternative formulations. One test is the reduction of the number of indicators in the GIPRO index, using only the five environmental indicators. The second test is the modification of the target change ratio distribution. The third test is the calculation of a performance index. We used identical data and the same time period for all three tests.

9.2. Composite GIPRO index with only five environmental indicators

We construct an alternative GIPRO index by deleting the GIVA and GEMP variables to show the impact of including only the five resource use and pollution parameters on the progress ranking of the 18 provinces (Annex Table 10). The ranking of the top three provinces changes slightly. Liaoning drops from one to two and Guangdong moves up from four to three. The province Sichuan drops from ranking two to four and Jilin follows a similar path from ranking three to five. In the new ranking Tianjin moves up from five to one; a possible explanation is that Tianjin experiences regress on the GIVA and GEMP indicators. The finding suggests that GIVA and GEMP are major determinants for greening the industries in Tianjin province. The three lowest ranked provinces with the five parameters retain the same ranking with the seven parameters. Interestingly, the top fourteen provinces show a progress and the lowest four shows a regress with both five and seven indicators.

9.3. Modification of the target change ratio distribution

We construct a second alternative GIPro index with the same set of variables but modify the target change ratio (λ) for goods from the 90th percentile to the 80th percentile of the ch_ratio distribution. And for bads, the target ch_ratio (β) is modified from the 10th percentile to the 20th percentile of the ch_ratio distribution. The ranking of the top three provinces changes slightly (Annex Table 11). Liaoning ranks first using the new index with a score of 2.08, which is much greater than the 90th percentile score of 0.76 (Annex Table 11).

Sichuan and Jilin drop in similar fashion from two to four and from three to six respectively and Guangdong moves up from four to three. The surprising aspect of the modified index is in the greening status of Tianjin province. Its status changes from progress to significant regress and its ranking drops from five to eleven. The reason for this is not clear but it may be associated with the modification of the percentile distribution, which means Tianjin makes negative progress based on the target set by 20 percent of the best performing provinces. Qinghai province moves up from seventeen to thirteen whereas Shandong retains the same ranking.

9.4. Green Industry Performance Index (GIPer)

We calculate a Green Industry Performance (GIPer) index to test the robustness of the GIPro findings for the 18 provinces. The GIPer index, a non-linear aggregation similar to the Human Development Index and Competitive Industrial Performance, is calculated as the weighted geometric average of the seven indicators. Footnote seven below summarizes the GIPer methodology and the paper titled “Green Industry Progress (GIPro) and Green Industry Performance (GIPer) Index: A Comparative Analysis” describes in considerable detail the findings summarized in the next paragraph⁷.

⁷ With the GIPer methodology, each of the seven I_{ij} indicators is normalized into the range [0, 1], with higher scores representing better outcomes. Normalization is carried out by the ‘min-max’ method, where the minimum and maximum values of each indicator sample values are estimated by following the equation: (1).

$$I_{ijt} = \frac{X_{ijt} - \min_j X_{ijt}}{\max_j X_{ijt} - \min_j X_{ijt}} \quad (1)$$

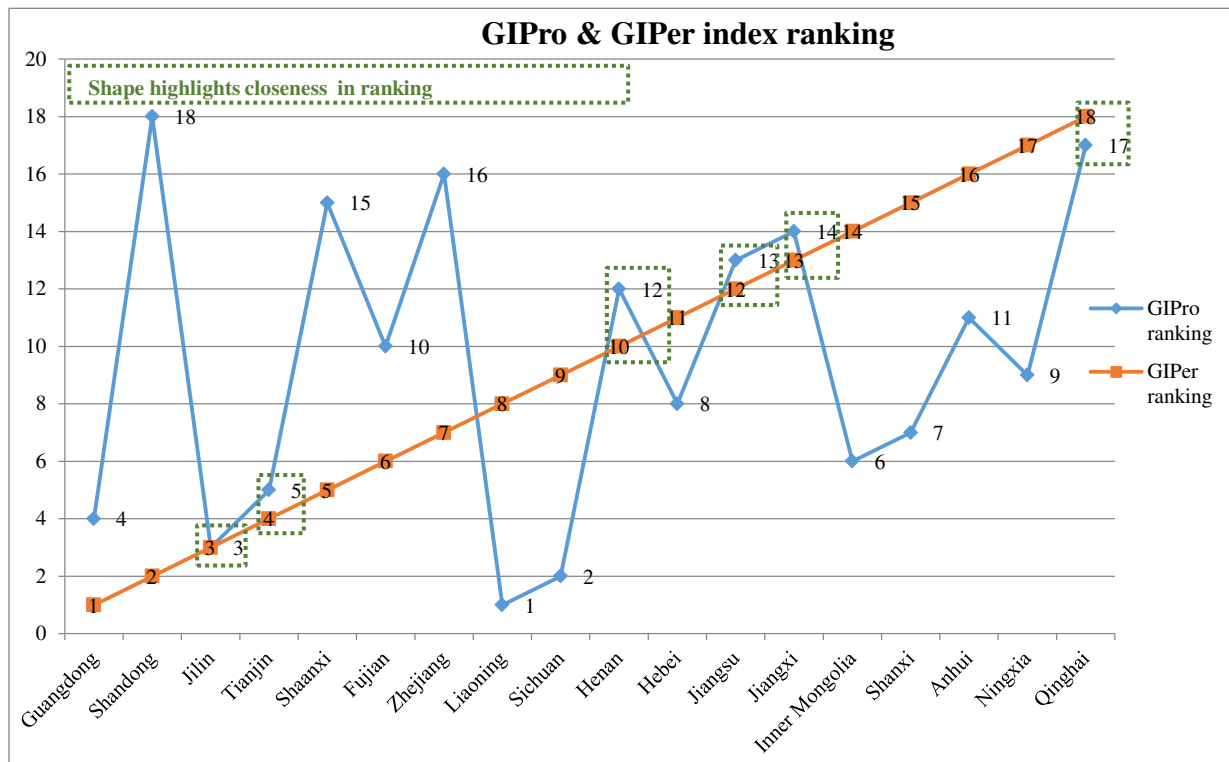
Geometric aggregation is chosen as the aggregation method. Using this method, the GIPer Index is constructed as a weighted geometric average of the q indicators, using equal weights for each of the indicators and each province. The following equation is used

$$\text{GIPer}_{jt} = (\prod_{i=1}^q I_{ijt})^{1/q} \quad (2)$$

With the GIPer_{it} values in the range [0,1] (UNIDO, 2017).

The ranking of Jilin province is the same with both indexes, but the rankings of the other seventeen provinces differ between the two methodologies. On the one hand, the GIPer rankings of six provinces (Jilin, Tianjin, Henan, Jiangsu, Jiangxi, and Qinghai) are quite close to the GIPro ranking as shown in Figure 11. On the other hand, the rankings of eight provinces (Shandong, Shaanxi, Zhejiang, Liaoning, Sichuan, Inner Mongolia, Shanxi, and Ningxia) differ significantly.

Figure 11. Major similarities in GIPro & GIPer index ranking



10. Conclusion

The GIPro index highlights critical aspects of the green industrial development challenges that policymakers must address in a coordinated manner in order to ensure a transition to a green economy. It addresses these challenges by providing information on where provinces stand in terms of green industrialization and what the achievable policy priorities are in order to bridge the gaps between targets and current status. The index shows that 14 out of 18 provinces achieved overall progress between 2006 and 2015 in

their transition towards green industrialization. When considering indicators on an individual basis, on average, progress is found to be most significant in reducing energy intensity, water intensity, chemical oxygen demand intensity and sulphur dioxide intensity in the 18 provinces. However, on average, provinces did not progress as much in areas of green industry value added, green industrial employment, and hazardous waste intensity. Many provinces even experienced regress for those indicators. The progress on each indicator identifies the impact of each indicator on a province's overall ranking among the 18 provinces. Finally, this report offers policy recommendations to government for consideration, pinpointing the indicator or indicators for each province that it needs to improve to enhance its overall green industrialization progress.

11. References

- Fu, J. Xiao, G. Guo, G. Wu, C. (2018). Measuring the Dynamic Efficiency of Regional Industrial Green Transformation in China. *Sustainability* 10.628.
- Ministry of Industry and Information Technology. (2016). Industrial Green Development Plan (2016-2020), China. Retrieved from <http://www.un-page.org/china%E2%80%99s-industrial-green-development-plan-issued-miit>
- National Bureau of Statistics of China. (2015). *China Statistical Yearbook-2015*. Retrieved from <http://www.stats.gov.cn/tjsj/ndsj/2015/indexeh.htm>
- OECD. (2008). Handbook on Constructing Composite Indicators: Methodology and User Guide. Retrieved from <https://www.oecd.org/std/42495745.pdf>
- PAGE. (2016). Transition to a Green Economy in China—Jiangsu Province a Stocktaking Report. Retrieved from http://www.un-page.org/files/public/page_china_stocktakingreport_2016.pdf
- nv
- PAGE. (2017a). The Green Economy Progress Measurement Framework – Methodology. Retrieved from http://un-page.org/files/public/gep_methodology.pdf
- PAGE. (2017b). The Green Economy Progress Measurement Framework – Application. Retrieved from http://www.unpage.org/files/public/green_economy_progress_measurement_framework_application.pdf
- UNEP. (2015). Indicators for Green Economy Policymaking – A Synthesis Report of Studies in Ghana, Mauritius and Uruguay. Geneva: UN Environment. Retrieved from http://www.greengrowthknowledge.org/sites/default/files/downloads/resource/Indicators_for_Green_Economy_Policy_Making_A_Synthesis_Report_of_Studies_in_Ghana_Mauritius_and_Uruguay_UNEP.pdf
- UNDP. (2016). Human Development Report 2016, Human Development for Everyone, United Nations Development Programme: New York. Retrieved from http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf
- UNIDO. (2011). *UNIDO Green Industry*. Policies for supporting green industry. Retrieved from http://www.greenindustryplatform.org/?page_id=1092

UNIDO. (2014). *Competitive Industrial Performance Report 2014*. UNIDO. Retrieved from http://www.unido.or.jp/files/WP2014_12_CIPReport2014.pdf

UNIDO. (2017). *Competitive Industrial Performance Report 2016*. UNIDO. Retrieved from <https://stat.unido.org/admin/publicationPdf;jsessionid=2C4BFD2622AE49F06185A07210960224?CIP-2016-Volume-II-V5.pdf>

12. Annexes

Annex Table 1. Weights for parameters and 18 provinces

Provinces	GIVA weight 1	GIVA weight 2	GEMP weight 1	GEMP weight 2	ENERGY weight 1	ENERGY weight 2	WATER weight 1	WATER weight 2
Tianjin	0.82	0.23	0.83	0.23	0.42	0.12	0.49	0.13
Hebei	0.85	0.17	1.04	0.20	1.03	0.20	0.23	0.05
Shanxi	0.96	0.16	1.04	0.17	1.60	0.26	0.30	0.05
Inner Mongolia	1.43	0.15	1.09	0.11	1.39	0.14	0.40	0.04
Liaoning	1.03	0.19	0.96	0.18	0.64	0.12	0.29	0.05
Jilin	0.84	0.11	0.90	0.12	0.70	0.10	0.56	0.08
Jiangsu	0.77	0.17	0.79	0.18	0.48	0.11	0.97	0.22
Zhejiang	1.01	0.24	0.74	0.18	0.50	0.12	0.26	0.06
Anhui	0.80	0.14	0.86	0.15	0.86	0.15	1.73	0.30
Fujian	0.72	0.18	0.78	0.20	0.52	0.13	1.01	0.26
Jiangxi	0.82	0.15	1.00	0.18	0.62	0.11	1.30	0.24
Shandong	0.81	0.21	0.78	0.20	0.45	0.12	0.08	0.02
Henan	0.75	0.18	0.93	0.22	0.75	0.17	0.39	0.09
Guangdong	0.72	0.20	0.74	0.20	0.15	0.04	0.53	0.15
Sichuan	0.85	0.13	0.99	0.15	0.92	0.14	1.10	0.17
Shaanxi	0.72	0.16	0.89	0.20	0.53	0.12	0.31	0.07
Qinghai	1.36	0.04	1.29	0.04	1.94	0.05	1.29	0.04
Ningxia	1.19	0.09	1.00	0.08	2.62	0.20	0.59	0.05
Provinces	HWASTE weight 1	HWASTE weight 2	COD weight 1	COD weight 2	SO2 weight 1	SO2 weight 2		
Tianjin	0.61	0.17	0.18	0.05	0.27	0.08		
Hebei	0.55	0.11	0.73	0.14	0.65	0.13		
Shanxi	0.15	0.03	0.77	0.13	1.27	0.21		
Inner Mongolia	1.98	0.20	1.65	0.17	1.82	0.19		

Liaoning	1.05	0.20	0.72	0.13	0.69	0.13		
Jilin	2.70	0.37	1.14	0.15	0.54	0.07		
Jiangsu	0.84	0.19	0.30	0.07	0.30	0.07		
Zhejiang	0.74	0.18	0.57	0.14	0.39	0.09		
Anhui	0.26	0.05	0.71	0.12	0.61	0.10		
Fujian	0.23	0.06	0.33	0.08	0.37	0.09		
Jiangxi	0.26	0.05	0.68	0.13	0.80	0.15		
Shandong	1.01	0.26	0.33	0.09	0.40	0.10		
Henan	0.24	0.06	0.59	0.14	0.65	0.15		
Guangdong	0.98	0.27	0.26	0.07	0.27	0.07		
Sichuan	0.78	0.12	1.08	0.16	0.95	0.14		
Shaanxi	0.36	0.08	0.72	0.16	1.02	0.22		
Qinghai	27.10	0.76	1.50	0.04	1.22	0.03		
Ningxia	0.01	0.00	4.22	0.33	3.25	0.25		

Annex Table 2. Percentage of IVA in GDP in 31 provinces

Year	Henan	Shanxi	Tianjin	Shandong	Hebei	Jiangsu	Inner Mongolia	Guangdong
2006	48.79	50.94	50.68	51.96	47.84	51.04	40.97	47.08
2007	50.01	52.15	50.68	51.53	47.88	50.37	43.31	47.02
2008	51.77	52.88	50.88	51.38	49.29	49.29	45.66	47.03
2009	50.82	47.82	48.15	49.85	46.32	47.78	46.23	45.82
2010	51.75	50.63	47.82	48.15	46.85	46.54	48.14	46.64
2011	51.80	53.04	48.03	46.90	48.01	45.37	49.45	46.32
2012	50.74	49.73	47.49	45.58	47.08	44.23	48.71	45.23
2013	46.40	46.13	46.30	43.93	46.39	42.68	46.96	43.05
2014	45.25	42.87	45.01	42.64	45.31	41.43	44.48	42.98
2015	42.76	34.15	42.22	41.13	42.36	39.93	43.40	41.56
Average	49.01	48.03	47.73	47.31	46.73	45.87	45.73	45.27
Year	Liaoning	Zhejiang	Shaanxi	Jilin	Qinghai	Jiangxi	Fujian	Anhui
2006	43.17	48.26	44.14	38.81	40.88	39.52	42.60	36.65
2007	43.82	48.47	44.19	41.08	43.21	41.59	42.13	38.17
2008	46.53	48.12	44.77	41.84	46.00	41.70	42.44	39.60
2009	45.53	45.75	42.86	41.97	43.50	41.76	41.73	40.39
2010	47.62	45.66	45.03	45.33	45.44	45.36	43.41	43.75
2011	48.12	45.43	46.82	46.53	48.59	46.24	43.71	46.15
2012	46.71	44.25	47.37	46.76	47.31	45.01	43.36	46.63
2013	45.20	41.95	46.33	46.44	43.01	44.78	43.24	46.18
2014	44.21	41.75	45.19	46.55	41.43	43.58	43.34	45.35

2015	39.31	40.15	40.75	43.46	36.98	41.37	41.65	42.10
Average	45.02	44.98	44.75	43.88	43.64	43.09	42.76	42.50
Year	Chongqing	Sichuan	Hubei	Heilongjiang	Hunan	Guangxi	Ningxia	Xinjiang
2006	40.10	36.19	38.45	49.08	35.22	33.55	39.61	40.76
2007	42.87	37.13	38.44	46.83	35.99	35.89	40.99	39.88
2008	45.00	39.33	38.76	46.50	37.30	37.42	42.11	41.96
2009	44.68	40.13	39.99	41.34	36.90	36.91	38.45	36.38
2010	46.66	43.24	42.13	42.72	39.31	40.34	38.06	39.75
2011	46.85	45.14	43.49	41.60	41.30	41.39	38.85	40.85
2012	43.66	44.19	43.75	38.28	41.25	40.50	37.53	37.97
2013	36.24	43.73	40.90	35.22	40.62	38.76	36.20	34.65
2014	36.29	41.53	40.15	31.81	39.76	38.70	35.37	34.29
2015	35.36	36.73	39.03	26.88	37.87	37.85	33.65	29.39
Average	41.77	40.73	40.51	40.03	38.55	38.13	38.08	37.59
Year	Shanghai	Gansu	Yunnan	Guizhou	Beijing	Hainan	Tibet	
2006	43.28	38.12	35.14	35.88	22.44	22.36	7.47	
2007	41.26	39.34	35.54	33.94	21.15	22.20	8.09	
2008	39.64	37.54	36.05	33.56	19.18	20.55	7.47	
2009	35.95	35.53	33.85	32.02	18.95	18.17	7.50	
2010	38.08	38.90	36.05	32.96	19.58	18.66	7.83	
2011	37.55	38.32	33.67	32.08	18.76	18.83	7.95	
2012	35.17	36.64	33.47	32.36	18.43	18.25	7.90	
2013	32.72	34.04	31.81	33.22	18.01	14.87	7.50	
2014	31.24	33.10	30.43	33.90	17.57	14.69	7.18	
2015	28.51	26.19	28.26	31.57	16.12	13.12	6.81	
Average	36.34	35.77	33.43	33.15	19.02	18.17	7.57	

Annex Table 3. GIVA Calculations

Provinces	2006	2015	change	Ch ratio	Target Ch ratio (λ)	y_star	threshold (t)	GIVA progress	Ranking
Shanxi	58.87	71.44	12.57	1.21	1.20	70.73	56.64	1.06	1
Liaoning	54.86	66.32	11.46	1.21	1.20	65.90	56.64	1.04	2
Inner Mongolia	39.68	47.55	7.86	1.20	1.20	56.64	56.64	0.46	3
Sichuan	66.65	67.96	1.31	1.02	1.20	80.07	56.64	0.10	4
Anhui	70.91	72.28	1.37	1.02	1.20	85.19	56.64	0.10	5
Guangdong	78.78	79.17	0.39	1.00	1.20	94.65	56.64	0.02	6
Ningxia	47.80	47.84	0.04	1.00	1.20	57.43	56.64	0.00	7
Fujian	79.26	77.32	-1.93	0.98	1.20	95.22	56.64	-0.12	8
Shandong	70.34	67.35	-2.99	0.96	1.20	84.50	56.64	-0.21	9
Jilin	67.66	64.30	-3.36	0.95	1.20	81.28	56.64	-0.25	10
Hebei	66.50	62.29	-4.20	0.94	1.20	79.89	56.64	-0.31	11
Zhejiang	55.90	50.70	-5.19	0.91	1.20	67.16	56.64	-0.46	12
Shaanxi	78.65	70.91	-7.74	0.90	1.20	94.49	56.64	-0.49	13
Jiangsu	73.61	66.16	-7.44	0.90	1.20	88.44	56.64	-0.50	14
Qinghai	41.78	32.42	-9.35	0.78	1.20	56.64	56.64	-0.63	15
Jiangxi	69.11	60.28	-8.83	0.87	1.20	83.03	56.64	-0.63	16
Tianjin	68.84	58.89	-9.95	0.86	1.20	82.71	56.64	-0.72	17
Henan	75.28	52.43	-22.85	0.70	1.20	90.44	56.64	-1.51	18

Annex Table 4. GEMP Calculations

Provinces	2006	2015	change	ch_ratio	Target ch ratio (λ)	y*	t	GEMP progress	GEMP ranking
Shanxi	64.35	71.32	6.97	1.11	1.08	69.55	67.08	1.34	1
Jiangxi	67.08	72.90	5.83	1.09	1.08	72.49	67.08	1.08	2
Sichuan	67.60	72.88	5.29	1.08	1.08	73.06	67.08	0.97	3
Anhui	78.00	82.54	4.54	1.06	1.08	84.30	67.08	0.72	4
Jilin	74.81	78.72	3.91	1.05	1.08	80.86	67.08	0.65	5
Henan	72.31	75.38	3.06	1.04	1.08	78.16	67.08	0.52	6
Hebei	64.78	66.65	1.87	1.03	1.08	70.02	67.08	0.36	7
Liaoning	69.90	70.58	0.68	1.01	1.08	75.54	67.08	0.12	8
Tianjin	81.13	80.87	-0.26	1.00	1.08	87.68	67.08	-0.04	9
Shaanxi	75.21	74.92	-0.29	1.00	1.08	81.28	67.08	-0.05	10

Jiangsu	84.78	84.23	-0.56	0.99	1.08	91.63	67.08	-0.08	11
Guangdong	90.93	90.23	-0.70	0.99	1.08	98.27	67.08	-0.10	12
Fujian	85.62	84.47	-1.15	0.99	1.08	92.53	67.08	-0.17	13
Shandong	86.14	84.96	-1.18	0.99	1.08	93.10	67.08	-0.17	14
Zhejiang	90.84	89.29	-1.55	0.98	1.08	98.18	67.08	-0.21	15
Inner Mongolia	61.48	58.64	-2.84	0.95	1.08	67.08	67.08	-0.51	16
Qinghai	52.12	41.88	-10.24	0.80	1.08	67.08	67.08	-0.68	17
Ningxia	67.11	60.84	-6.27	0.91	1.08	72.53	67.08	-1.16	18

Annex Table 5. ENERGY Calculations

Provinces	2006	2015	change	ch_ratio	Target ch ratio (β)	y*	t	ENERGY progress	ENERGY ranking
Jilin	0.75	0.19	0.56	0.26	0.43	0.32	1.08	1.30	1
Sichuan	1.00	0.35	0.64	0.35	0.43	0.43	1.08	1.13	2
Anhui	0.93	0.43	0.51	0.46	0.43	0.40	1.08	0.95	3
Inner Mongolia	1.50	0.83	0.67	0.55	0.43	0.64	1.08	0.78	4
Ningxia	2.83	1.48	1.35	0.52	0.43	1.08	1.08	0.77	5
Henan	0.81	0.48	0.33	0.60	0.43	0.35	1.08	0.70	6
Jiangxi	0.67	0.40	0.27	0.60	0.43	0.28	1.08	0.70	7
Fujian	0.56	0.38	0.19	0.67	0.43	0.24	1.08	0.58	8
Zhejiang	0.54	0.37	0.17	0.69	0.43	0.23	1.08	0.54	9
Guangdong	0.16	0.12	0.04	0.73	0.43	0.07	1.08	0.47	10
Liaoning	0.70	0.51	0.18	0.74	0.43	0.30	1.08	0.46	11
Jiangsu	0.52	0.39	0.14	0.74	0.43	0.22	1.08	0.46	12
Hebei	1.11	0.82	0.29	0.74	0.43	0.47	1.08	0.45	13
Shaanxi	0.57	0.46	0.11	0.81	0.43	0.24	1.08	0.33	14
Qinghai	2.10	1.72	0.38	0.82	0.43	0.89	1.08	0.31	15
Tianjin	0.45	0.38	0.07	0.85	0.43	0.19	1.08	0.26	16
Shanxi	1.73	1.65	0.08	0.96	0.43	0.74	1.08	0.08	17
Shandong	0.48	0.46	0.02	0.96	0.43	0.21	1.08	0.08	18

Annex Table 6. WATER Calculations

Provinces	2006	2015	change3	ch_ratio	Target ch ratio (β)	y*	t	WATER progress	WATER ranking
Qinghai	142.07	21.62	120.45	0.15	0.32	45.77	110.13	1.25	1
Sichuan	121.14	30.54	90.61	0.25	0.32	39.03	110.13	1.10	2
Anhui	191.00	67.27	123.74	0.35	0.32	61.53	110.13	0.96	3
Inner Mongolia	44.22	16.19	28.03	0.37	0.32	14.24	110.13	0.94	4
Shaanxi	33.90	12.89	21.01	0.38	0.32	10.92	110.13	0.91	5
Fujian	111.27	44.66	66.61	0.40	0.32	35.85	110.13	0.88	6
Liaoning	31.49	12.66	18.83	0.40	0.32	10.14	110.13	0.88	7
Jilin	61.85	25.30	36.55	0.41	0.32	19.93	110.13	0.87	8
Jiangxi	142.63	59.35	83.28	0.42	0.32	45.95	110.13	0.86	9
Guangdong	58.21	24.78	33.43	0.43	0.32	18.75	110.13	0.85	10
Zhejiang	28.60	12.32	16.28	0.43	0.32	9.21	110.13	0.84	11
Ningxia	65.40	29.93	35.47	0.46	0.32	21.07	110.13	0.80	12
Tianjin	53.46	24.51	28.95	0.46	0.32	17.22	110.13	0.80	13
Hebei	25.66	11.88	13.78	0.46	0.32	8.27	110.13	0.79	14
Henan	43.05	22.11	20.93	0.51	0.32	13.87	110.13	0.72	15
Jiangsu	106.68	56.90	49.78	0.53	0.32	34.37	110.13	0.69	16
Shanxi	33.26	20.95	12.31	0.63	0.32	10.71	110.13	0.55	17
Shandong	8.94	7.61	1.33	0.85	0.32	2.88	110.13	0.22	18

Annex Table 7. HWASTE Calculations

Provinces	2006	2015	change	ch_ratio	Target ch ratio (β)	y*	t	HWASTE progress	HWASTE ranking
Tianjin	3.47	1.20	2.28	0.35	0.72	2.51	5.68	2.35	1
Liaoning	5.95	4.27	1.68	0.72	0.72	4.29	5.68	1.01	2
Guangdong	5.56	4.02	1.55	0.72	0.72	4.01	5.68	1.00	3
Jilin	15.30	12.44	2.86	0.81	0.72	5.68	5.68	0.30	4
Hebei	3.13	3.07	0.06	0.98	0.72	2.26	5.68	0.07	5
Inner Mongolia	11.26	13.38	-2.12	1.19	0.72	5.68	5.68	-0.38	6
Jiangsu	4.77	6.08	-1.31	1.27	0.72	3.44	5.68	-0.98	7
Sichuan	4.44	6.17	-1.73	1.39	0.72	3.20	5.68	-1.40	8
Qinghai	153.83	372.23	-218.41	2.42	0.72	5.68	5.68	-1.47	9

Fujian	1.33	2.30	-0.97	1.73	0.72	0.96	5.68	-2.61	10
Henan	1.36	3.13	-1.78	2.31	0.72	0.98	5.68	-4.69	11
Zhejiang	4.18	9.71	-5.53	2.32	0.72	3.01	5.68	-4.74	12
Shandong	5.71	13.37	-7.66	2.34	0.72	4.12	5.68	-4.81	13
Shaanxi	2.03	5.26	-3.23	2.59	0.72	1.46	5.68	-5.70	14
Shanxi	0.87	3.13	-2.27	3.62	0.72	0.62	5.68	-9.41	15
Anhui	1.48	6.43	-4.96	4.36	0.72	1.06	5.68	-12.05	16
Jiangxi	1.47	6.87	-5.40	4.68	0.72	1.06	5.68	-13.18	17
Ningxia	0.07	6.63	-6.56	89.29	0.72	0.05	5.68	-316.48	18

Annex Table 8. COD Calculations

Provinces	2006	2015	change	ch_ratio	Target ch ratio (β)	y*	t	COD progress	COD ranking
Inner Mongolia	7.90	0.84	7.07	0.11	0.12	0.95	4.79	1.02	1
Sichuan	5.16	0.56	4.60	0.11	0.12	0.62	4.79	1.01	2
Jilin	5.44	0.68	4.76	0.13	0.12	0.66	4.79	0.99	3
Liaoning	3.45	0.47	2.98	0.14	0.12	0.42	4.79	0.98	4
Anhui	3.40	0.60	2.80	0.18	0.12	0.41	4.79	0.94	5
Shandong	1.59	0.32	1.27	0.20	0.12	0.19	4.79	0.91	6
Hebei	3.51	0.72	2.79	0.21	0.12	0.42	4.79	0.90	7
Henan	2.83	0.63	2.20	0.22	0.12	0.34	4.79	0.88	8
Ningxia	20.18	4.63	15.56	0.23	0.12	2.43	4.79	0.88	9
Jiangxi	3.27	0.89	2.38	0.27	0.12	0.39	4.79	0.83	10
Shanxi	3.67	1.05	2.62	0.29	0.12	0.44	4.79	0.81	11
Shaanxi	3.45	0.99	2.46	0.29	0.12	0.42	4.79	0.81	12
Zhejiang	2.73	0.79	1.94	0.29	0.12	0.33	4.79	0.81	13
Tianjin	0.88	0.27	0.61	0.31	0.12	0.11	4.79	0.79	14
Jiangsu	1.41	0.48	0.93	0.34	0.12	0.17	4.79	0.75	15
Fujian	1.57	0.57	1.01	0.36	0.12	0.19	4.79	0.73	16
Qinghai	7.15	2.98	4.17	0.42	0.12	0.86	4.79	0.66	17
Guangdong	1.26	0.93	0.33	0.74	0.12	0.15	4.79	0.30	18

Annex Table 9. SO₂ Calculations

Provinces	2006	2015	change	ch_ratio	Target Ch ratio (β)	y*	t	SO ₂ progress	SO ₂ ranking
Sichuan	19.15	3.43	15.72	0.18	0.25	4.76	20.12	1.09	1
Anhui	12.23	3.02	9.21	0.25	0.25	3.04	20.12	1.00	2
Inner Mongolia	36.70	9.14	27.56	0.25	0.25	9.12	20.12	1.00	3
Fujian	7.42	1.95	5.47	0.26	0.25	1.84	20.12	0.98	4
Shaanxi	20.45	5.44	15.01	0.27	0.25	5.08	20.12	0.98	5
Guangdong	5.35	1.43	3.92	0.27	0.25	1.33	20.12	0.98	6
Tianjin	5.51	1.48	4.04	0.27	0.25	1.37	20.12	0.97	7
Henan	13.05	3.85	9.19	0.30	0.25	3.24	20.12	0.94	8
Jilin	10.87	3.29	7.58	0.30	0.25	2.70	20.12	0.93	9
Jiangxi	16.08	4.97	11.11	0.31	0.25	3.99	20.12	0.92	10
Jiangsu	6.01	1.89	4.12	0.32	0.25	1.49	20.12	0.91	11
Ningxia	65.40	20.68	44.72	0.32	0.25	16.25	20.12	0.91	12
Zhejiang	7.88	2.65	5.23	0.34	0.25	1.96	20.12	0.88	13
Hebei	12.99	4.38	8.61	0.34	0.25	3.23	20.12	0.88	14
Qinghai	24.56	8.68	15.88	0.35	0.25	6.10	20.12	0.86	15
Liaoning	13.87	5.14	8.73	0.37	0.25	3.45	20.12	0.84	16
Shandong	7.97	3.14	4.83	0.39	0.25	1.98	20.12	0.81	17
Shanxi	25.45	13.77	11.68	0.54	0.25	6.32	20.12	0.61	18

Annex Table 10. Composite GIPro index with five environmental indicators

Provinces	GIPro Index	GIPro ranking	ENERGY progress	ENERGY ranking	WATER progress	WATER ranking
Tianjin	1.19	1	0.26	16	0.80	13
Liaoning	0.85	2	0.46	11	0.88	7
Guangdong	0.84	3	0.47	10	0.85	10
Sichuan	0.68	4	1.13	2	1.10	2
Jilin	0.68	5	1.30	1	0.87	8
Hebei	0.60	6	0.45	13	0.79	14
Inner Mongolia	0.58	7	0.78	4	0.94	4
Fujian	0.48	8	0.58	8	0.88	6
Ningxia	0.47	9	0.77	5	0.80	12
Henan	0.31	10	0.70	6	0.72	15

Jiangsu	0.19	11	0.46	12	0.69	16
Anhui	0.15	12	0.95	3	0.96	3
Shanxi	0.06	13	0.08	17	0.55	17
Shaanxi	0.00	14	0.33	14	0.91	5
Jiangxi	-0.16	15	0.70	7	0.86	9
Zhejiang	-0.89	16	0.54	9	0.84	11
Qinghai	-1.08	17	0.31	15	1.25	1
Shandong	-1.84	18	0.08	18	0.22	18
Provinces	HWASTE progress	HWASTE ranking	COD progress	COD ranking	SO2 progress	SO2 ranking
Tianjin	2.35	1	0.79	14	0.97	7
Liaoning	1.01	2	0.98	4	0.84	16
Guangdong	1.00	3	0.30	18	0.98	6
Sichuan	-1.40	8	1.01	2	1.09	1
Jilin	0.30	4	0.99	3	0.93	9
Hebei	0.07	5	0.90	7	0.88	14
Inner Mongolia	-0.38	6	1.02	1	1.00	3
Fujian	-2.61	10	0.73	16	0.98	4
Ningxia	-316.48	18	0.88	9	0.91	12
Henan	-4.69	11	0.88	8	0.94	8
Jiangsu	-0.98	7	0.75	15	0.91	11
Anhui	-12.05	16	0.94	5	1.00	2
Shanxi	-9.41	15	0.81	11	0.61	18
Shaanxi	-5.70	14	0.81	12	0.98	5
Jiangxi	-13.18	17	0.83	10	0.92	10
Zhejiang	-4.74	12	0.81	13	0.88	13
Qinghai	-1.47	9	0.66	17	0.86	15
Shandong	-4.81	13	0.91	6	0.81	17

Annex Table 11. Modification of target change ratio distribution⁸

Provinces	GIPro index 1*	Ranking 1	GIPro index 2	Ranking 2
Liaoning	0.76	1	2.08	1
Sichuan	0.65	2	0.67	4
Jilin	0.57	3	0.39	6
Guangdong	0.49	4	0.90	3
Tianjin	0.48	5	-0.50	11
Inner Mongolia	0.44	6	0.48	5
Shanxi	0.44	7	1.80	2
Hebei	0.40	8	-0.02	7
Ningxia	0.30	9	-0.15	9
Fujian	0.24	10	-0.14	8
Anhui	0.23	11	-0.25	10
Henan	0.04	12	-2.67	16
Jiangsu	0.02	13	-1.01	12
Jiangxi	0.00	14	-1.58	15
Shaanxi	-0.09	15	-1.39	14
Zhejiang	-0.67	16	-2.79	17
Qinghai	-1.05	17	-1.04	13
Shandong	-1.16	18	-3.24	18

⁸ Index 1 & Ranking 1 = with the 0.9 & 0.1 percentile of target change ratio distribution
 Index 2 & Ranking 2 = with the 0.8 & 0.2 percentile of target change ratio distribution