The Status of the Biomass Industry in China: Past Mistakes and Future Opportunities

Simon Parker

CEO, DP CleanTech Co. Ltd

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Executive summary

After 10 years of unpredictable and uneven progress, the agri-based biomass to power industry in China is set for rapid and sustained growth; and will generate above-normal profit returns for those companies which have understood and addressed the problems of the past.

The biomass combustion to power industry in China has evolved far more rapidly than in other countries; from a "standing start" in 2004 to an estimated ~300 biomass power plants to date. Inevitably, many mistakes have been made in this precipitous growth. Since the first pilot projects were demonstrated in 2006, the industry has already gone through a cycle of rapid growth, then stagnation. The initial euphoria and early success of the first few years was undermined by 3 fundamental factors.

Firstly, the lack of understanding regarding the complexity of biomass combustion frequently resulted in selection of the 'wrong' technology, with disastrous economic and operational consequences. Secondly, there was significant underinvestment in the fuel supply and logistics infrastructure. Finally, the experience and adjustment curve necessary for measured development was negated by the "land grab", and the resulting problems stifled genuine progress.

These related factors combined to create some high profile failures, which have had a subsequent negative effect on investor confidence, bankability of projects and therefore the growth of the industry. Many of the projects failed catastrophically, and were unable to recover. Despite this negative environment, those projects led by DP CleanTech achieved relative success – due largely to the company's superior biomass technology; extensive fuel expertise and long experience in the biomass industry. On the whole, domestic competitors and operators simply did not have the necessary level of knowledge or understanding of complex fuel biomass combustion. For the most part, developers were relatively unsophisticated and overly focused on the 'cost of purchase', rather than 'total cost of ownership' for a 20+ year investment. This was symptomatic of a short term approach which pervaded the industry and led to a high level of failures. Some renewable energy industry participants have now been able to learn from early experiences and in some cases, the profitability of biomass plants now exceeds that of most other renewable businesses in their portfolio. Today, a combination of socio-economic factors, government policies and a more sophisticated approach to biomass investment are in place to drive a new, positive business cycle.

The industry appears poised for renewed, and more considered growth. The Chinese government has long outlined its ambitions for renewable energy as a key element of its energy portfolio. As such, it has always recognized the huge potential to utilize straw biomass for distributed energy. The truly renewable nature of straw provides many advantages over wood- based fuels, yet today less than 5% of available straw in China is effectively utilized for biomass energy, compared to over 85% in Denmark.

The Chinese government has strongly and repeatedly voiced 3 overarching priorities for the nation. We believe that these priorities are also 3 very compelling reasons to believe that the future of the biomass industry in China is assured.

1. Food security for the nation
2. Social redistribution of wealth from rich to poor and urban to rural dwellers
3. Improving and managing environmental pollution

The number one objective for the Chinese government is to be able to feed its people and this has been stated by Chinese central planners and enshrined in planning documents. Whilst the second and third factors are extremely powerful in driving economic and social progress, they are both inextricably linked and subsequent to the primary objective of food security. The goal of achieving food security is the highest priority but it is also the driver for realising the other objectives. Every measure taken to increase productivity in the field (whether land change, industrialization, mechanization, education, and crop yield improvement) has a direct and immediate impact on the agri-biomass industry. We would therefore make the very strong case that investing in the agricultural biomass industry is a de facto investment that parallels the Chinese Government's priorities and long term primary agenda. The 20+ year investment horizon for power plants is well matched to the targeted outcome of the government's agri-policies. However in order to ensure profitability it is clear that the "mistakes made" must become "lessons learned". Shrewd operators and investors who have recognized this are starting to emerge and take advantage of the significant opportunities being presented. As an industry pioneer, DP CleanTech is committed to be at the forefront of this change, ensuring that the industry is stronger and more sustainable for stakeholders and beneficiaries.

The future fuels for biomass energy

In the mid to long term there is no doubt that the most abundant biomass resource will be agri-residues.

- The Chinese Government's top priority is agricultural reform
- Agricultural reform (industrialization, land reform, productivity improvements) will increase independence of food production and improve the social redistribution of wealth to rural china.
- All Government incentives in this, and the environmental protection agenda, will flow through to improving biomass industry dynamics. Straw is a natural by-product of agriculture and the development of agriculture will see more and more by-product become available.

- Today 50% of existing straw is not utilized. In Denmark 85%+ of the straw resource is used in production of power and heat.
- Straw agricultural residue is a truly renewable resource because the energy is captured and renewed every year or 2 times per year along with grain food production. There is no depletion of resources.
- Wood takes years to regenerate. The supply of easily collected wood residue is finite - much of it is inaccessible in mountainous and forested areas; and difficult to collect and transport. Wood residue supply will become more limited in the future and the relative prices will rise.

A biomass power plant built today MUST be based on the future security of the fuel supply (availability and price) for the next 20 years and beyond NOT ONLY about what has historically been cheap, accessible and available.

The science of biomass combustion is indisputable

Biomass combustion is complex - but there are some incontrovertible facts:

- Agri-residues will have relatively high chlorine and high sodium (Na) and potassium (K) content. High temperature corrosion is a substantial risk with such fuel types.
- The same factors will result in a low ash melt point that must be managed
- The density of agri-residues is always low, and will therefore have a tendency to slag.

Many of the catastrophic failures in China's history come from the fact that there was limited appreciation or understanding of these factors. Using modified coal fired technologies which were cheaper resulted in permanent shutdown of plants with loss of debt and equity**.**

Any power plant built today must acknowledge these facts and select technology that is proven to be able to handle them throughout the 20+ year investment.

The economics of a successful biomass industry are clear and well proven

A Feed in Tariff (FiT) is particularly important at the early stages of industry growth. In China, a unified network power price of CNY 0.75/Kwh has been in place for both agricultural & forestry biomass energy projects since 2010. It is expected that support for biomass will continue as part of the overall renewables agenda and over time, we may expect to see some differentiation in incentives between forestry and agri-biomass to align with government priorities. Aside from the FIT, the most important factors are:

- Power plant availability: This is the single biggest determinant of profitability. Selecting the right technology is critical. Beyond this, investing in automation, reliable equipment, commissioning, operator training, and scheduled maintenance programmes are all directly relevant to profitability.
- Boiler and plant efficiency: This becomes increasingly important as fuel becomes more expensive. Put another way, buying the most efficient and flexible solutions provides the

greatest insurance against future fuel price spikes; whilst paying attention to total plant efficiency adds directly to the bottom line.

- Fuel availability in the long term: Food stocks are the driver and these may change as the country progresses. Logic would dictate that the design and construction of plants should be as flexible as possible in order to handle varied fuels.

In summary, we would assert that the following points are the key considerations for any developer or stakeholder (investor/ financial lender/ company) who is reviewing the opportunities for biomass power plant investments in China.

- Biomass to energy offers substantial profit potential
- However, the skills in successfully developing and managing a biomass plant are quite distinct from those required for a conventional fossil fuel power plant
- Long term fuel availability is a major factor in power plant economics. Existing agricultural policies in China highly favour a future that is centred on straw availability and affordable utilization. The relative price of wood-based feedstock is likely to increase over time
- Key characteristics of straw biomass agri-residues are high chloride levels; low ash melt points and varying densities. Combustion boilers and auxiliary plant equipment must be designed for these properties
- Power plants must be designed and built with maximum fuel flexibility
- Design and build power plants that are as efficient as possible as an 'insurance' against future fuel and energy price variability
- A 20+ year investment horizon must consider the implications of all the above to ensure that the right technology is selected; and that the project is designed and executed as a total "fuel to stack" solution.

The Status of the Biomass Industry in China:

Past Mistakes and Future Opportunities

1. Recent history of biomass in China

The last 10 years of biomass development in China have been a very condensed cycle of 'boom to stagnation'. In some senses, it is a typical China growth story which has been seen in various industries. Change is rapid, there are few checks and balances, and limited industry knowledge at the outset allows poor industry practices to flourish - ultimately creating a dramatic halt to successful growth.

Since its inception in 2004, DP CleanTech has been a key player in the industry in China. For better or worse, we have therefore been witness to, and involved in, many of the developments that have taken place. We entered the market in China with a deep understanding of biomass and of the fundamental factors that affect profitability at a power plant level and success at an industry level. However, we entered the market with little to no understanding of the China market and how it operates. We feel privileged to have been on a unique journey which has given us unrivalled experience and a distinctive position in the China market. The market is maturing quickly, and offers incredible opportunities within China, as well as enabling us to take what we have learnt out of China to improve profitability in other regions.

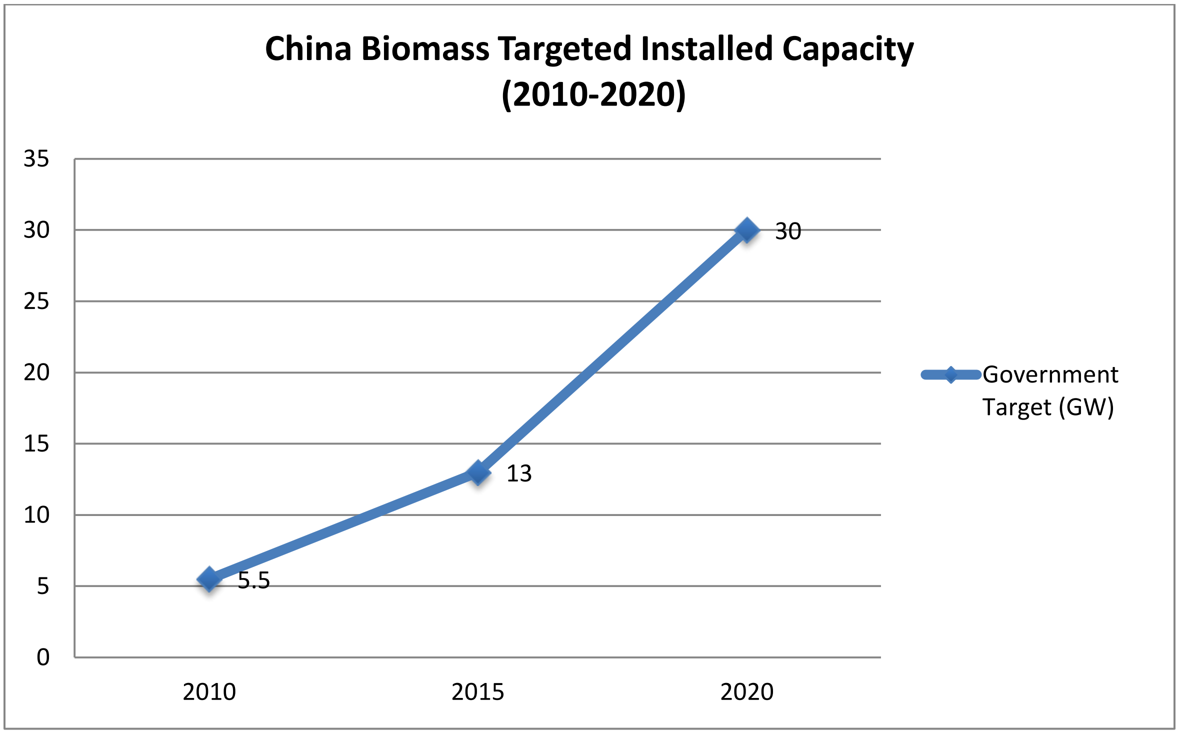
The building blocks of the business are essentially to correctly align specific technologies to specific fuels; and to implement this in a commercial manner. The way in which these elements complement each other to deliver long term profits are governed by regulatory policy, combustion science and longstanding experience.

Our depth of understanding of the industry leads us to firmly believe that many of the fundamentals have now taken their place in a virtuous circle of development; and that going forward; the circumstances in China are well poised for profitable growth.

2. Is biomass an important part of the energy supply portfolio in China?

Government targets for biomass as a renewable energy source have been in place for many years, and have remained unchanged, if somewhat ambitious.

Fig 1. Biomass targets in China[1]



Sources: NDRC 10th/11th/12th Five Year Plans for biomass development

The laws of numbers in China always provide fascinating - if hard to comprehend - facts. China intends to generate 30 GW of power from biomass (not just renewables) by 2020. This is greater than the entire electricity production of nations such as Ireland and Slovakia; and achieving this target in biomass alone would make China the world's 65th largest electrical power producer[2]. Based on available figures, it is estimated that installed capacity from biomass is ~12GW[3] .

[1] *Source: NDRC 2010 " Long term development plan for renewable energy" (可再生能源中长期发展规划)*
[2] *Source: US Energy Information Administration - International Energy Statistics 2012*
[3] *Source: "2013 China Biomass Project Construction Statistical Report" (2013 中国生物质发电建设统计报告) released by National Renewable Energy Information Management Center.*


Wheat straw


Wood bark

3. What is the status of biomass fuels in China today?

A review of the potential biomass feedstock available for use indicates the extent of the massive under-utilisation of existing resources.

Fig 2. Biomass resource availability and utilization[4]

Biomass Fuel Type	Location	Theoretical Arithmetic (Tons)	Current annual utilisation (Tons)	Remaining Potential (Tons)
Agricultural straw, waste from agri-food processing (corn, rice, wheat, cotton and oil crops) AGRICULTURAL STRAW WASTE	13 major crop producing areas, including Plain of North China, lower & upper reaches of Yangtze river, Northeast China etc.	690,000,000 per annum	350,000,000 for fertilizer, animal feed, mushroom cultivation base and paper-making etc.	340,000,000
Rice husk, bagasse and other agri – food processing AGRICULTURAL WASTE - NON STRAW	Not specified	120,000,000 per annum	60,000,000 Landfill	60,000,000
Forestry Residue including fuelwood, waste from cutting & processing WOOD COLLECTION AND WASTE WOOD	Mainly mountainous areas of China	350,000,000 Current availability, but not sustainable year on year		350,000,000, capable of producing 50,000,000 tons of biofuel annually

[4] *Source: NEA 12th Five Year Plan for Biomass Development 2010-2015 (生物质能发展十二五规划)*

Agricultural waste

- China has a theoretical 690 million tons per annum of straw production. Of this, an estimated 350 million tons are used for purposes other than energy production.
- If all 690 million tons was used for biomass energy... This equates to 800+ G.Kwh units of energy per annum.
- , Based on current usage patterns, 340 million tons of straw and 60 million tons of agricultural waste from food processing (husks, shells etc.) remain available per annum
- However, most of this is currently being lost through field burn / decomposition
- This equates to about 500+ G.kwh units of energy EACH YEAR if all is converted to power
- This is equivalent to more than 2000 x 30MW biomass power plants.
- As domestic fuel burning decreases, and food production increases we believe the actual potential to be far greater

Currently there are approximately 300 biomass power plants in China using different technologies[5].

Wood harvesting and wood waste

- China has about 350,000,000 mill tons of woody wastes that can theoretically be used for energy, which equates to about 400 G.kwh units of energy each year.
- A large percentage of this is in forest regions that are very difficult to collect and transport and there is limited incentive to increase access to these potential fuel supplies.
- The readily available wood is the waste byproducts from industry; such as furniture.
- This available waste is high quality, relatively dense, easy to burn. It is the 'low hanging fruit' of the biomass world. The problem with this is that it always gets eaten first.

There is sufficient biomass potential in China for a long term biomass industry, but in order for it to play an economically viable part in the biomass to power industry it must be sustainable and affordable.

Fig 3. Major crop producing areas and biomass potential[6].

Agri straw types	Million Tons	Major crop producing areas
Rice Straw	211	Liaoning, Jilin, Heilongjiang,
Wheat Straw	154	Inner Mongolia, Hebei,

[5] Calculation based on "2013 China Biomass Project Construction Statistical Report" (2013 中国生物质发电建设统计报告) released by National Renewable Energy Information Management Center. By end 2013, excluding Qinghai, Ningxia and Tibet, 28 provinces have biomass power plants. Total approved installed capacity reached ~12230MW, of which 7790MW was connected to the grid, about 63.72%. If calculated on 30MW/ each power plant, around 260 power plants are in operation. We therefore estimate the total number to be around 300.

[6] Source: Nov 2011 NDRC " The Implementation Plan on the Comprehensive Utilisation of Agricultural Straw during 12th Five Year Plan" ("十二五" 农作物秸秆综合利用实施方案)

Corn Straw	273	Henan, Hubei, Hunan, Shandong, Jiangsu, Anhui, Jiangxi, Sichuan
Cotton Straw	26	
Oil Crop Straw (rape, peanuts)	37	
Beans	28	
Potato	23	

4. Chinese government priorities and policies

Chinese Government laws and strategy are outlined at the highest level through the "Five Year Plans". These are then filtered down to a provincial level for implementation, with an overlay of medium level plans from Ministries and Development Agencies.

The most recent National plan for development issued by the NPC is China's "12th Five Year Plan" (FYP) 2011-2015[7], released in March 2011. The 13th Five Year Plan is expected within 2016.

The 12th FYP blueprint[8] for development emphasized 'high quality growth" rather than "rapid growth". Key themes revolved around:

- Sustainable growth
- Moving up the value chain
- Reducing disparities
- Scientific developments
- Environmental protection
- Energy efficiency
- Domestic consumption.

Provincial –level laws and policies reflecting the targets, priorities and direction outlined in the 12th Five Year Plan have subsequently been included in the Five Year Plans of individual provinces; and ministries and agencies such as the NEA (National Energy Agency), NDRC (National Development and Reform Commission) and MOA (Ministry of Agriculture) and others have also drafted supporting laws and targets for implementation of the Plan.

Ahead of official publication of the 13th Five Year Plan and in the intervening period since the release of the 12th Five Year plan, there have been many indications regarding the priorities that will be pursued. It is expected that the following themes will continue:

- Food security for 1.3 billion people - primarily through agricultural industrialization
- Social redistribution of wealth – rich to poor, urban to rural – through formal integration of urban migrants and land ownership reform

[7] *See: https://www.kpmg.com/cn/en/IssuesAndInsights/ArticlesPublications/Documents/China-12th-Five-Year-Plan-Overview-201104.pdf*
[8] *See: http://www.gov.cn/2011lh/content_1825838.htm (国民经济和社会发展第十二个五年规划纲要)*

- Controlling environmental pollution – energy, water, air pollution
- Economic transition towards services based and value added economy – development of key industries.

In addressing these issues, there are significant direct and indirect implications for the future of renewable energy and biomass energy in particular.

5. Agricultural industrialization and energy policies in China 2011-2015

Many policies have been introduced that promote and support the development of agriculture in order to:

- Increase the output and productivity of agriculture in order to improve food security
- Promote the comprehensive use of straw residues (for energy and other industries).

The policies cover mechanization, soil and crop improvements, land reform, water and transport infrastructure. Since 2010, there have been increasingly explicit directives from government agencies to guide the development of agriculture and the efficient utilization of straw byproducts.

We are also observing policies aimed towards increasing forest cover; moving away from deforestation practices; and discouraging domestic wood burning as part of the environmental and pollution management policies.

For a list of relevant policies, please see Appendix 2

The scale and breadth of agricultural reform policies imply that in the future there will be:

- Increased volumes of agricultural straw residues for use available at relatively lower costs
- Relatively less wood fuels available

It is clear that any operators considering a biomass-related strategy in China MUST look ahead and be focused on the *efficient* conversion of straw to energy in order to be viable in the long term. This has implications for all aspects of the supply chain as well as the technology choice.

6. Biomass fuel types and the science of combustion

Almost any agricultural residue can be combusted, and for centuries, agricultural by-products have been used domestically for fuel and heating. However, to combust agricultural by-products efficiently and on an industrial scale requires very specific understanding of the fuel composition and characteristics. Furthermore, the storage, feeding system and feedstock size are all important factors in optimizing the energy output.

As a general rule, wood-based fuels are the easiest to combust. Straw based fuels and other agri-wastes from food processing are more corrosive - due to their high alkali content - than wood based fuels. Whilst energy can still be extracted from such fuels, the failure to understand the impact of corrosiveness, and to apply the correct technology does not simply result in lower efficiencies, it can result in the total and complete collapse of the boiler installation.

During the post-oil crisis years of the 1980's, a number of forward-thinking states in Europe began to reconsider their paths to energy security, in particular the use of biomass. Denmark, which had an economy highly focused on straw-based agriculture, led the research and development into efficient ways to handle and extract energy from these high alkaline fuels. The Danish government invested millions of dollars to develop and put into operation the first successful commercial scale straw-fired biomass plant in the world[9]. It was operational in 1990 and is still operating today. DP CleanTech acquired this technology; brought it to China and since 2006 has deployed it on a substantial scale. DP now has over 50 biomass plant references in China alone, and has a corresponding depth of experience unrivalled by any other providers globally.

DP CleanTech's patented technologies were designed and developed specifically for the combustion of biomass fuels. The overall solution and detailed design engineering are considered from beginning to end, starting with fuel analysis through to emissions control. Understanding the relationships between fuel, equipment and profitability are key to any power plant design.

A fundamental factor in the success of DP's technology is its ability to handle straw biomass, as well as mixtures of woody and herbaceous biomass. Importantly, we use High Pressure High Temperature boilers which derive better efficiencies. DP's experience in China has enabled additional adjustments for characteristics of domestic fuel types that further enhance such efficiencies. If the fuel of the future is trending towards high alkali corrosive fuels, the technology must be able to handle these characteristics.

Wheat straw

Corn straw

[9] *2.3MW plant in Rudkobing, Denmark, 1990*

Rice straw

Bean Straw

Fig 4. Fuel slagging propensity – Alkali content[10]

			Total Alkali			
Fuel	Btu/lb (dry)	Ash %	% in Ash	lb/ton	lb/MMBtu	
WOOD						Minimal Slagging
Pine Chips	8,550	0.70%	3.00%	0.4	0.07	.4 lb/MMBtu
White Oak	8,165	0.40%	31.80%	2.3	0.14	
Hybrid Poplar	8,178	1.90%	19.80%	7.5	0.46	
Urban Wood Waste	8,174	6.00%	6.20%	7.4	0.46	Probable Slagging
"Clean"						
Tree Trimmings	8,144	3.60%	16.50%	11.9	0.73	
PITS, NUTS, SHELLS						
Almond Shells	7,580	3.50%	21.10%	14.8	0.97	Certain Slagging
Refuse Derived Fuel	5,473	9.50%	9.20%	17.5	1.60	
GRASSES						
Switch Grass	7,741	10.10%	15.10%	30.5	1.97	
Wheat Straw-average	7,978	5.10%	31.50%	32.1	2.00	
Wheat Straw-hi alkali	7,167	11.00%	36.40%	80.0	5.59	
Rice Straw	6,486	18.70%	13.30%	49.7	3.80	

7. What can we learn from the history of China's biomass industry?

The early success of China's biomass industry was followed rapidly by a period of stagnation and divestment. DP CleanTech has been part of this cycle and is uniquely placed to review the lessons to be learned from the past.

[10] *Source: Thomas R. Miles, Thomas R. Miles Jr., Larry L. Baxter, Bryan M. Jenkins, Laurance L. Oden. Alkali Slagging Problems with Biomass Fuels, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry, Volume 1, 1993*

In countries where the industry has matured, the path to maturity has taken more than 25 years. In China, the first national demonstration plants were operational in 2006 and regulatory policies and incentives drove a rapid increase in the industry. Within several years, however, the industry was much less profitable and was beset by many problems which eroded investor and operator confidence. An 18-month moratorium on new plant approvals was imposed by the government in 2011 to early 2013. This provided the necessary time for the industry to recalibrate; and for the more mature companies to reflect on the key drivers of long term profitability. Today, the main areas of focus for such companies are the long term availability and affordability of feedstock, and the selection of the right technology.

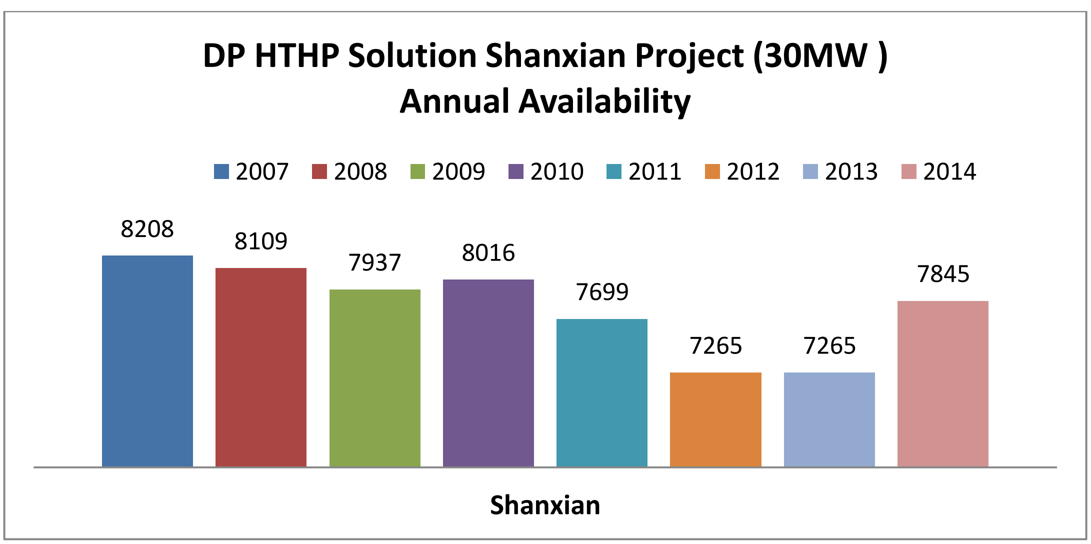
8. 2005-2011: The first phase of biomass industry growth

In 2005, active Government policies and incentives were put in place to develop a biomass-to-power industry in China.

Three national demonstration biomass combustion projects were approved in 2000.

1) Shanxian (DP HPHT Water Cooled Vibrating Grate solution for NBE))
2) Rudong Jiangsu province (Water Cooled Vibrating Grate solution by Wuxi HuaGang)
3) Jinzhou province (Water Cooled Vibrating Grate solution by Wuxi HuaGang)
   - Of the pilot projects, only Shanxian was successful (see table below)
   - Shanxian was able to operate more than 8000 hours each year (from 2006 until today).
   - The Rudong HTHP plant took 5 years to ramp up to normal operation.
   - The JinZhou MTMP plant failed after several years.
   - DP's HTHP high efficiency solution saved 20% biomass fuel when generating the same power as the other solutions.

Fig. 5. National Demonstration Project (NBE) Annual Availability 2007-2014. [11]



[11] *NBE statistics 2007-2014*

8.1. National Bioenergy Co. Ltd (NBE)

From 2005 - 2008 NBE (National Bioenergy Co. Ltd) was the leading investor in China's new biomass industry and developed one of the National Demonstration Projects. Shanxian started operation in 2006 and proved to be the only demonstration project which was successful.

Shanxian succeeded where the other pilot projects failed due to the key factors of superior combustion technology and rigorous project execution. Using DP CleanTech HPHT technology, the plant design was properly matched to the fuel combustion characteristics. The project was vertically integrated, from design to commissioning, using expert analysis, design and manufacturing input from global DP CleanTech resources. This ensured a high quality solution where the design basis and principles were followed through into operation. Thorough training was provided to the operators and maintenance schedules were followed.

DPCT's guaranteed European technology was used for all further NBE projects, which was not made available for non- NBE project developers. With strong government support and with DP CleanTech as a reliable technology and project execution partner, over 40 plants were built in the initial 7 years.

However, although the technology remained very robust, the 'execution' of subsequent plants, and the ability to follow the design principles and philosophy became less reliable. This, in turn, led to inconsistent results. The right technology ensured that there were no failures, only 'better' and 'worse' performing plants. Furthermore, the long term negative effects of inadequate investment of time and intellectual capital into the issues of feedstock management started to become clear, and plants became less profitable. (See Appendix 1 for a Comparison of DP and non-DP power plant performance).

Fig 6. Operational statistics for DP's first five biomass plants[12]

Power output (M/kwH) 2007-2014

Project	2007	2008	2009	2010	2011	2012	2013	2014	Operation date
Shanxian	225.64	207.54	225.04	222.05	200.61	217.94	223.27	235.34	12/1/2006
Weixian	141.99	177.47	206.82	226.7	212.44	228.46	223.92	211.14	4/16/2007
Chengan	155.52	179.55	204.6	223.65	202.28	221.74	225.02	223.37	4/16/2007
Gaotang	139.39	195.04	190.49	214.92	185.9	204.28	212.4	226.41	4/18/2007
Kenli	76.99	151.23	201.51	212.12	206.07	176.19	198.63	210.77	6/27/2007

[12] *NBE statistics 2007-2014*

Power plant availability (hours/annum)

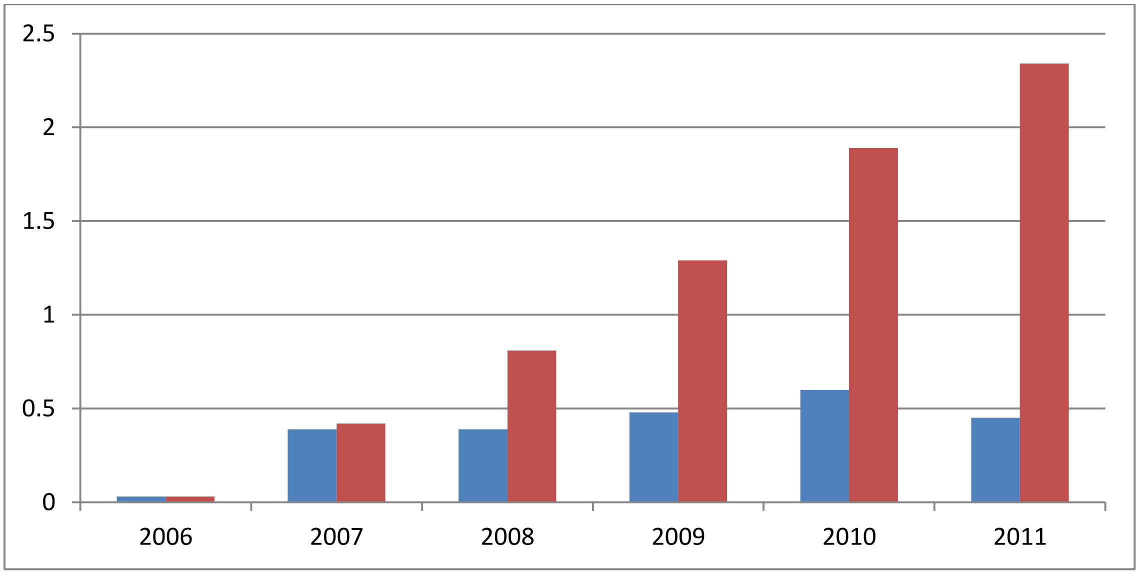
Project	2007	2008	2009	2010	2011	2012	2013	2014	Operation
Shanxian	7521.3	6918.0	7501.3	7401.7	6687.0	7264.7	7442.3	7844.7	12/1/2006
Weixian	4733.0	5915.7	6894.0	7556.7	7081.3	7615.3	7464.0	7038.0	4/16/2007
Chengan	5184.0	5985.0	6820.0	7455.0	6742.7	7391.3	7500.7	7445.7	4/16/2007
Gaotang	4646.3	6501.3	6349.7	7164.0	6196.7	6809.3	7080.0	7547.0	4/18/2007
Kenli	2566.3	5041.0	6717.0	7070.7	6869.0	5873.0	6621.0	7025.7	6/27/2007

The first biomass power plant in China
– DPCT/NBE Shanxian power plant

8.2. Rest of the market

The rest of the market also grew, mainly using domestic MPMT (Medium Pressure Medium Temperature) or CFB (Circulating Fluidized Bed) technology. However, the approach to investment, execution and operation standards continued to reflect those of the existing coal-based 'build and operate' power industry.

Fig 7. Growth in biomass plants in China 2006 – 2011[13]



Annual Increase in plant capacity (GW)
Total annual capacity

The "Big 5" Chinese utility companies entered the market early - partly to meet renewable energy targets mandated by the Government, Using predominantly MTMP solutions adapted from their experience in coal-firing, the complex reality of biomass combustion eluded their understanding. The plant sizes were small and they did not receive the sufficient attention and focus required in order to be successful. The failures were significant enough for several utility companies to seek to divest their biomass businesses within several years. To meet renewable energy obligations, the State Utilities turned instead to wind, and latterly to solar, where the scale was greater and the requirement for success was driven more by financial capital than technology.

The natural first response to biomass plant failures was to blame a lack of adequate Feed in Tariff (FiT) incentives. However the truth was that they were due to a fundamental misunderstanding of biomass power plant economics; a failure (or refusal) to focus adequately on detailed feasibility studies and solutions, and to a short term approach to investment. Power plant failures began to dominate the perception of the industry, and it

[13] *Source: NEA statistics 2011*

became increasingly difficult to find financing.

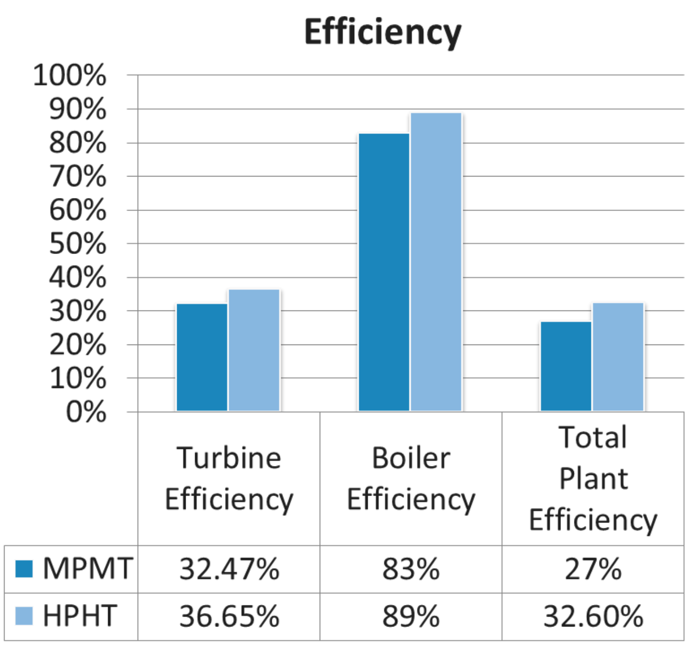
9. 2011-2013 Biomass industry stagnation and the path to maturity

Industry stagnation

After 5 years of rapid growth, the government became alarmed at the rate of failure and as a partial response it imposed restrictions on biomass power plant approvals from late 2010-2012. During this period, the authorities sought to identify the fundamental problems afflicting the success of the industry, and a number of policies to address the key problems of fuel quality and collection began to emerge.

At the same time, the more astute biomass industry players had also started to comprehend the economic relationships of the key factors - specifically the importance of fuel - and sought out the expertise of technology experts such as DP CleanTech to explain and demonstrate the relative efficiency and benefits of HTHP solutions.

Fig 8. Comparison of Medium Pressure, Medium Temperature and High Pressure, High Temperature efficiencies[14]



	MPMT	HPHT
Temperature	470°C	535°C
Pressure	4.90MPa	8.83MPa
Total Investment Cost (USD)	$37m	$41m
Annual Fuel Cost (USD)	$10.5m	$8m

Some biomass companies and suppliers also began to upgrade their technology to reflect some of the technology gaps.

[14] *Source: DPCT calculations based on operational data 2012*

It also became evident that the technologies and understanding required for wood based combustion was less complex; and the range of technologies available greater. The scale of the failures and mistakes were less catastrophic. For example, Kaidi, with a focus on wood-based fuels began to realize the importance of efficiencies and upgraded pressure and temperature ranges for their equipment. Since 2011 they have developed many plants.

Kaidi operational data from 2011-2013[15] show the improvements that have been made in the change from MTMP to UHP.

Fig. 9 Kaidi operational data 2011 - 2013

Reporting Period	Power Plant Number & Installed Capacity	Total Output / Month (MW.h)	Average Output/Power Plant / Month (MW.h)
May, 2013	6 (2* 12MW)	88253.4	14708.9
Oct, 2013	6 (2* 12MW)	9380.87	15630
Sep, 2013	6 (2* 12MW)	110111.8	18351
July, 2013	6 (2* 12MW)	67429.3	11238
Jun, 2013	6 (2* 12MW)	50110.23	8351
Jan, 2013	7 (2* 12MW)	68739.1	9810
Dec, 2012		56654.8	9440
Nov, 2012		65745.6	10950
Oct, 2012		36200	6030
Sep, 2012		37250.6	6200
Aug, 2012		19128.3	3180
Jul, 2012		9604.6	1600
Jun, 2012		23434.2	3900
May, 2012		41540	6923
Apr, 2012		38965.2	6494
Mar, 2012		41157.4	6859
Feb, 2012		33866.9	5644
Jan, 2012		60812.4	10135
Dec, 2011		53006.2	13251
Nov, 2011		41776.4	10444
Oct, 2011		45680	11420
Sep, 2011		39766.5	9941
Aug, 2011		34213.2	8553
Jul, 2011	4 (2* 12MW)	44364.1	11091
Jun, 2011		46640	11660
May, 2011		43960	10990
Apr, 2011		41530	10382
Mar, 2011		43405.2	10851
Feb, 2011		25931.6	6482
Jan, 2011		30149.5	7537

[15] *Source: various media; self-reported by Kaidi.*

Some companies opted for a wood-based fuel strategy as an easier and more manageable solution that could yield acceptable levels of profitability; and this sector has seen improved results. However, a subset of the market continued to look for longer term solutions in which there is greater flexibility in fuel choice. Operators such as Chant (Yishui), Everbright (Dangshan), and other investors have generally avoided technologies that heavily restrict fuel flexibility. This reflects a fundamental and important change in levels of understanding related to the importance of matching fuel and technology.

10. The key problems affecting the smooth development of the biomass industry in China?

In the early years, the industry was dominated by a general lack of understanding of the complexity of biomass fuels and the economics of biomass power plant economics.

- Most entrants were Government utility power companies with little or no understanding of biomass combustion or fuel characteristics.
- They believed that biomass was not only like coal, but that all types biomass was also the same: 'Biomass is biomass'
- They completely underestimated the importance of fuel collection/ logistics
- Feasibility studies were poorly executed
- The focus and competence was on large centralized units (the fossil fuel model); not on decentralized power
- Deficiencies in technical knowledge and understanding:
  - the fuel handling/ preparation/ feeding and combustion (excluding DPCT plants)
  - Installation and Commissioning (excluding DPCT plants)
- The importance of operations and maintenance. Significant under- training of operatives, and reluctance to consider proactive maintenance.
- Short term investment mentality focused on 'cost of purchase'
- The structure of the existing power industry restricted potential changes in business approach.

During the 1970's and 80's, the economic and logistic infrastructure of the power industry was developed rapidly to facilitate low cost mass deployment and drive economic development using coal fired plants. The industry norm was, and still is, to build plants using separate specialists for manufacture and execution (design institutes, installation, turbine suppliers, commissioning companies). Arguably, this model was suitable for standard coal fired plants. However it is totally inappropriate for the complexities of a biomass plant which demand vertical specialization and integration from fuel analysis, to design, emission controls and commissioning. Deploying and integrating solutions 'from field to the stack' is a fundamental change in industry structure which was difficult for many companies to comprehend or embrace.

11. So how and why were DPCleanTech projects able to outperform?

DP projects consistently outperformed other plants due to the superior, proven technology and the application of biomass expertise in design, construction and operation. (See Appendix 2)

- DP solutions (fuel handling/ fuel feeding and most importantly, combustion) were designed specifically for the most challenging of biomass fuels (high in alkalis).
- However DP solutions are also capable of handling less complicated biomass (woody residues).
- When fuel types became variable and quality deteriorated, DP's solutions were flexible enough to handle it and maintain performance levels.
- Vertical integration at the outset. The first Shanxian project deployed expert European resources to implement a fully integrated approach to design and operation. Fuel analysis, design, manufacturing supervision, installation, commissioning and O&M training, were considered as a 'whole solution', thereby ensuring an overall optimization of efficiency.

Did DP make any mistakes?

In hindsight, there were a number of areas in which DP were not successful. With a strong desire to scale the industry, the demands of standardization became pressing. Modularization was (and is) important for scalability, but over time, plants were being built without the application of the necessary discipline in design, commissioning and operation. Whilst all plants performed adequately, they were, in fact, underperforming against potential.

At the same time, the pressure on pricing brought about by the 'cost to purchase' mentality began to dominate, leading to compromises and cost reductions which were rationalized by the upfront savings. Insufficient time was spent in explaining design parameters, commissioning, in E&I, in automation and in operator training. For many projects, operators did not endorse vertical integration, and focused on further driving down costs through the use of multiple supplier contracts and equipment. The result was poor and variable performance in several plants.

Subsequently, DP engineers and biomass experts have worked intensively with clients to review and address performance issues at a number of power plants. Through this exercise, DP has gained considerable operational knowhow, and has used this information to implement important modifications to meet the challenges of biomass fuel and logistics in China.

12. 2013+: Cautious growth towards a profitable future in biomass

Today, we are observing a greater emphasis on the wood-based biomass industry, driven by lower technical barriers, cheap and available fuel from wood processing industries and a lesser need for focus and deep involvement in fuel logistics and preparation. However, we envisage that a strategy based on low hanging fruit will not be sustainable, and over time the industry could once again become dominated by plants that cannot handle the fuels available.

Fortunately, a number of business driven, data-centric companies are emerging that may change this balance. With the benefit of a slightly later entry to the market, companies such as EverBright, ShaoNeng and Chant are leading the way towards a paradigm change in the industry; pursuing performance and investing in efficiency and quality. Existing players, such as NBE have learnt from their experience and now have a deeper understanding of the issues and problems that need to be overcome. It would appear that many of the fundamentals are aligning to provide a renewed and different basis for growth.

Will they succeed?

Within the biomass industry, there is a greater understanding of the need for vertically integrated solutions rather than the traditional 'horizontal' model on which the power industry in China is built. This model does not focus on the optimizing the value chain..

Investors, operators and design engineers are beginning to understand and appreciate the relationship between fuel, technology and power plant efficiencies and adjust their business strategies accordingly. They are increasingly focused on long term plant availability and efficiency; and understand that these are dependent on selecting the right technologies for the fuels that will be available. The importance of fuel characteristics and fuel logistics is now better accepted, and it is increasingly obvious that the smarter companies are planning plants that will be consistent with government policies to promote greater agricultural production usage of straw-based by-products.

Approaching power plant design, acquisition and ongoing operation as a whole solution - not as individual projects - enables a plant that is designed and integrated - from fuel analysis to operations and emissions control. This is the best approach to maximizing plant profitability.

Many positive platforms are now in place to ensure that the industry can grow steadily and profitably. The strategic companies have learnt from the experience of others and are positioning themselves with regard to:

- Government policy (renewables/agriculture)
- The science and technology of biomass fuel combustion (HPHT/UHP)
- Fuel and power plant economics (plant reliability, fuel price variability, plant efficiencies)

13. Some predictions for the China biomass power industry

- Those companies which can learn from the past will be in a strong position to take advantage of the changing economic environment. Some key players will rapidly emerge.
- There will be a change to focus on 'cost of ownership', not 'cost of purchase'
- This will lead to a shift in approach regarding the importance of technology selection, overall plant design and long term boiler and operational efficiencies.

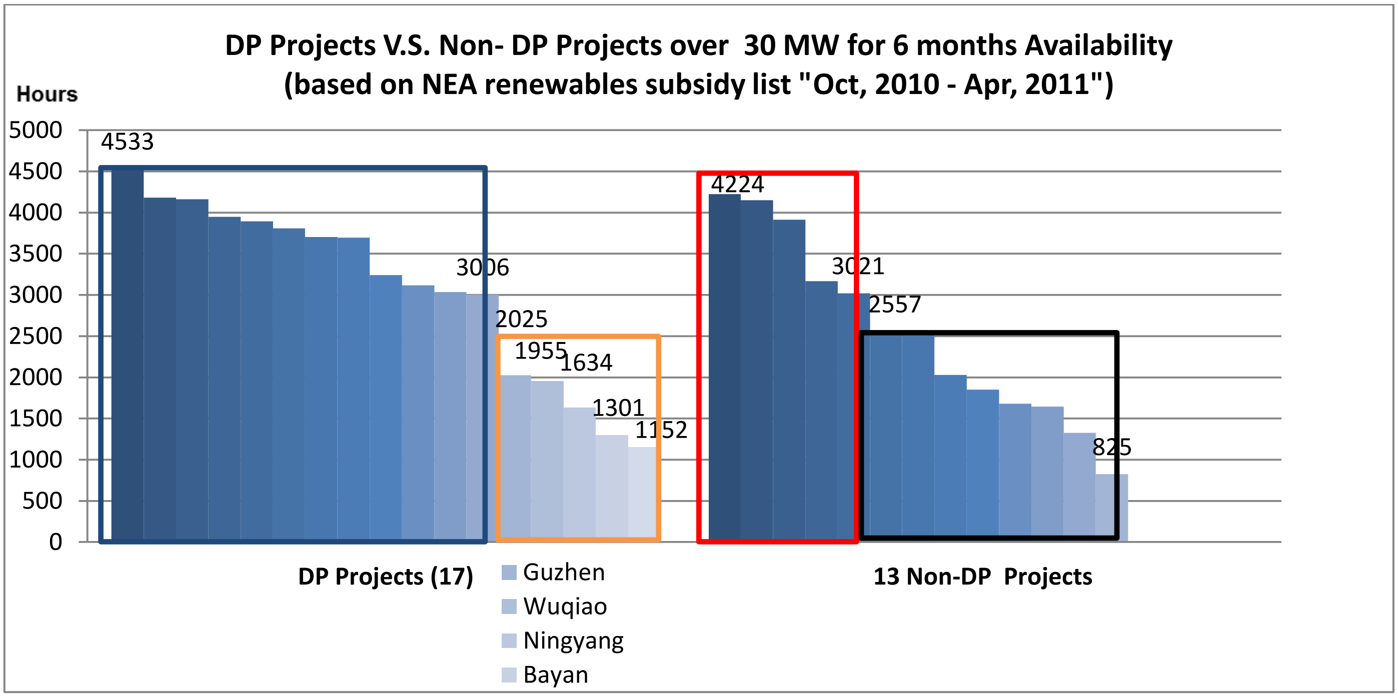
- Specifically:
    - Increased emphasis on overall plant and equipment efficiency
    - Higher investment in energy management to reduce auxiliary power requirements by up to 5% (from 11-12% to ~7%)
    - An increase in pressure parameters (to 160 bar)
    - Investment in more efficient and reliable turbines
    - Greater understanding of importance of commissioning, and the specialized skills required
    - Greater reliance on automation/fuzzy controls and reduction in human resources to run the plants
    - More proactive maintenance scheduling to reduce unplanned outages and other costs
    - Development of more efficient auxiliary equipment (e.g. feeding systems)
    - Increased consideration of fuel handling and fuel storage economics
    - Relative reduction in long term profitability of CFB technology plants
    - It is anticipated that the 13th Five Year Plan will continue to promote utilization of straw for biomass fuel; and continue to support biomass power plants as a primary renewable energy source
    - Government initiatives to stabilize marginal land through fast growing energy crops will also provide new sources of feedstock
    - The industry in China can become not only more profitable but innovative technologies developed and refined in China can lead the way for nascent biomass industries worldwide

As a leading player and pioneer in the biomass industry, DP CleanTech is committed to be at the forefront of this change, ensuring that the industry is stronger and more sustainable for stakeholders and beneficiaries. The company is introducing technologies specifically focused around the future requirement of clients in China, as well as working to bring the 'lessons learned' to other countries.

Biomass fuel collection

Appendix 1

Comparison of plant availability: DP CleanTech and non-DP CleanTech technology plants



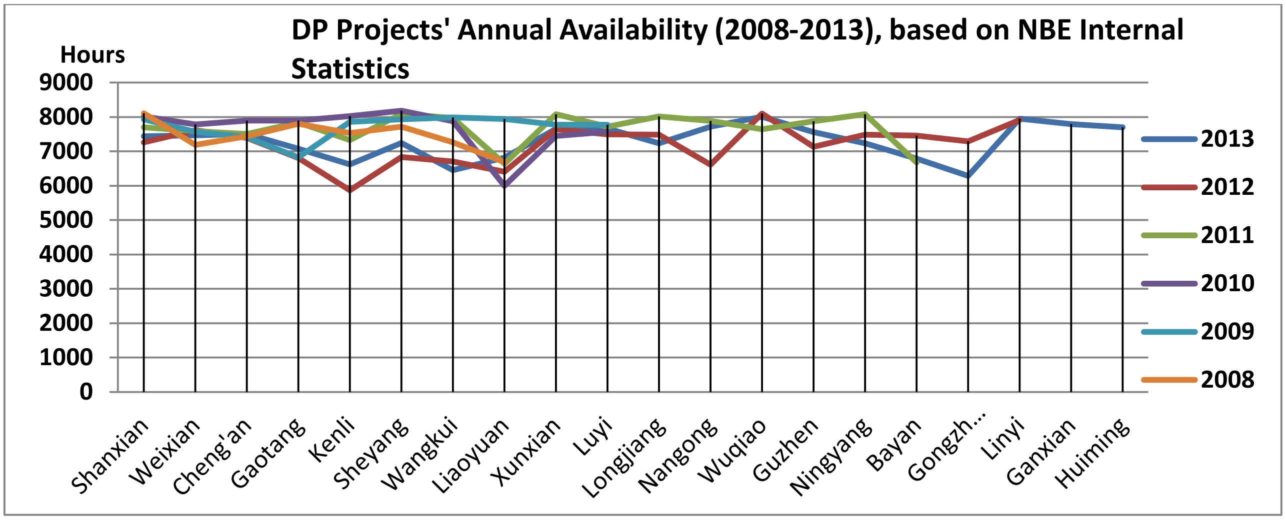
Source: All data is based on NEA Renewable Energy Power Generation Project Subsidy list (Oct, 2010 – Apr, 2011); (2010 年 10 月至 2011 年 4 月可再生能源发电项目补贴表)

- All projects are 30MW, located in different regions.
- Projects are sorted in descending order; each bar represents 1 project

Key findings:

1. **12 out of 17 DP projects (71%, blue box)** have an availability over 6 months period of between **3000 – 4500** hours
2. **5 projects** DP projects (**29%, orange box**) operated at **below 2500 hours**. These are **Bayan, Guzhen, Wuqiao, Ningyang and Liaoyuan**:
   - **Bayan** operated for 4 months;
   - **Guzhen** operated for 4 months;
   - **Wuqiao** operated for 4 months;
   - **Ningyang** operated for 3 months;
3. **Liaoyuan** has been operating since Nov 2011, therefore reasons for low availability are not clear. **5 (38%, red box) out of 13 non-DP projects**' availability over a 6 month period is between **3000 – 4500** hours
4. **9 (69%, black box)** non- DP projects operated **below 2500 hours**. We do not have information about reasons for low availability.

5. Overall, the availability of DP projects is higher than non-DP projects.



Source: NBE internal statistics

- All projects are 30MW, operating for at least 12 months / entered stable operation / completed warranty period in that year;
- **The period covered is from 2008 -2013**. The number of projects increased year on year.

Year of Operation	No. Projects with Annual Availability Above 8000hs		No. Projects with Annual Availability 7000-8000hs		No. Projects with Annual Availability 6000-7000hs		No. Projects with Annual Availability Below 6000hs		Total No. of Projects operating for more than 12 months
2013	1	5%	14	70%	5	25%	0		20
2012	1	6%	11	61%	5	27%	1	6%	18
2011	3	19%	11	69%	2	13%	0		16
2010	3	30%	6	60%	0		1	10%	10
2009	0		9	90%	1	10%	0		10
2008	1	12.5%	6	75%	1	12.5%	0		8

Key findings:

1. 2008-2013, 5-30% of DP projects annual availability was above 8000 hours
2. 2008-2013, most (60-70%) of DP projects annual availability was 7000-8000 hours
3. 2008-2013, some (10-27%) of DP projects annual availability was above 6000-7000 hours
4. 2008-2013, very few (6-10%) of DP projects annual availability was below 6000 hours
5. Overall, the majority of DP projects have maintained a stable operation during this period, with annual availability between 7000-8000 hours.

Appendix 2

A Summary of High Level Policies, Opinions and Work PLANs supporting Agricultural Reform in China (2011-2015)

1. **2010 July, "The Notice on Agricultural and Forestry Biomass Energy Price Policy" (关于完善农林生物质发电价格政策的通知) released by NDRC**

Main Points:

- Confirmed the unified network power price for all agricultural & forestry biomass energy projects in China as CNY 0.75.

2. **2010 September, "The Notification on Management for Biomass Power Plant Approval" (关于生物质发电项目建设管理的通知) released by NDRC**

Main Points:

- No approval unless project is included in biomass energy development program.
- No approval unless projects have confirmed biomass resources.
- No more than 1 biomass power plant per 100km radius.
- Priority for power and heat. Only 2 unites are permitted for each power plant.
- In consideration of fuel collection, the installed capacity should be within 30WM.

3. **2011 November, "12th Five Year Agri-Straw Comprehensive Utilization Implementation" （"十二五"农作物秸秆综合利用实施方案）released by Ministry of Agriculture/NDRC**

Main points:

China's agricultural straw output has reached 840 million tons, of which around 700 (752M) million tons could be collected. This is made up of

- paddy rice straw (211M),
- wheat straw (154M),
- corn straw (273M),
- cotton straw (26M),
- oil crops straw (37M),
- beans straw (28M)
- potato straw (23M).

In 2010 around 500M (483M) of agricultural straw was being collected and used. Approximately 218M tons is used for animal feed; 107M tons for fertilizer; 18M tons for mushrooms; 18M tons for paper-making; 122M tons for fuel (household, biomass).

The official government estimate of the utilization rate is therefore around 71% .

Most of the straw biomass is to be found in China's 13 major grains producing areas: Liaoning, Jilin, Heilongjiang, Inner Mongolia, Hebei, Henan, Hubei, Hunan, Shandong, Jiangsu, Anhui, Jiangxi and Sichuan. In these regions, the total straw production is about 615M tons, occupying ~73% of China's total cultivated land.
The plan aims to direct comprehensive utilization towards:

- Fertilizer and on ground fertilization - encouraging the use of straw shredders.
- Animal feed
- Straw-based mushroom cultivation.
- Straw based paper-making, construction panels, activated carbon and xylosic alcohol.
- Straw energy utilization including direct-combustion, gasification, pellet, and carbonization.

4. **2012 January, "The program to control greenhouse gas emissions during 12th Five Year Plan Period" (“十二五”控制温室气体排放工作方案) released by the State Council**

Main Points:

- To reach the 2015 goal of 17% reduction in carbon dioxide emissions the program aimed to speed up the development of low carbon urban energy and industrial infrastructure.

5. **2012 July, "12th Five Year Plan for Biomass Development 2010-2015" （关于印发生物质能发展“十二五”规划的通知）released by NEA**

Main Points:

- Enhance biomass energy R&D and management; complete biomass energy technology systematic management; guarantee biomass raw material supply security; cultivate energy crops; support enterprises efforts to explore biomass raw material collection system and make a balance between supply and consumption.

6. **2012 August, "Development Plan for Renewable energy of the 12th Five Year Plan Period" (可再生能源发展十二五规划) released by NDRC**

Main Points:

- By the end of 2015, the target for installed capacity of bio-mass energy is 13,000MW; and the 2020 target is 30,000MW.
- By the end of 12th "Five Year Plan Period", bio-mass energy in the countryside will reach 8,000MW; bio-gas energy will reach 2,000MW while waste to energy is 3,000MW.

7. **2013 March, "National Modern Agriculture Development Plan (2011-2015) III" （全国现代农业发展规划 2011—2015 年）released by the State Council**

Main Points:

- This plan outlined key tasks in 8 areas, and is very much focused on improving productivity and quality of agricultural output. A full list of relevant policies at Ministry level over the last 4 years is highlighted in the Ministry of Agriculture's website.
- Improve the modern agricultural industry system; Large-scale development of high standard farmland construction; accelerate agricultural mechanization; Improve agricultural infrastructure and equipment; Improve agricultural infrastructure and equipment; Improve agricultural industrialization and scale management level.

8. **2013 December, "Central Rural Work Conference address" （中央农村工作会议）released by CPC, Central Economic Work Committee**

Main Points:

- In an unprecedented move by a President of China, President Xi JingPing personally attended and addressed the conference, reiterating the importance of rural transformation and food security.
- The Conference set a 'red line' guarantee of arable land for food production.

9. **2014 November, "Opinions to guide the development of rural land rights and moderate scale agricultural management"（关于引导农村土地经营权有序流转发展农业适度规模经营的意见）released by the State Council**

Main Points:

- Reform of land operation rights and moderate scale development will help to optimize land resources allocation, increase productivity, secure food safety and supply, promote new technology application, and increase farmers' income.
- Improved agricultural management is the only path to agricultural modernization in China.

10. **2014 December, "Central Rural Work Conference"（中央农村工作会议）released by CPC, Central Economic Work Committee**

Main Points:

- Agricultural modernization, rural land reform, and pricing of agricultural produce were the main areas for discussion.
- The protection of national food security remains as the primary task, by ensuring the basic self-sufficiency of grain. Further promotion of the transformation and utilization of agricultural wastes will continue as well as an increase in favourable agricultural policy and capital investment.

11. **2015 January, "Encourage biomass CHP implementation" (关于加强和规范生物质发电项目管理有关要求的通知) released by NDRC**

Main Points:

- China NDRC published a Notice on "Standardizing & Reinforcing Biomass Project Construction" which explicitly encourages CHP (combined heat & power) biomass project construction to improve the efficiency of biomass utilization and strictly prohibits any co-firing of fossil fuel.
- Newly built projects should implement CHP. Completed projects should consider a CHP retrofit if there are heat users.
- Newly built projects should be included in national / provincial planning.
- Any biomass project which co-fires fossil fuels in order to get government FIT would face heavy penalties.
- Non-CHP biomass projects require provincial government approval whereas CHP biomass and WtE can be approved by local governments.

12. **2015 February, "Number 1 Document Rural Reforms, Modernize Agriculture and Food Security"（关于加大改革创新力度加快农业现代化建设的若干意见）released by Central Committee of the CPC /State Council**

Main Points:

- Agriculture, rural community and farmer-related issues are the topics of China's "No. 1 Central Document" - the first policy document jointly released by the Central Committee of the Communist Party of China and the State Council
- Food security is listed again as the top priority.
- The Document calls for reforms and innovation in agriculture to speed up the modernization drive in this sector and maintain agriculture as the foundation of the economy.
- It further identifies 33 point in 5 areas related to specific issues of 'agriculture, rural areas and farmers'.
- Long term mechanisms for sustainable agriculture development and establishment of new agricultural management systems. Increased investment in agriculture sectors and improved pricing mechanisms

13. **2015 May, "Sustainable Development Plan of China Agriculture (2015-2030)"（全国农业可持续发展规划 2015—2030 年）released by Various Ministries NDRC/Ministry of Agriculture/Ministry of Finance**

Main Points:

- By end 2020, the target is for >68% of major crops to be using machines for cultivation and collection.
- The mandatory minimum of cultivated land has been set as 1.8bn ha.
- By the end of 2030, 100% of straw resources are targeted to be fully utilized in major cultivation areas. (This includes 13 major crop producing areas, including Plain of North China, lower & upper reaches of Yangtze River, NE China).

14. **2015 July, "Opinions on Accelerating the Transformation of Agricultural Development"（关于加快转变农业发展方式的意见）released by the State Council**

Main Points:

- By the end of 2020, China should have more than 800 million acres of high quality grain production.
- High quality, highly efficient grain production bases for paddy rice and wheat should be built in the Northeast, Yellow River, Huaihe River, Haihe River and Yangtze River
- Speed up the mechanization of straw collection