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The socio-political economy of electricity generation in China

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ABSTRACT

In addition to providing a review of electricity generation developments in China, this paper features the development of a framework for understanding the socio-political economy influencing electricity market development. It documents and presents a critical evaluation of the social, technological, economic and political forces which influence electricity generation policy in China. The analysis provides insight into why China's electricity generation shopping basket is being filled with both coal and CO_2-reduced electricity generation technologies. It concludes that installed capacity of hydro power, wind power, nuclear power and solar PV power will outpace government projections due to inter alia a proclivity on the part of the Chinese government to set conservative (and achievable) targets, waning apathy toward pollution associated with coal-fired power, progressive improvements in grid connection and resilience, increased economic viability of these alternative energy sources and government support for these industries as strategic commercial sectors.

Contents

1. Introduction

Analyzing energy generation developments in China is akin to observing a person emerging from a supermarket with a shopping cart half-full with dietary products and half-full with chocolates and other sweets and trying to determine whether or not the person is going on a diet. On one hand, in 2009, China surpassed the United States as the world's largest emitter of greenhouse gases (GHG). Not only is China the world's largest consumer (and producer) of coal, by 2030, coal consumption in China is expected to increase 41% from 2010 levels [1,2]. On the other hand, China also boasts the fastest growing wind power market in the world. In 2010, one of every two wind turbines installed in the world were installed in China [3]. As of June 2011, China enjoys top global spot in aggregate installed wind power capacity with 50,000 MW installed, 20% of global capacity [4]. China is also the fastest growing nuclear power market in the world with 40 GW of installed nuclear power capacity expected by 2020.

So what is happening in China's electricity generation sector? Is it going on a CO_2 reduced diet or not? Given its voluminous GHG emissions, mitigating the worst effects of climate change will not be possible without substantial GHG emission reductions in China. Accordingly, gaining an accurate picture of the evolution of China's energy generation sector is a pre-requisite for predicting

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the potential for success of global climate change mitigation efforts and for predicting the impact that China's electricity supply strategy will have on global energy markets.

This paper presents a critical evaluation of the social, technological, economic and political forces which influence electricity generation policy in China. As will be demonstrated, unique national circumstances in China dictate policy design and implementation because energy policy in China (like in other nations) is primarily a product of socio-economic political forces which promotes a gradualist approach to electricity mix planning that favors alternative energy development. This may not be optimal in terms of facilitating an expedient transition away from coal-fired production [5]; but it is optimal in terms of facilitating a socio-economic balance that the Chinese leadership (with good justification) views to be crucial for maintaining social, economic and political stability [6].

The layout of this paper is as follows: Section 2 provides an overview of China's electricity generation sector, Section 3 explains the STEP analytical methodology applied in this paper, Section 4 presents the STEP analysis of China's electricity generation sector and, Section 5 concludes by synthesizing the analysis to anticipate trends. In the process, the paper provides insight into why China's electricity generation shopping basket is being filled with both coal and CO_2-reduced electricity generation technologies.

2. Energy in China

Due to the dual distinction of being the world's most populous nation and the world's fastest-growing economy over the past decade, total primary energy (TPE) consumption in China has mushroomed. Upon first glance of Fig. 1, it appears that China's growth in TPE consumption over the past decade has merely kept pace with global growth trends. However, closer examination reveals a more engaging fact – China's TPE consumption growth has largely driven the global increase. Between 2000 and 2011, growth in China's TPE consumption accounted for 54.9% of the global increase. As Fig. 2 illustrates, China's TPE consumption now accounts for a whopping 21.5% of global energy consumption.

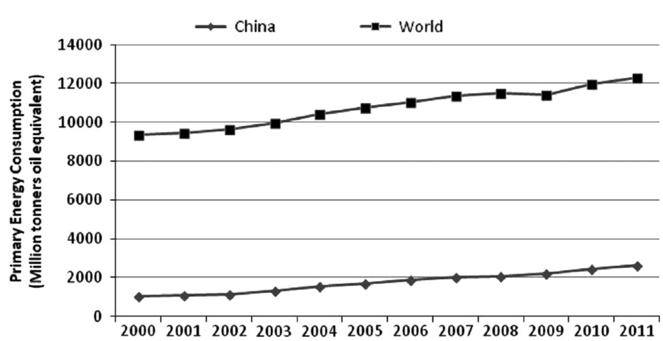


Fig. 1. Primary energy consumption trends 2000–2011. .
Source of data: [7]

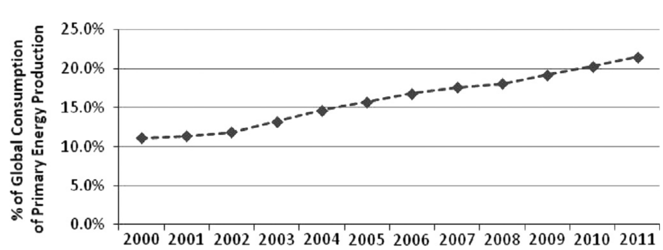


Fig. 2. Global primary energy consumption attributed to China, 2000–2011.
Source of data: [7]

Only the United States with a 18.5% share of global energy consumption comes near to matching China's prodigious consumption levels.

As Fig. 3 suggests, the fact that China's immense energy appetite is currently being satiated by a CO_2-intensive energy mix (largely due to the dominance of coal-fired power) is of great international consternation regarding climate change mitigation efforts.

Fig. 4 graphically illustrates the comparative scale of Chinese coal consumption. Of the top 10 coal consuming nations, China's total coal consumption in 2011 was 35% higher than the nine others combined.

It is primarily due to coal-fired power that China is now the largest contributor of GHG emissions. As Fig. 5 illustrates, between 1990 and 2010, CO_2 emissions in China increased 323%. China's 5.0 Gigatonne increase constituted 54% of the 9.3 Gigatonne global increase over the same period. By 2010, CO_2 emissions in China accounted for 24% of global annual CO_2 emissions. Consequently, China has been criticized internationally for a perceived indifferent approach to climate change mitigation. As former U.S. Secretary of State Colin Powell quipped in 2009, "You know what the first thing is that Hu Jintao does not think about when he wakes up every morning? Climate change." [8].

Yet, such criticism ignores notable developments in China's electricity generation sector which paint a picture of a nation that is far from indifferent to stemming GHG emissions. Expansion of alternative energy generation capacity has been nothing short of remarkable in terms of pace, scale and scope of development.

As Fig. 6 illustrates, wind power in China has flourished. China is now the world's largest wind power market, as measured in installed capacity and annual growth. According to the World Wind Energy Association, in the first half of 2012, China added 5400 MW of installed capacity. The nation now hosts over 20% of all global wind power generation capacity [4]. To illustrate just how aggressive China's energy policymakers have been in supporting wind power development, China released a *Mid-and-Long Term Development Plan for Renewable Energy* in 2006 which set a 2020 target for installed wind power capacity of 30,000 MW [10]. As of June 2012, 67,700 MW of wind power capacity was in place, surpassing the 2020 target by 125%. With technically exploitable wind power potential estimated to be as high as 2548 GW, it appears that wind power hold great promise in China [11].

In hydroelectric development, generation capacity in China tripled between 2000 and 2011, despite a dip in capacity in 2011 (Fig. 7). As of 2011, China possessed 21% of global hydropower generation capacity. China's hydropower output now surpasses the combined hydropower production in Brazil and Canada (the nations with the 2nd and 3rd highest levels of hydropower output).

In terms of nuclear power, China's program is still evolving and the nation's 14 reactors provided less than 1.8% of the country's electricity in 2011 [7]. However, there are 25 reactors under construction – the most in the world – and despite the disaster in Fukushima Japan, some nuclear power analysts in China contend that there is a "high probability" that the government will upgrade its targets to 60–70 GW for 2020 [12]. By 2035, China is projected to displace the US as the nation with the highest amount of installed nuclear power capacity [13] and by 2050, the Communist Party of China (CPC) aims to reach 400 GW of installed capacity (roughly 400 reactors) [14]. To support these ambitions, the CPC actively sponsors major research and development efforts to improve indigenous designs and develop technological prowess in fuel enrichment, fuel processing, and waste storage.

Even China's notorious coal-fired power sector has undergone sweeping changes aimed in part at reducing the adverse environmental impact associated with low-tech coal-fired energy generation [15]. A 2006–2009 government initiative to replace

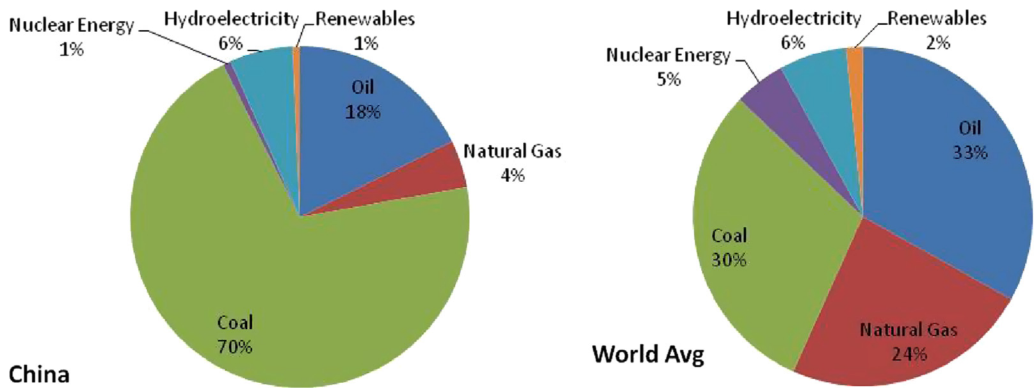


Fig. 3. Comparison of primary energy fuel profile in China vs. global average in 2010.
Source of data: [7]

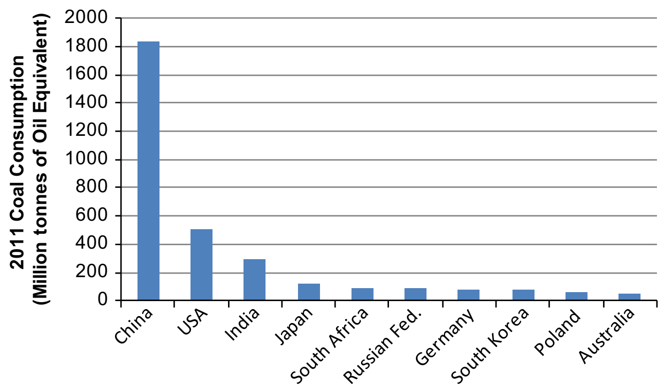


Fig. 4. Aggregate consumption of top 10 coal consuming nations in 2011.
Source of data: [7]

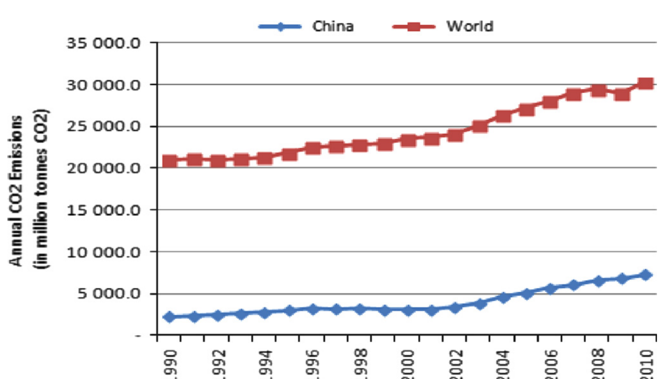


Fig. 5. CO_2 emissions trends in china and globally.
Source: [9]

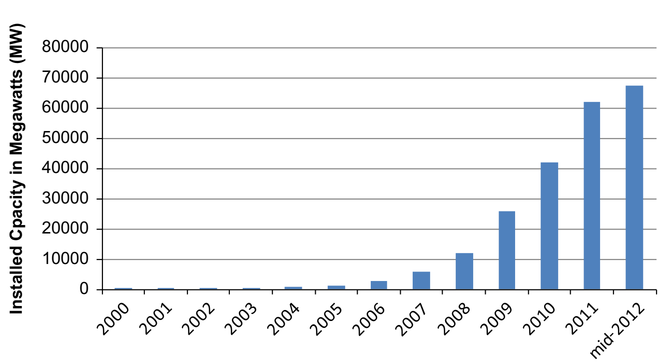


Fig. 6. Wind power expansion in China.
Source: global wind energy council website (accessed 27.12.12)

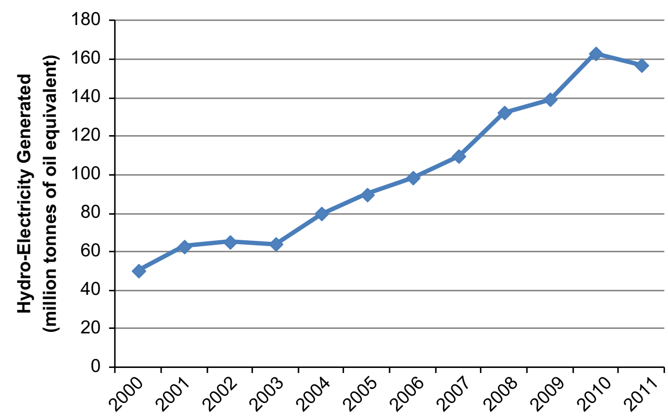


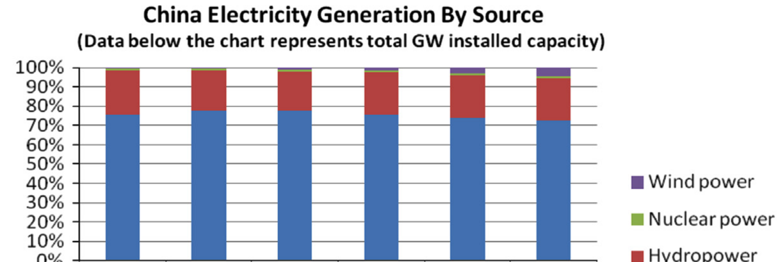
Fig. 7. Hydropower expansion in China.
Source: [7]

small-scale, inefficient coal-fired power plants with more efficient coal-fired generation technologies eliminated 60 GW of inefficient coal-fired generation capacity [10,16]. Consequently, between 1993 and 2009, coal utilization efficiency in power generation improved 18%, from 417 kg of coal equivalent per kilowatt hour (kgce/kW h) to 342 kgce/kW h.

Overall, developments within China's electricity sector depict a nation where inroads in alternative energy development have been negated by increases in fossil fuel electricity generation capacity as the nation strives to develop an electricity network that can effectively support unbridled industrial growth [10]. Between 1990 and 2009, when global GDP in purchasing power parity terms (GDP-PPP) grew by 92.7%, China's GDP-PPP grew 532.8%. In aggregate, China's 2009 GDP-PPP amounted to 19.3% of global GDP-PPP [17]. Over this same 20-year economic boom period, China's total primary energy (TPE) consumption increased 160% from 1251 mtce (million tonnes coal equivalent) to 3245 mtce [17]. Fig. 8 illustrates how expansion of coal-fired power capacity averaging 1.2 GW per week between 2005 and 2010 has negated progress in alternative energy capacity expansion and left China's energy mix virtually unchanged.

Perhaps surprisingly, given international criticism, China's energy efficiency ratio is comparatively middling. In 2009, China consumed 19.5% of global TPE to generate 19.3% of global GDP-PPP [1,17]. By comparison, in 2009, the US consumed 19.4% of global TPE to generate only 17.7% of global GDP-PPP and Canada consumed 2.7% of global TPE to generate just 1.6% of global GDP-PPP [1,17].

Although critics and indeed even prominent Chinese leaders would agree that China's carbon-intensive energy profile is far from desirable, Chinese efforts at decoupling energy consumption



	2005	2006	2007	2008	2009	2010
Wind power	1.26	2.56	5.87	12.02	25.81	44.73
Nuclear power	6.85	6.96	9.08	9.08	9.08	10.82
Hydropower	116.52	128.57	145.26	171.52	196.76	213.4
Thermal power	384.41	484.05	554.42	601.32	652.05	706.63

Fig. 8. China's electricity generation mix.
Source of data: [18]

from economic growth should not be lightly dismissed. Since 1990, CO_2 emissions as a percentage of GDP (PPP) declined 51.6% in China, compared to a global average improvement of 28.2%. China's "carbon intensity" which has been estimated at 0.55 kg of CO_2 per US$ in 2009 is commensurate with nations such as Canada (0.51 kg/US$) and Australia (0.56 kg/US$)[17]. Although China's 2009 per capita CO_2 emission rate of 5.14 t per person was still about 20% higher than the global average of 4.29 t per person, this is considerably lower than average per capita emissions of 9.83 t found in OECD nations. Clearly, China has a lot to be criticized for in terms of aggregate contributions to GHG emissions; however, it also deserves recognition for endeavoring to decouple CO_2 emissions from the economic growth process. A review of recent government policies demonstrates the scale and scope of the CPC's ambitions.

In 2006, the government released its 11th five-year plan of national economic and social development (2006–2010). A key objective was reduction of energy consumption per unit of GDP by 20% from 1.22 tce to 0.98 tce. With continued economic growth, this meant that TPE consumption would rise 23% to 2.7 billion tce by 2015. These projections re-affirmed the need to de-carbonize the electricity grid in order to abate CO_2 emissions. It is for this reason that the CPC also passed the Renewable Energy Law which came into effect on January 1, 2006.

The Renewable Energy Law decidedly influenced the pace of renewable energy development. Prior to the passage of the law in 2005, installed capacity for wind power and hydropower were 1.26 GW and 116.5 GW, respectively [18]. By 2010, installed wind power capacity had mushroomed to over 50 GW and installed hydropower capacity had surpassed 200 GW. The law forced utilities to purchase all generated renewable energy from approved projects at favorable prices. However, it also established a foundation for renewable energy R&D, funding for the development of projects in remote areas, access to preferred finance rates and tax benefits for approved projects [19].[1]

In September 2007, the National Development and Reform Commission (NDRC) released its "Medium and Long-Term Development Plan for Renewable Energy in China". Overall, the plan established targets for alternative energy of 10% of TPE by 2010 (up from 7.5% in 2005) and 15% of TPE by 2020. To facilitate this, the targets outlined in Table 1 were established. In 2007, the government's alternative energy strategy further congealed with the announcement of plans to install 40 GW of nuclear power capacity by 2020.

Table 1
2007 medium and long-term development plan for renewable energy in China.
Source of data: [20].

	2005	2010	2020
Hydropower (MW)	117,000	190,000	300,000
Biomass (MW)	2000	5500	30,000
Wind power (MW)	1260	5000	30,000
Solar PV (MW)	70	300	1800

By 2009, installed hydropower capacity (197 GW) had already surpassed the 2010 target while installed wind power capacity (20 GW) amounted to quadruple the 2010 target. Although solar PV was slower to develop, 0.2 GW was achieved by 2009 [19]. In aggregate, actual contributions from alternative energy sources amounted to 9.1% of TPE consumption in 2009, just shy of the 2010 target [19].

On March 5, 2011, the government released its 12th five-year plan of national economic and social development (2011–2015). According to the document, energy consumption per unit of GDP declined by 19.06% between 2006 and 2010, falling just short of the 20% target laid out in the 11th 5-year plan. The plan outlined intentions to further reduce energy consumption per unit of GDP by 16% from 2010 levels, increase the proportion of non-fossil fuels in TPE to 11.4% by 2015 and reduce CO_2 emissions per unit of GDP by 17% from 2010 levels by 2015 [21]. It also identified further development of new-generation nuclear energy, photovoltaic and photo-thermal power generation, wind power technology, intelligent power grids and biomass energy as strategic energy priorities.[2]

There are also indications that the CPC is currently revising its 2007 medium and long-term development plan for renewable energy in China. The revised plan purportedly targets 300 GW of hydropower, 150 GW of wind power, 30 GW of biomass power, and 20 GW of solar PV, for a total of 500 GW of renewable power capacity by 2020. If achieved, this would account for almost one-third of China's expected total power capacity (1600 GW) by 2020 [22].

Increased certitude of meeting alternative energy development targets, progressive improvement in energy efficiency (albeit lower than planned) and a massive reforestation program intended to add 40 million ha of forest area between 2006 and 2020, have

[1] An English version of this law is available at: http://www.renewableenergyworld.com/assets/download/China_RE_Law_05.doc

[2] A translation of this plan is available at http://cbi.typepad.com/china_direct/2011/05/chinas-twelfth-five-new-plan-the-full-english-version.html

seemingly provided the Chinese government with the confidence necessary to play a less tentative role in international climate change mitigation negotiations. Prior to the 15th Conference of the Parties to the Kyoto Protocol (COP15) in 2009, the government announced an intention to reduce carbon intensity (as a percentage of GDP) to 40–50% of 2005 levels by 2020, eclipsing the 17% target set forth by the United States [23]. During the subsequent COP17 conference held in South Africa, China deviated further from its reactive negotiation approach by expressing a willingness to discuss adopting GHG reduction targets provided that industrialized nations were willing to commit to further GHG reduction targets.

Unfortunately, more questions than answers still surround energy governance in China. Will Chinese energy policy continue to reflect a clash between forces for short-term economic advantage (which favor coal-fired energy production) and forces for longer-term sustainability? Are the projections set forth in the 12th 5-year development plan as conservative as they have been in the past? How much of a long-term commitment can we expect from China in terms of alternative energy development? What are the driving forces behind government support for each of China's electricity generation technologies? Gaining insight into these questions is essential for understanding the evolution of international energy markets and the future trajectory of climate change negotiations. The next section outlines the approach taken in this paper to addressing these questions.

3. The value of STEP analysis

The challenge of predicting the evolution of energy policy in any given nation typically begins with a two-step process of (i) analyzing historical trends and (ii) evaluating existing government policies and statements which may help shed light on whether historical trends will change. Section 2 did this by presenting recent energy trends and providing an overview of the existing policy climate in China. This review suggested that China will continue to support development of alternative energy technology (in particular nuclear power, wind power, solar thermal and hydropower). However, the review also indicated that China's policymakers view continued utilization of coal-fired energy as a necessary evil to economically satisfy explosive market demand for electricity. In affirmation, in addition to the renewable energy targets outlined earlier, the 12th 5-year development plan also identifies the construction of large scale "coal bases" and the development of associated "clean and efficient" large-capacity coal-fired power plants as strategic priorities (Ref. footnote 2). In short, analyzing trends and government policy documents suggests a business-as-usual trend. Table 2

However, comparing the 11th and 12th 5-year development plan targets for renewable energy with actual achievements suggests that government targets tend to err on the conservative side. Regardless of whether CPC estimates are conservative or the market is evolving faster than anticipated, alternative energy development is considerably outpacing stated targets (Table 3).

The problem with making market projections for China based on historical analysis and existing government policy statements is that (i) government projections tend to be overly-conservative, and (ii) energy markets are subject to forces which can alter market dynamics and produce unanticipated results. As Thomas P. Hughes noted, energy supply and demand occurs within a "socio-technical" system consisting of a "seamless web" of technical, social, political, and economic causal factors that supports the development of a given technological regime [24]. Therefore, speculating on the development of China's electricity generation sector needs to incorporate an analysis of these forces and how they might impact actual market development.

In this paper, a STEP analysis will be employed for this purpose. Efforts will be made to identify social (*S*), technological (*T*), economic (*E*) and political (*P*) forces that impinge on Chinese energy policy. In strategic management, a STEP analysis is a common tool for assessing exogenous influences on market dynamics [25]; accordingly, it was deemed a viable approach for evaluating market dynamics in China's electricity generation sector. Moreover, Valentine [26] previously demonstrated how STEP can be successfully applied in analyzing forces which influence wind power market dynamics. Therefore, a useful methodological precedent existed for applying a STEP analysis in an energy market context.

Data for this analysis was acquired primarily through literature reviews, government documents, energy and industry statistics. The literature review was conducted using Science Direct, Scopus and ABI Inform databases using keywords: "China and energy". The bulk of leading journals on energy policy are avaialble on these databases. The review process included nearly 100 peer-reviewed journal articles. Unstructured interviews with Chinese energy policy experts were undertaken during visits to Beijing in order to confirm trends or clarify understanding when necessary.

A three-step coding approach was adopted for collating the data based on a previous methodology introduced by Valentine [26]. First, forces that were identified in two or more sources as having an influence on energy policy in China were culled from the research sources. Second, these forces were then assigned to one of the four STEP categories. For example, under the "technological" category, "the cost of new connections" was identified as an issue which significantly influenced energy policy. Third, an attempt was made to consolidate all influential factors by searching for unifying themes. For example, "the cost of new connections", "poor inter-conductivity between regional grids", and "the sub-optimal role of using coal for supporting stochastic energy

Table 2
2015 renewable energy development targets in China.
Source of middle column data: China NDRC, 2011 (see footnote 2).

	2009	2011–2015	2015 projection
Hydropower (MW)	197,000	+120,000	317,000
Wind power (MW)	42,000	+70,000	112,000
Solar PV (MW)	200	+5000	5200
Nuclear (MW)	10,800	+40,000	50,800

Table 3
Projections for renewable energy development in the 12th five-year renewable energy plan.Data: 2009/10 actual: [19], 11th 5-yr plan: [20], 12th 5-year plan: (China NDRC, 2011 – see footnote 2).

	2009/2010 actual	11th 5-year plan 2010 target	11th 5-year plan 2020 forecast	12th 5-year plan 2015 projection
Hydropower (MW)	197,000	19,000	300,000	317,000
Wind Power (MW)	50,000	5000	30,000	112,000
Nuclear (MW)	10,800	n/a	40,000	50,800
Solar	200	300	n/a	5200

Table 4
Socio-cultural influences on Chinese electricity generation policy.

Factor	Conditions in China	Influence
Level of social activism	Low	Enables continued expansion of energy systems that carry high social costs
Distribution of wealth	Existence of severely impoverished rural communities	Promotes sensitivity over energy price management
Education levels	Rapidly improving	Enables policymakers to consider a shift to more technologically demanding energy systems
Expectations for living environment	Massive expansion of manufacturing activity has caused severe pollution	Creates environmental externalities which desensitize the public to energy externalities but also potentially sires social discontent
Public expectationsof leaders	The complexities of managing a major, globally connected economy have amplified public expectations	The government now faces the challenge of developing electricity mixes which are affordable, provide jobs and do not adversely impact the living environment
Notable perspectives on energy	High sensitivity to the social costs of mega hydro-projects and emerging sensitivity to fossil fuel pollution	Creates a degree of public support for alternative technologies which may bear short-term economic transition costs

flows" represent three influential factors which were then grouped together under "grid management" challenges.

Researchers who are more comfortable with quantitative studies may find a degree of conceptual discomfort with this application of grounded-theory methodology [27]. In defense of this methodology, the reader is reminded of the intent of this study. This study is attempting to put forth a model which identifies and describes the array of influences on energy policy in China and provides an analysis of the impact that these influences appear to be having on the evolution of energy policy in China. This study is not intended to provide quantifiable estimates of technological development; but rather, it is aimed at creating a theoretical foundation that could be used to guide future quantitative study.

It is hoped that future studies in other nations will assess the external validity of the PEST factors deemed influential in China′s electricity market. External validation of these factors will provide a much-needed framework for better understanding the socio-political economy of electricity markets.

4. STEP analysis of China′s electricity generation sector

4.1. Socio-cultural Influences

Research indicates that there are at least six socio-cultural drivers that have a marked influence on energy policy in China. Table 4 summarizes these six factors, which will be elaborated upon in this section.

Despite progressive reform, the CPC has a well-documented disposition for responding to large-scale civil disobedience with force [28]. Perhaps as a result, although there have been some exceptional instances of civic activism in regard to ill-conceived large-scale energy projects (such as the Three Gorges Dam project) [29], government-led development projects tend to engender public acquiescence. On the one hand, this predilection enables China′s state-owned enterprises (SOE) to pursue the development of energy projects that carry high social costs, which in other nations might not be tenable. Public acquiescence has played a role in enabling government commitment to nuclear power [30] and ongoing support for environmentally invasive coal-fired power plant expansion. On the other hand, low levels of civic activism also implies that NIMBY (not-in-my-back-yard) opposition to wind projects, which tend to emerge as wind power capacity evolves in a given country [26] will be attenuated in China.

Despite China′s recent economic success, over 300 million Chinese still live in impoverished conditions. Leaders within the CPC are painfully aware that failure to close the poverty gap could fuel political instability [23]. Consequently, the NDRC′s Price Department, which sets wholesale and retail electricity prices tends to establish benchmark prices that challenge utilities to reduce costs [31]. These "average social cost" benchmarks are province-specific to reflect provincial economic disparities [19]. One of the unintended side effects of this policy is that China′s utilities cannot amass the financial reserves necessary to sufficiently fortify infrastructure to accommodate higher levels of renewable energy into the electricity grids.

Marked progress in education also influences China′s energy market dynamics. Since Zhou Enlai′s Four Modernizations initiative in the early 1960s, China has long-exhibited a commitment to nurturing engineers [32]. In fact, many of China′s ruling elite received training as engineers [30]. However, the scale and scope of engineering programs in China has progressively enlarged. By 2006, higher education enrollments reached 18.85 million students, with 1/3rd enrolled in engineering programs. To put this into perspective, there were 50% more students enrolled in engineering programs in 2006 in China than there were enrolled in all higher education programs in 1990 [33]. Amplification of engineering competency has provided the skill base necessary for policymakers to begin thinking of alternative energy in strategic economic development terms. For example, within China′s burgeoning wind power industry, there are now 60+ domestic turbine manufacturers capable of competing at international levels and a plethora of smaller enterprises which engineer affordable components in support of these manufacturers [34]. The Chinese nuclear power industry enjoys similar human capital benefits [30]. Conversely, due to advances in education, the numbers of unskilled laborers are also diminishing which debases the importance of coal mining and coal-fired power as sources of jobs for unskilled laborers. One recent study estimated that between 2006 and 2010, there were 472,000 net job gains from alternative energy projects which displaced coal-fired plant projects [16].

In terms of community expectations, there is evidence of public dissonance and escalating public pressure to minimize environmental degradation [35]. In the first decade of the 21st century, 8% of China′s population was purportedly affected by environmental disasters caused in part by inefficient development planning [29,36]. Those who took in the splendor of the Beijing Olympics would have also noticed the shroud of smog enveloping many of the venues. International experience suggests that growing affluence will progressively amplify public demand for less environmentally-invasive industrial practices [37] and this engenders support for alternative energy.

Modern Chinese society is globally connected and has aspirations to match the economic well-being of industrialized nations.

Table 5
Technological influences on Chinese electricity generation policy.

Factor	Conditions in China	Influence
Grid management	Infrastructure expansion projects striving to keep pace with demand	Grid expansion is reactive and R&D funding for developing smart grids is taken up by basic expansion activities
Energy flow management	Insufficient investment to enhance grid resiliency and peak-load capacity	The dominance of coal-fired power and insufficient regional interconnectivity inhibit wind and solar power expansion
Geographic challenges	Coal mines and mainstream renewable energy sources are geographically separated from demand centers	Delivering energy to demand centers raises the cost of energy provision and produces costly environmental externalities
Resource management	China's rich fossil fuel reserves are diminishing at an alarming rate	The certitude of China being self-sufficient in electricity provision has evaporated
Technological expertise	Educational advances and joint ventures have amplified expertise in all energy technologies	Electricity technology in China is approaching world-class standards
Entrenched systems	Coal-fired power plants enjoy significant regional political support	The phase-out of coal-fired power gives rise to stakeholder resistance

As society evolves economically, perceptions of what constitutes acceptable governance also evolve. In energy policy, the both political and public perspectives on good energy governance now reflect perspectives found in most industrialized nations. Energy policymakers are now expected to establish a balance in terms of energy affordability, accessibility, minimal ecological impact, and energy supply security [38]. This means that the 1990s strategy of building one or two coal-fired power plants each week is falling into disfavor.

Aside from increasing affluence, one key driver of changing perceptions on good energy governance arises from public health concerns. In China, respiratory and cardiovascular problems stemming from pollution has become the primary cause of mortality [39]. Heightened public concern over the adverse health impact of fossil fuel electricity generation technology is increasingly fueling public support for alternative energy technologies, which until recently included nuclear power [40]. In the 1980s, nuclear power development in China was seen as a symbol of national pride [30]. However, following the nuclear crisis in Fukushima Japan, public confidence in nuclear power development has deteriorated. Although, many analysts believe that plans for further nuclear power expansion will not be derailed by the Fukushima disaster, the media and the public are now beginning to question the safety of overly ambitious nuclear power development [41]. The convergence of these two trends - health concerns stemming from coal-fired power and skepticism over the safety of nuclear power - is engendering increasing public support for renewable energy solutions.

4.2. *Technological influences on Chinese electricity generation policy*

Research indicates that there are at least six technological clusters of forces that impact energy policy in China. Table 5 summarizes these six factors, which are then discussed in this section.

Grid coverage and resiliency in China is a concern. In response to unprecedented growth in demand for electricity, the government has initiated numerous grid expansion projects to connect new power sources and costly inter-connectivity projects (between China's regional power grids) to improve grid resilience. Between 2005 and 2009 grid investment rose 150% from RMB153 billion to RMB385 billion [31]. Nevertheless, as Fig. 9 indicates, since 1978, investment in grid infrastructure has lagged behind investment in generation capacity expansion [42]. Consequently, the power grid is no longer capable of effectively supporting installed capacity. To illustrate, in 2010, only 70% of installed wind power capacity was actually connected to the grid [43]. Of greater consternation, this also suggests that requisite funding for R&D to enhance smart grid technology and improve network resilience to incorporate higher contributions from renewable sources has been

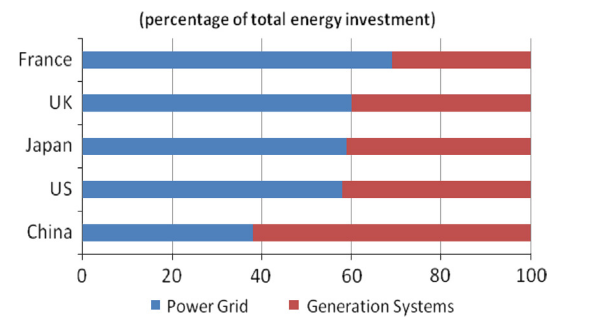


Fig. 9. National comparisons of investment in energy infrastructure vs. generation systems.
Source: [42]

insufficient to keep pace with renewable energy supply expansion. The CPC will need to spend US$1.1 trillion by 2020 to provide sufficient grid coverage and resiliency [2]. As the grid fortifies, the technological barriers to connecting renewable energy begin to diminish.

Although insufficient infrastructure partly explains why 30% of total installed wind power capacity was not connected to the grid in 2010, another impediment is the inherent rigidity of China's electricity mix. Coal-fired power dominates China's electricity mix. The current system lacks sufficient peak-load technologies to dampen power fluctuations from stochastic renewable energy technologies, such as wind power. Consequently, although China's Renewable Energy Law requires utilities to purchase all available renewable energy at prescribed prices, there is evidence that many utilities have been slow to accommodate new projects because the absence of sufficient peak-load technologies forces utilities to run coal-fired power plants at sub-optimal levels to provide peak-load support [31]. This inflates generation costs and has exacerbated utility resistance to wind energy [42].

The geographic separation of renewable energy supply centers from key demand centers also poses logistical challenges and inflates costs. 78% of China's hydropower resources are concentrated in the sparsely populated west. Meanwhile, the 11 provinces with the highest population concentrations possess only 6% of total hydropower resources [11]. The wind power story is similar. The areas of greatest onshore wind power potential lie in China's north – in regions such as Xinjiang, Gansu and Inner Mongolia. Conversely, aside from Hebei and Jiangsu Provinces, the major electricity demand centers in eastern and southern China possess limited onshore wind power potential [42]. Even in terms of solar energy where potential is more effectively dispersed across the nation, it is estimated that approximately 60% of the national solar PV potential still lies in the sparsely populated western and central regions of China [11].

Table 6
Reserves to production ratio for coal, oil and natural gas. Data from [10].

(Years)	China	World Avg	USA	India
Coal	41	122	224	114
Oil	11.1	42	12.4	18.7
Natural gas	32.3	60.4	11.6	35.6

All of this points to the foundations of a logistical dilemma. In order to tap China's abundant renewable energy potential, grid connections must be established to deliver electricity from supply centers to geographically distant demand centers. The CPC is striving to address this challenge. For example in 2007, the government awarded a contract to Siemens to construct a 1400 km high-voltage 800 kV DC transmission system with 5000 MW of capacity to connect Yunnan to Guangdong. Another project is now underway to connect Xinjiang's wind power riches to the rest of China. There is also a 1100 km long power line being constructed between Qinghai and Tibet that will cost roughly US $850 million (about US$772,000 per kilometer) due to the complexity of the terrain to traverse. Overall, it has been estimated that on average a 500 kV, 250,000 kV amp transmission line costs about $220,000 per kilometer in China [44]. In other words, although there is awareness that grid infrastructure needs to be improved, such projects take time and the sheer cost of expanding coverage and enhancing grid resilience forces policymakers to make some delicate fiscal trade-offs [43]. In the short-term, this dilemma enhances the attractiveness of larger nuclear and coal-fired generation plants that can be located near existing grid connections and partly explains the government policy of encouraging the development of wind farms of 100 MW or more [45].

It should be noted that the geographic challenge of getting energy to demand centers is not new in China. Many of China's coal mines are located in China's heartland, far from the major coastal demand centers. Consequently, coal transport uses almost half of all rail transport capacity in China [12].

Energy self-sufficiency has become an added concern for China's energy policymakers. Up until the first half of the 1990s, China was self-sufficient in its TPE supply. However, consumption growth rates ranging between 5 and 8% per year resulted in China becoming a net TPE importer in 1997 [11]. In petroleum, which is the stable fuel for powering transport, China imported only 7.6% of its supplies in 1995; but by 2007, petroleum imports exceeded 50% of consumption. In coal, which constitutes the dominant resource for electricity generation, abundant domestic reserves have permitted China to maintain a net export balance. However since 2000, China's export surplus in coal has declined from 52.9 million tons to 5 million tons in 2008 [10].

China's voracious consumption of energy has significantly diminished fossil fuel reserve-to-production ratios. Table 6 provides a comparison of fossil fuel reserve-to-production ratios for China, the United States, India and the global average. This data provides an indication of how long proven domestic reserves of the resource in question will last under current levels of annual usage. At current rates of consumption, China may have less than 41 years remaining before it becomes almost entirely dependent on imported fossil fuel [10]. Alarm over fossil fuel resource depletion has catalyzed a number of initiatives designed to improve energy efficiency and stimulated political support for alternative energy development [10,18].

The broadening of technological expertise provides policymakers with electricity generation diversification options that did not always exist. Prior to the 1970s, China's two core electricity generation technologies were coal-fired power and hydropower. Yet even so, engineering quality was desultory, as evidenced by the tragedy of the Banqiao Dam in Henan Province which collapsed in 1975 causing deaths in excess of 100,000. However, in the 1970s, technological expertise began to gel in new energy areas. China's commercial nuclear program formally began in 1972 with the "728 project", an initiative to develop submarine reactors [46]. Since then, Chinese engineers have completed 15 reactors in four locations; totaling 11,881 MW of installed capacity.[3] One of the government's key objectives in the early days of the program was to amass requisite knowledge and capability in all stages of the fuel cycle (uranium extraction and refining, fuel processing, plant construction, operation, and decommissioning) so that China could become self-sufficient by the end of the 1990s. As a consequence, Chinese policymakers now consider nuclear power expansion as a strategically attractive alternative to coal-fired power [47]. Similarly, although the first wind farm that was built in 1986 in Shandong used imported turbines [19], technological transfer has resulted in four Chinese manufacturers within the top 10 wind power turbine manufacturers in the world and scores of component suppliers [45].

The process of enhancing engineering prowess in electricity generation technology has been methodically planned. The CPC has even gone as far as to establish a specialized university – the North China Electric Power University in Beijing – with separate departments solely dedicated to advancing renewable energy and nuclear power science. To ensure China's new engineers developed world-class applied experience, the government has pursued a policy which encouraged joint ventures with foreign nuclear power and wind power firms [45]. In addition to training engineers to perform up to world standards, this policy has facilitated technological transfer.

The breadth of expertise that now exists within power engineering circles in China undermines the already wavering strength of coal-fired power interests. The coal industry has been an important employer of China's rural, unskilled laborers – employing nearly 4.9 million workers in 64,000 coal mines in 1997. Coal revenues have also been of high economic importance to coal rich provinces such as Shanxi, Inner Mongolia, Liaoning, Heilongjiang, Shandong and Henan. Consequently, a network of political support historically developed around the coal sector [48]. However, since the late 1990s, government initiatives to centralize coal production (to enhance safety and improve economies of scale) reduced the number of coal mines to 3215 in 2008. As of 2006, employment in coal mining had fallen to 2.6 million, a 47% decline from 1997 levels [48,49]. Although the economic importance of coal as a commodity remains high in many of the coal-rich rural provinces, the political importance of the coal mining sector has diminished as employment numbers fall and educational levels improve, thereby broadening employment opportunities. Furthermore, with exports now comprising almost 50% of all Chinese coal production, pressure to sustain the coal mining industry through a commitment to coal-fired power plants has lessened [48]. Overall then, coal-fired power plant advocates enjoy far less political leverage nowadays than they did a mere decade ago.

4.3. Economic influences on Chinese electricity generation policy

Research indicates that there are at least seven economic drivers that significantly influence electricity market dynamics in China. Table 7 summarizes these seven factors which are elaborated upon in this section.

[3] Source: World Nuclear Association: http://www.world-nuclear.org/info/inf63.html

Table 7
Economic influences on Chinese electricity generation policy.

Factor	Conditions in China	Influence
Fossil Fuel Price Levels	Worldwide, fossil fuel prices have been progressively escalating	Fossil fuel price inflation encourages increased production of both coal and oil; however, this also provides renewable energy technologies with a competitive window of opportunity
Volatility of fossil fuel prices	Worldwide, fossil fuel prices have fluctuated significantly over the past five years	Capricious fossil fuel prices make it difficult for electricity generation utilities to effectively set prices. Profitability in energy-intensive Chinese industries has been disrupted by energy price oscillations
Government fiscal health	The level of government savings is high; however, there are also many infrastructure development needs	Fiscal well-being allows Chinese policy makers to begin making longer-term energy policy decisions
Market development strategy	Tendency to support joint ventures to facilitate technology transfer. Established markets are gradually opening up to foreign competition	Heated competition in electricity generation technologies in China includes advanced supercritical coal, nuclear power, wind power and mini-hydro
Social costs	Pollution from coal-fired power plants is contributing to enormous health costs	With alternative energy technologies available, the social costs of coal-fired power are increasingly scrutinized
International economic influence	There is pressure from the international community for China to play a greater role in climate change mitigation	China is now the largest market in the world for CDM projects. International incentives encourage renewable energy development
Perspectives on economic security	Domestic fossil fuel reserves are dwindling	The justification that reliance on coal-fired generation provides a degree of domestic economic security is increasingly tenuous

Table 8
Fiscal surpluses in China (as a percentage of GDP).
Source of data: Govt savings [50]; China GDP (World Bank); GDP Savings (author's calculations).

	2002	2003	2004	2005	2006	2007	2008
Govt savings rate (%)	3.2	3.3	4.1	4.2	5.0	6.4	6.4
China GDP (2011 US$trillion)	1.45	1.64	1.93	2.26	2.71	3.49	4.52
Govt savings (2011 US$billion)	46.4	54.1	79.1	94.9	135.5	223.4	289.3

The progressive escalation of fossil fuel prices over the last five years has had some predictable consequences in China. High fossil fuel prices have heightened the economic contribution of fossil fuel production in fossil fuel abundant regions. This is particularly salient for coal-rich rural provinces such as Shanxi province. However, the escalation of coal prices has also diminished the national incentive to utilize coal for generating power. Moreover, as coal prices escalate, alternative energy technologies such as wind power and mini-hydro have become increasingly cost competitive. The evolving competitive dynamics partly explains aggressive development aspirations for wind power, hydropower and nuclear power in China.

In addition to price inflation, fossil fuel commodity prices have been extremely capricious in recent years. Price volatility is particularly damaging to utilities and electricity generators. The NDRC's Price Department has a practice of setting wholesale prices based on province-specific "average social costs", which tends to push inefficient generators to improve operating costs. Therefore, coal price volatility (which accounts for between 50 and 70% of coal-fired generation costs) complicates the process of rate setting. Moreover, when coal prices exceed benchmark prices for an extended period, it can create enormous financial hardship on power generation firms because the NDRC only allows 70% of coal price increases to be passed along to end-users through tariff increases. Although it is true that sudden dips in the cost of coal can cause windfalls for these same firms, coal price volatility is occurring during an inflationary trend, which suggests that there will be more losers than winners [19]. Indeed, a recent study of coal-fired power plants found that all the coal-fired plants in 10 selected provinces posted financial losses during the first three quarters of 2010 [43]. In short, price volatility incentivizes utilities to embrace forms of electricity generation that possess more predictable cost profiles. This enhances the appeal of alternative technologies (particularly wind power and hydropower) which exhibit more stable marginal cost profiles and somewhat offsets utility aversion to stochastic alternative energy technologies.

The financial ability of the CPC to facilitate technological transition within the electricity sector is enhanced thanks to an expanding economy and a high level of government savings. Despite extensive investment demands to bolster infrastructure and enhance social services, the government has managed to maintain fiscal surpluses since 1992 [50]. Table 8 illustrates the extent of savings. Between 2002 and 2008, the CPC amassed over US$922.7 billion in savings. Overall, the combination of a high degree of government savings and a proclivity on the part of the CPC to strategically guide economic development means that policymakers are able to think and act strategically in regard to electricity policy. In testament to this, as mentioned earlier, China's 11th national development plan (2006–2010) established robust targets for hydropower, wind power, solar PV, biomass and energy efficiency. In 2009, China purportedly invested a whopping US$34.6 billion in renewable energy development, compared to US $18.6 billion invested in the United States (the second highest level of renewable energy investment) [23].

China's approach to industrial development has also influenced electricity market dynamics. In many sectors – including electricity technology – the CPC has employed a two-pronged strategy of (i) encouraging joint ventures with foreign firms in order to facilitate the transfer of technology and production know-how and (ii) strategically protecting key industrial sectors from direct foreign competition to allow Chinese firms time to establish entrenched market positions. For example, China's first nuclear power plants were joint ventures which helped China's indigenous nuclear power firms acquire applied technical knowledge. As China's nuclear power firms matured, the government adopted a policy of allowing selective competition in order to push domestic firms to higher levels of performance [51]. Similarly, in wind power development, the Chinese government initially established local content regulations in order to ensure that Chinese firms were given the chance to develop manufacturing capacity. Once Chinese wind power manufacturers became established, these regulations were relaxed [52].

The economic costs of externalities associated with electricity technology also influences energy market dynamics. Chiefly, reliance on coal-fired electricity production has contributed to undesirable levels of atmospheric pollution. Additionally, as mentioned earlier, transporting coal from supply to demand centers in China congests rail networks and results in transport delays and increased costs for other transportable products. In 2007, 1220.8 million tons of coal was shipped an average of 607 km/ton along China's rail arteries, comprising 46.7% of all goods shipped by rail in China [12]. However, coal is not the only villain in the electricity sector. In hydropower too, mega projects such as the Three Gorges Dam have produced extensive environmental and social costs that the government is keen to avoid [53]. When there were no economically-viable technological alternatives to coal-fired electricity and large-scale hydropower, bearing the cost of negative externalities was considered unavoidable; however, this is all changing as costs for renewable and conventional energy converge.

Increasingly, international financial incentives and disincentives also influence China's electricity market. The Clean Development Mechanism (CDM) which allows fungible Certified Emission Reduction (CER) credits to be generated for approved alternative energy projects in developing nations such as China has played a support role in the development of alternative energy projects in China. CDM projects in China have accounted for 58.8% of global CERs issued since the program began.[4] Furthermore, an agreement made during the COP17 Conference in South Africa will give developing nations (such as China) access to a US$100 billion Green Climate Fund. Therefore, despite the possibility that the Kyoto Protocol (and the CDM) might collapse, international financial incentives for China to support renewable energy expansion remains. In terms of disincentives, international support appears to be amassing for "border taxes" – a carbon tax applied onto imported goods based on the energy profile of the exporting nation [54]. This is a disturbing development for Chinese firms because many of their exports are energy intensive. China is the largest producer of steel, cement and flat glass [10]. In 2008, CO_2 emissions associated with the production of goods for export accounted for approximately 3.1 Gigatons of China's aggregate CO_2 emissions of 6.5 Gigatons [55]. Any border taxes applied to Chinese exports could have a significant economic impact on industrial profitability. Consequently, it is in the interests of the CPC to ensure that China's electricity infrastructure is flexible enough to mitigate the impact of international disincentives of this type.

The economic security justification for coal-fired power is also crumbling and this will alter market dynamics. Historically, the latent economic value of China's coal reserves has underpinned a coal-dominated electricity generation sector. However, as Table 6 outlined, given that the consumption of coal-fired electricity is expected to double in China by 2035, coal will only be an abundant domestic resource for a few more decades [13]. Meanwhile, wind power, solar PV and nuclear power are increasingly seen in political circles as technologies which will enhance economic security in the near future [20].

4.4. Political influences on Chinese electricity generation policy

Research indicates that the influences of social, technological and economic forces have engendered change within the political environment that increasingly influences energy market development. Table 9 summarizes six key developments which are examined further in this section.

The CPC's perspective on energy security has evolved over the last two decades from a predilection to facilitating low-cost electricity generation to a more balanced view which also considers energy supply and environmental security as key considerations because prior prioritization of low-cost electricity generation has given rise to congested rail networks, high levels of pollution, amplified health costs and the gradual drawdown of China's ample coal reserves. Now, energy planners are aware of the need to reduce dependency on coal and oil as catalysts for fueling economic development [56,57] and there is a National Leading Group on Climate Change led by Premier Wen Jiabao to drive policy on decarbonizing China's industries [58]. Yet, there is also an understanding that transitioning away from coal and oil takes time; and as a result, the CPC has been active in overseas procurement of fossil fuel resources to bolster supply [12,59]. Advanced coal combustion technologies, carbon capture and sequestration and coal liquefaction have also been targeted for government support. Nevertheless, R&D investments are increasingly channeled into alternative energy technology both domestically and with overseas partners [60]. China now has over 60 collaborative agreements with other nations to enhance the pace of technological progress in renewable energy development [61].

In many nations, political opposition can have a significant impact on government energy policy [62]. In China, political competition only exists within the CPC; however, this intra-party power contest has been described as a "battleground of negotiation among different power actors with competing interests" [15]. Over the past five years there have been efforts on the part of the CPC to harmonize control over energy strategy. In 2005, the National Energy Leading Group (NELG) was established under the leadership of Premier Wen Jiabao to guide policy; and a State Energy Office was created under the State Council to coordinate strategic control of energy policy. The State Energy Office was assigned authority over the National Oil Companies and co-control over the National Energy Bureau, which was a bureau within the National Development and Reform Commission (NDRC) that was charged with implementation of energy policy. Lamentably, many of the administrative functions associated with energy (i.e. price setting, project financing, environmental oversight etc.) remained with other ministries, and the coordination between ministries was weak [58]. In part, this explains why grid connections were insufficient for supporting wind power capacity expansion in the mid-2000s [43].

In 2008, the CPC announced an intention to elevate the importance of energy governance by creating a National Energy Commission (NEC), which has been described as a "high-level discussion body with ministerial rank" [58]. The NEC would be responsible for centralizing energy strategy and setting energy policy while a sub-body, the National Energy Administration (which replaced the NDRC Energy Bureau) would take on the day to day tasks of managing China's energy system. It is perhaps illustrative of the politicization of energy in China to note that the establishment of the NEC and NEA took almost two years to finalize. In the end, it was agreed that the NEC and the NDRC would assume shared control over the NEA [58]. Some critics of this re-organization contend that the oversight of the NDRC complicates centralization of control and repeats the past error of too many cooks in the kitchen [63]. The restructuring also leaves authority for price setting with NDRC and fails to address the political power of the two state-owned grid companies and the "big five" state-owned power companies, organizations that are chaired by senior politicians [58]. Structurally, criticism of these reforms has some merit. Despite recent reforms, there are still a

[4] Source: UNFCCC web-site: http://cdm.unfccc.int/Statistics/Issuance/CERsIssuedByHostPartyPieChart.html

Table 9
Political influences on Chinese electricity generation policy.

Factor	Conditions in China	Influence
Energy security	Priority has shifted from affordability to a balanced focus; affordability, supply security and environmental security	A broader perspective diminishes the attractiveness of coal
Political opposition	No formal political opposition but rivalry between central and regional policymakers exists	Regional electricity generation strategies are emerging which exploit regional technological advantages
Government involvement in energy provision	Electricity generation is a strategic good. Two SOE operate control China's power grid	Emergent electricity strategy lacks transparency; but once declared, implementation of the strategy receives a great deal of buy-in
Investment perspective	The CPC possesses the will and means to direct development	Increasingly, China's energy projects are massive scale
General policy approach	The government exhibits a gradualist approach to economic development	This gradualist approach allows policy to be altered to improve efficacy
Economic development policy	"Scientific development" and rural infrastructure enhancement are top priorities	Alternative energy technologies better fit in with developmental ideology. Recent successes embolden new initiatives

number of national institutions that are involved in energy governance. These include the National Development and Reform Commission (NDRC), the National Energy Commission (NEC), the Ministry of Environmental Protection (MEP), the state Electricity Regulatory Commission (SERC), the National Leading Group on Climate Change (NLGCC) and the State Council Energy Conservation and Emissions Reduction Leading Group (SEPA) [58]. However, it bears pointing out that the NEC is Chaired by Premier Wen Jiabao, the most powerful administrative official in the nation. Furthermore, the Deputy Chairperson is Li Keqiang, who is widely touted to be Wen Jiabao's successor as Premier [64]. Therefore, there is an argument to be made for a contention that the progressive realignment of China's energy governance network is yet another manifestation of gradualist policy in action. The historical obstacles to a centrally harmonized energy policy regime are gradually being attenuated.

Unfortunately, the implementation of policy faces another set of obstacles. Under the NDRC, a host of sub-national development reform commissions (DRCs) exist at the provincial, municipal and county (district) levels. These DRCs all have responsibilities for implementing certain aspects of NDRC policy. However, these sub-national bodies are also accountable to sub-national political units. The Provincial DRC also reports to the Provincial Governor's Office, the Municipal DRC reports to the Mayor's office, and the County (or District) DRC reports to the Office of County Magistrate (or District head) [58,65]. Conflict occurs within this system of "two-dimensional" management whenever regional or local development aspirations conflict with national policy and the DRCs are forced to find a balance to appease its two masters. As one critic described this system, "there are policies from above and countermeasures from below" [66]. With the creation of the NEC, this picture is bound to become more complicated because the NEC effectively represents another master to obey.

In principle, the central government possesses the power to ensure acquiescence over sub-national government bodies; however, there is increasing proclivity within the CPC to allow regional policymakers to have more influence over regional development initiatives [67]. This certainly applies to electricity generation planning. Since the 1980s, provincial-level control has grown to the point where 45% of generation assets were owned by provincial-level companies in 2006 [31]. Consequently, regional electricity projects, which exploit regional technological advantages (coal or renewables) are receiving increasing support from the central government. An example is the Northwest power grid upgrading project, which has been centrally funded to connect wind power projects in Xinjiang to the China grid [44].

The CPC fully understands the strategic role that electricity plays in supporting economic development [10]. Therefore, even though the CPC has adopted a host of market reforms, it maintains control over electricity generation through the NEC and the NDRC's Price Department which sets wholesale and retail power prices and through two SOEs (the State Grid Corporation and the South China State Grid Corporation), which control China's six regional electricity grids. Government control over electricity has pros and cons. On one hand, policy design occurs in a black box, which makes it difficult to anticipate new directives. On the other hand, once CPC policy is announced, implementation tends to move forward with emphatic commitment. Government policy currently signals an ever-increasing commitment to alternative energy development [22] but the transition is proceeding at a comparatively cautious pace to ensure that such a transition can be (i) technologically supported and (ii) carried out without adverse economic consequences on China's industrial sector.

In China's centrally planned economy, the financial capacity of the CPC directly influences the pace and scale of development in the power generation sector. As mentioned earlier, the CPC possesses a significant amount of savings which allows it to drive development. Furthermore, by international standards, China's households and businesses possess extremely high levels of savings [50]. This suggests that government investment can be supplemented by the mobilization of private investment funds and indeed, in wind power development, this has been the case [68]. In aggregate then, one can likely expect government targets to be exceeded in the future as government projects upon which such projections are based are joined by private investment [45].

China's well-documented gradualist approach to economic development also applies to electricity sector development and influences energy market dynamics [69,70]. Although the gradualist approach has been criticized as being potentially sub-optimal in terms of expediting end-goals [5], the gradualist approach allows the government to assess the economic impact of a transition away from carbon-intensive electricity generation, to undertake the investment necessary to improve infrastructure for supporting such a transition and to refine policies to better encourage private involvement and effective power utility commitment [22].

A final influence on electricity market dynamics relates to the role that electricity technology plays in economic development strategy. In China, alternative energy technologies are seen as more than just technologies which provide electrification, they are seen as strategically significant industries which can electrify remote, impoverished communities and mesh seamlessly with China's "scientific development" ideology [18]. Successful wind power development has demonstrated that support for alternative energy yields commercial success. There are indications that this successful industry support policy will soon be replicated and applied to the solar PV industry, where Chinese firms already supply 30% of global demand [11]. There have been reports that new targets for solar capacity of 10 GW by 2015 and 50 GW by 2020 are imminent.[5] There are also indications that in addition to wind power and solar PV, the CPC views nuclear power as a strategically significant, commercial sectors [30].

5. Conclusion

The goal of this paper was to apply a STEP analysis to provide some insight into the forces which influence the evolution of China's electricity generation sector; and in particular, to determine how these forces will influence the pace, scale and scope of alternative energy. Predicting the evolution of electricity generation strategy in China will always be subject to interpretive error because electricity systems evolve in response to changeful influences from various social, technological, economic and political factors [24], which in aggregate comprise a complex adaptive system [71]. In a complex adaptive system, numerous interconnected variables change in response to both exogenous and endogenous influences and the nature of these interrelationships are so complex that the system cannot be quantitatively modeled to a sufficient degree of confidence [72,73].

According to complexity theory, although predicting developments within a complex adaptive system is fraught with potential for inaccuracy due to the complexity and malleability of interrelationships, general trends can be anticipated by focusing on how key variables respond to likely scenarios. Beinhocker [74] refers to this process as "emergent landscapes". In electricity generation, likely scenarios include the continuation of high fossil fuel prices at or above current levels [2,75], progressive improvement in the economic competitiveness of alternative generation technologies [76,77] and escalating international pressure to abate GHG emissions. If we assume that these three conditions will be evident over the next three decades, we can draw from the STEP Analysis presented in the previous section to gain some insight into the evolution of China's electricity sector.

In China, economic influences still significantly shape electricity generation policy. The government sees affordable access to electricity as vital both for social stability and continued economic growth in many of China's energy intensive manufacturing sectors (especially in rural areas) [19]. However, the combination of escalating, unpredictable fluctuations in coal cost has served to undermine the competitive attractiveness of this energy source. Meanwhile, with wind power, mini-hydro and nuclear power all within striking distance of economic parity [19,78], there is ample economic incentive for policymakers to reconsider the role of coal in China's electricity generation mix. Furthermore, congestion of Chinese rail networks caused by coal transport is increasingly scrutinized as the nation struggles to provide sufficient transportation infrastructure to support emerging industry [15]. This all points to amplified levels of political support for wind power, mini-hydro, geothermal power (where possible), and nuclear power.

The economic case for some alternative energy technologies is bolstered by the strategic commercial potential of these sectors. China's experience with wind power to date has been largely positive. In the process of becoming the world's largest wind power market, it has nurtured the development of four of the top ten wind power firms in the world. There are growing indications that the government intends to replicate the experiment with solar PV by setting an enormous target of 50 GW by 2020 (China currently has about 700 MW of installed solar PV capacity).[6]

Wind power faces a particularly bright future in China once short term development barriers are overcome. The costs and logistical challenges of ensuring sufficient grid connections and providing suitable peak-load capacity to offset stochastic power flows suggests that the pace of wind power growth may soften somewhat as Chinese energy planners endeavor to implement the infrastructure investments necessary to accommodate high levels of this resource. It is likely that the 12th five-year plan will establish a wind power capacity target of approximately 100 GW for 2020, which would represent a doubling of 2010 capacity. Although this would be an impressive accomplishment, indications are that the economic benefits of wind power developments to rural regions, the growing strategic importance of the wind power industry and the affordability of wind power will produce significantly amplified levels of wind power development as China's electricity grid develops. It would not be surprising to see the CPC establish a 2040 target of 300 GW for wind power.

Over the next decade or two, the STEP analysis suggests that nuclear power may enjoy sizable gains in aggregate capacity development. Low levels of civic activism, centralized control over electricity system planning, negligible political opposition, public acceptance of relatively high levels of environmental risk and indigenous engineering competency provided ideal conditions for the cultivation of nuclear power development [30]. Despite the nuclear disaster in Japan, the CPC has shown no signs of backing away from its nuclear power development ambitions [42]. Not only does this suggest that the 11th five-year development plan target of 40 GW by 2020 may be soon upgraded to 60 GW, if coal prices continue to rise and international pressures for GHG mitigation continue to escalate, it would not be inconceivable for China to significantly ramp-up development. A 2040 target of 300 GW for installed nuclear power capacity in order to support government ambitions of reaching 400 GW by 2050 would not be surprising.

Hydropower capacity can also be expected to increase significantly over the next decade or two. The low-carbon characteristic of this energy source and low levels of civic activism suggest that even major hydropower projects may be forthcoming. Economically exploitable hydropower capacity in China has been estimated at 402 GW. Therefore, although the government may continue to endorse hydropower development to provide much needed peak-load support, it is doubtful that it would establish a mid-term target for 2040 that exceeds 400 GW [11,44].

China's 12th five-year plan also portends a significantly enhanced commitment to solar PV development. Increasingly, rumors are emerging that the next renewable energy plan will establish a 2015 target of 15 GW and a 2020 target of 50 GW for solar PV. This represents an enormous commitment to solar PV. In terms of industrial policy, one should not be surprised to see the Chinese government adopt a similar strategy to supporting solar PV industry development as it did for supporting the wind power industry. Although some critics have called solar PV a "great gamble" [79], given the enormity of China's electricity generation infrastructure, 50 GW of solar PV power would have negligible adverse economic impact on aggregate electricity generation costs. Conversely, such a commitment would exert a substantial positive influence on development prospects for solar PV firms in China.

In conclusion, this paper has hopefully demonstrated how it is possible to apply STEP analysis in an energy policy context to evaluate "emergent landscapes" in the electricity sector. Such an

[5] Shi er wu kezaisheng nengyuan fazhan mubiao mingque (12th Five-Year Plan Renewable Energy Development Targets Now Clear), Zhongguo Zhengquan Bao (China Securities Journal), August 30, 2011, available at http://news.xinhuanet.com/fortune/2011-08/30/c_121931669_2.htm.

[6] Source: "China Revs Up Renewable Energy Goals", 21 September 2011. http://www.sustainablebusiness.com/index.cfm/go/news.display/id/22926

analysis lacks the precision that may exist in studies where cause and effect relationships can be statistically verified. However, the elements identified within the STEP analysis as influencing energy market development in China represent a first step to better understanding the "seamless web" [24] of technical, social, political, and economic causal factors that influence the evolution of electricity networks. In Mandarin, there is an apt expression, "when the water ebbs, the stones will appear" (shuǐ luò shí chū 水落石出). In this context, only further research will validate the path altering capabilities of the strategic stones in China's electricity sector.

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