Renewable Energy 35 (2010) 1879–1886

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Review

Wind power development and policies in China

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ARTICLE INFO

Article history:
Received 7 June 2009
Accepted 10 November 2009
Available online 24 March 2010

Keywords:
Wind power
Potentials
Diffusion
Regulation
Policies
China

ABSTRACT

The People's Republic of China foresees a target of 30 GW for installed wind power capacity by 2010 (2008: 12 GW). This paper reports on the technical and economic potentials of wind power, the recent development, existing obstacles, and related policies in China. The barriers to further commercialization of the wind power market are important and may deter the 100 GW capacity target of the Chinese government by 2020. The paper concludes that the diffusion of wind power in China is an important element for not only reducing global greenhouse gas emissions, but also for worldwide progress of wind power technology and needed economies of scale.

1. Introduction

The present economic development in China is quite similar to that in Western Europe during the 1950s and 1960s: high growth rates and a low level of GDP per capita of US$$_{2008}$3200/cap. in 2008 (EU-15 2006: US$$_{2006}$32 900/cap.). China – like many other emerging countries – is undergoing complete industrialisation and a rapid increase in privately owned automobiles, which substantially increased its primary energy demand during the last decade up to 78 250PJ (1863 Mtoe; without non-commercial firewood) in 2007, despite major energy efficiency improvements achieved during the last decade [1].

1.1. Present and future energy demand, related air pollution and CO_2 emissions of China

Per capita primary energy use in China is presently (2007) 59 GJ/cap.*a, i.e. a third of EU-27 (155GJ/cap.*a), or a sixth of the US level. Domestic primary energy production was 69 800 PJ (1660 Mtoe) in 2007, with rapidly increasing oil imports (7600 PJ in 2007) due to the equally rapid growth in vehicles on the road [1]. Excluding non-commercial energy use (mainly wood), the structure of primary energy use in China has a 70% share of coal, reflecting the large domestic coal resources, 20% oil (increasing trend) and some natural gas (3.3%) and nuclear energy (0.76%) (see Table 1). Globally, China is the largest coal user and became the second largest oil consumer in 2002. Coal is likely to play a major role in China's energy system and in electricity and steel production for the foreseeable future.

This kind of energy structure and conversion technologies causes serious environmental problems at the local and regional levels due to harmful emissions such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter. The State Environmental Protection Administration (SEPA) estimated environmental costs as $64 billion (5.78% of GDP) in 2003 [2]. Sixteen of the world's twenty most polluted cities are located in China [3] and at least 400 000 deaths occur each year in China from pollution-related diseases. The heavy dependence on coal also causes some 6000 deaths annually in coal mining related accidents [4].

The primary energy structure contributes substantially to global greenhouse gas emissions, especially CO_2, which totalled 6.2 billion t in 2006 (about 21% of the world total of 29 billion t), making China, for the first time, the world's largest emitter of CO_2 [5]. Although China's per capita emissions (4.8 tCO_2/cap) are just a quarter of the United States', they will rise further due to large increases in coal usage (for power generation and steel making), oil products (for transportation) and natural gas (for industry, power generation, and heating). The IEA projects 6.2 tCO_2/cap in 2015 (surpassing Switzerland) and 7.9 tCO_2/cap in 2030 for China's energy-related CO_2 emissions in its Reference Scenario [6].

Because of the threat of climate change, the Chinese government is making monumental efforts to promote energy efficiency,

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doi:10.1016/j.renene.2009.11.024

Table 1
Structure of primary (2007) [1] and final (2006) [8] energy use in China.

Energy carrier	Coal	Oil/oil product	Natural gas	Electricity	District Heat	Hydropower	Nuclear	Total
Primary energy use in 2007 in PJ (%)	55 079 (70.4%)	15 456 (19.7%)	2545 (3.3%)	–		4591 (5.9%)	596 (0.8%)	78 262 (100%)
Final energy use in 2006 in PJ (%)	18 073 (43.1%)	13 277 (31.6%)	401.7 (1%)	9622 (22.9%)	569.4 (1.3%)	–	–	41 950 (100%)

R&D of clean coal technology, and the gradual substitution of coal use in electricity generation by hydropower, other renewables like wind and biomass, and natural gas and nuclear energy [7].

Given the dilemma of fast economic growth and related energy use versus the need to reduce global CO_2 emissions, China sees renewable energy resources as viable sources of primary energy in the mid and long term. Hence, at the World Renewables Conference in Bonn in June 2004, the Chinese government announced that it would generate 10% of its electricity demand using renewable energy sources (excluding large hydropower) by 2010 (in 2005, the share of hydropower was 17%). China also aims for a 20% increase in energy productivity from 2006 to 2010 (total increase till 2008: 10.08%). To aid these efforts, China is closing small, low-efficiency thermal power plants, small coal-mines, cement factories, steel and iron mills. 16.7 GW of small thermal power plants were shut down in 2008 [9]. When results fell short of target in 2007 by 1.3%, the government increased funding for energy efficiency efforts by 78% in 2008 to $6 billion. Furthermore, a mandatory government procurement list of energy-efficient products was issued, covering more than 10 000 items. SEPA was elevated to the Ministry of Environmental Protection, conferring it much greater powers of implementation, while the new National Energy Administration was also created [10].

1.2. Electricity use and generation in China

Today, China has the world's second largest electricity generating industry. The per capita electricity use of 2140 kWh/cap*a, however, still represents that of an emerging country (EU: 6000 kWh/cap*a). In 2008, total installed generation capacity crossed 792 GW, which the government expects to double by 2020 (to nearly 1500 GW; see Tables 2 and 3). But the boom in the Chinese economy and the related growth of per capita income, and the consequent impact of the global financial crisis, makes it difficult to predict future demand. The electricity intensity increased in the past few years, from a low of 0.42 kWh/$$_{2000}$ in 1999–0.56 kWh/$$_{2000}$ in 2007 (see Fig. 1), but is likely to reduce in a few years.

At present, 78% of China's power generation capacity is provided by thermal power plants, mainly coal-fired. Coal use in electricity generation increased from 190 Mtoe in 1990–829 Mtoe in 2006 [6], emitting 2.8 Mt of CO_2. The IEA's reference scenario projects a decreasing growth rate of coal use, averaged at 4.9% per year between 2006 and 2030, possibly due to increased shares of alternate sources of power, as well as gains in efficiency of coal-based power generation. The growth from 1971 to 2006 was 8% yearly, a trend expected to continue till 2015. Coal demand may reach 1639 Mtoe by 2010, and 2400 Mtoe by 2030.

The IEA envisages smaller contributions from renewables to electricity generation (15% including hydropower for 2030) than the Chinese government does (16% in 2020), maintaining the 80% share of fossil fuels in electricity generation in China. Both projections, however, foresee the CO_2 emissions of China crossing 10 billion t by 2020. This underlines the importance of new renewables, as well as more efficient energy use and carbon capture and storage technologies.

Given these challenges, this paper reports on the technical and economic potentials of wind energy use in China for the next two decades. It analyses present wind power use and development, including an overview of wind power equipment manufacturers in China (see Section 2). Major barriers to further market development and commercialization of wind power in China (see Section 3) and related current policies are outlined and discussed (see Section 4).

2. Wind energy development in China

In the last two decades, wind energy developed rapidly from an R&D innovative technology to a commercialized one, particularly in OECD countries. It is an important renewable energy resource, surpassing hydropower use in some countries with low hydropower potentials (e.g. Denmark, Germany, Spain). The wind power sector is now competitive with traditional hydrocarbon-fuelled electricity in many regions, due to the continued reduction in generation costs, especially over the last five years.

2.1. Wind energy potentials in China

China is located in South-East Asia, near the Pacific Ocean. It has long monsoon periods; the winter monsoon lasts six months in northern China, and the south-east monsoon affects half of eastern China. Comprehensive investigations were conducted on the wind

Table 2
Past [11] and future electricity generation capacity in China by energy source, 1995–2007, projections until 2030.

Year	Installed electricity capacity (GW)					
	Total	Hydropower (large)	Fossil fuel	Nuclear	Wind energy	New renewables
1995	217.2	52.2	162.9	2.1		
2000	319.3	79.4	237.5	2.1		0.3
2008	792.5	165	607	9.08	12.2	
2010[a]	950	194	700	<12	20	5.5(Bio)
2020[a]	1470	328	800	70	90–120	30(Bio)
2030[a]				120–160	180–270	
2030[b]	1775	300	1370	31	49	28

[a] *Source:* projection by the State Grid Corporation of China, NRDC and National Energy Association [12–14],
[b] *Source:* IEA 2007 Reference Scenario Projections [13].

Table 3
Past [15,11] and projected electricity production in China, 1995–2008, with projections up to 2030.

Year	Electricity production (TWh)				
	Total	Hydropower	Fossil fuels	Nuclear	New renewables
1995	1007	187 (18.6%)	807 (80.1%)	12.8 (1.3%)	n.a.
2000	1369	243	1108	16.7	0.8
2008	3433	563.3(16.4%)	2750	68.4(1.99%)	12 0.8(wind)
2010[a]	3810	650	3100	160	*200 (6.2%)*
2020[a]	7400	1100 (14.1%)	3460 (69.8%)	400 (8.1%)	*400 (8.1%)*
2010[b]	4200	575	3400	82	*44*
2020[b]	6400	800	5200	160	*90*
2030[b]	8472	1005	6948	256	*263*

[a] *Notes:* projections by the China Electricity Council, State Grid Corporation China [13]
[b] *Notes:* projections by the IEA WEO 2007 [6].