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Measuring energy security performance within China: Toward an inter-provincial prospective

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ABSTRACT

China has been the world's largest energy consumer and producer for many years, yet while myriad studies have investigated Chinese performance on energy metrics compared to other countries, few to none have looked internally at Chinese provinces. This paper firstly develops a five-dimensional evaluation system centered on the energy security dimensions of availability and diversity, affordability and equality, technology and efficiency, environmental sustainability, and governance and innovation. It then correlates these dimensions to 20 distinct energy security metrics that are used to assess the energy security performance of 30 Chinese provinces, divided into eight regions. Our results reveal both trends in energy policy and practice as well as provincial status of comparative energy security for the year 2013. We find, for instance, that there is no province which performs well in all five of the energy security dimensions, and that all provinces confronted threats related to energy availability and diversity. We also demonstrate that in comparative terms, the Middle Reaches of Yellow River and the Northwest were the most energy-secure, while the Middle Reaches of Yangtze River and the Northeast were least energy-secure.

1. Introduction

Recently, there has been no shortage of scholarly or practitioner interest in energy security. Of particular concern is China, which surpassed the United States as the world's largest energy consumer in 2010, with a share of 20.3% of world total energy consumption that year [1]. Energy demand in China is expected to increase 60% further from 2015 to 2035, and by the early 2030s, China could become the world's largest energy importer, overtaking Europe in terms of volume of imports, with its import dependence rising from 15% to 23% [2]. China even became a net coal importer since 2009 [3], and the country's dependence on foreign oil exceeded 60% in 2014 [4]. These resource dependence concerns also do little to address a second serious problem of climate change, which requires less fossil fuel consumption for climate change mitigation [5]. What's more, the consumption of fossil fuels causes serious ambient air pollution, leading to urban haze in major cities in eastern China, which has greatly threatened public health [6]. Further complicating matters, discussions about peak oil, price fluctuations, and energy inequality have drawn the attention of policymakers and investors, as energy security is closely related with national goals of sustainable development and economic growth [7].

Indeed, as the third largest entity of the world, China is also the largest energy producer, with a share of 19% of world's energy production [8]. However, China's provinces vary greatly in energy endowment, economy development, industrial structure, technology development, and even social and cultural customs, and there is a great spatial disparity between flows of energy fuels and services within them [9–13]. Due to these disparities, energy researchers and policymakers in China are left with at least three puzzling research questions:

(1) How can the spatial energy security trends of Chinese provinces be analyzed?

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(2) How can energy security performance be measured at the provincial level?
(3) How can the provincial energy security of China be enhanced?

Interestingly, despite an abundance of research on energy security metrics and performance [14–20], no studies have as of yet answered these three questions. Admittedly, many studies have investigated China's energy security issues [21–27]. For instance, Wu et al. measured China's security of energy supply with 14 indicators [22]. Geng and Ji developed a multi-dimensional indicator system to evaluate China's national energy security [25]. Yang and Chen established an evaluation framework to measure Chinese performance on energy security metrics [27]. None, however, have looked at Chinese energy security at the provincial scale.

Despite moderately clear roles about local, provincial, and national jurisdiction over energy, a degree of fragmentation exists actors at times duplicate and contradicts each other's actions [28]. Thus, it is naive to expect provincial leadership to govern the provincial energy security [29]. Instead, a group mainly consists of senior leaders as well as members of the Standing Committee of the State Council, senior military commanders and provincial leaders, is responsible for China's national energy policy [30]. Thus, its provincial energy security is quite different from national security, and it is essential to investigate China's energy security from an internal prospective.

To do so, this study first reviews the academic literature in energy studies to present five dimensions of energy security: availability and diversity, affordability and equality, technology and efficiency, environmental sustainability, and governance and innovation. It then corresponds these to 20 different metrics and assigns them weights based on Fuzzy Analytical Hierarchy Process (an established method in the energy studies and engineering fields), and investigates the energy security performance of 30 Chinese provinces with another two methods, Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), and Sensitivity Analysis. The final parts of the article present its results and analysis as well as policy implications and conclusions.

2. Dimensions and metrics of energy security

This section firstly reviews the conceptual underpinning of energy security, summarizing recent peer-reviewed research related to energy security dimensions and metrics.

2.1. Literature review

In the existing literature, energy security is most commonly defined as the reliable supply of energy at reasonable prices to support the economy and industry [31–36]. This traditional definition of energy security has been critiqued for being too narrow and for downplaying broader social and environmental factors such as climate change or community acceptance [37]. The “4A” framework of energy security (availability, accessibility, acceptability and affordability) proposed by APERC [38] is a more representative conception, one utilized by numerous scholars [39,40].

There is no shortage of simple or aggregated indexes to measure energy security. Kruyt et al. overviewed 24 simple and aggregated indicators for security of supply found in literature [41]. The most widely used are reserves to production ratios, diversity indices, including Herfindahl-Hirschman index (HHI) and Shannon Wiener index (SWI) [16,42–44]. A noteworthy energy security index developed by International Energy Agency integrated HHI with the political stability of importing sources and energy prices [45]. Taking a similar approach, Lefèvre designed an energy security price index and energy security physical availability index, and used these two indices to project the energy security of France and UK over the period of 2004–2030 [46]. Based on IEA's energy security index, Löschel et al. developed ex-post and ex-ante indicators of energy security, and used them to depict the energy security of Germany, Netherlands, Spain and the United States [47]. To measure the short-term risk of energy supply, Le Coq and Paltseva developed a Risky External Energy Supply Index, which combined net import dependency, political risks of the supplying country, energy transport risks, energy fungibility and the economic importance of each energy type, and used it to measure the risks of oil, gas and coal for the EU members [14]. By constructing the Gas Supply Security Index, Cabalu combined gas intensity, net gas import dependency, ratio of domestic gas production to total domestic gas consumption and geopolitical risk, and examined the relative vulnerability to natural gas supply disruptions of seven gas-importing countries in Asia for year 2008 [48]. These indexes all make meaningful contributions in examining security of energy supply.

There are also a number of metrics of energy security that have been proposed in the literature from a more synthesized prospective. Vivoda proposed a set of quantitative and qualitative indicators to evaluate national or regional energy security, supposing that it consists of 11 dimensions and 44 attributes [15]. Von Hippel et al. devised 29 indicators of energy security including six dimensions [49]. Unfortunately, they failed to conduct any empirical study with their instrument for any country or region. Sovacool and Mukherjee developed five dimensions consisting of 20 components and 320 simple indicators along with 52 complex indicators to assess energy security [50]. Wu et al. measured China's energy supply security with 14 indicators [22]. Martchamadol and Kumar used 19 indicators, which can be categorized into five sets, to analyze the energy security in Thailand for the period 1986–2030 in three energy scenarios presented by APERC [51].

2.2. Dimensions and metrics

To provide a comprehensive, yet capable and parsimonious approach to measuring energy on a provincial level, this paper synthesized such dimensions and indicators from the literature [15,23,24,49–53]. Thus, we hold that energy security consists of availability and diversity, affordability and equality, technology and efficiency, environmental sustainability, and governance and innovation. As presented in Table 1, these five dimensions can be effectively decomposed into 20 components, and thereby measured with 20 metrics. We must empathize that these five dimensions have been validated by recent quantitative assessments of energy security [23] as well as qualitative research with energy experts [17], a series of focus groups and workshops [20], and surveys of energy security attitudes both looking internally at China [21] as well as a comparative sample of eleven countries including China [54,55].

2.2.1. Availability and diversity

The dimension of availability and diversity represents security of energy supply and demand, which consists of factors relating to energy resources and endowments, energy production, imports and exports, and energy consumption. We decomposed this dimension into four components in Table 1: security of supply, energy potential, dependency, and diversity.

2.2.2. Affordability and equality

The dimension of affordability and equality refers to the economic aspects of energy security such as the prices of energy