8. Livelihood and economy of reed wetlands

Jan Felix Köbbing
Niels Thevs
Francesco Patuzzi
Marco Baratieri

8.1 Introduction

Reed, in particular common reed (*Phragmites australis*), is an important worldwide wetlands plant covering an area of more than 10 million ha worldwide (Allirand & Gosse 1995). The biggest extensions can be found in the Scandinavian countries, Kazakhstan and China. Providing a wide range of ecosystem services, local people are in particular interested in the raw material utilisation. Reed has been used for centuries as a fodder plant, as well as a construction material for houses, gardens and boats (Köbbing et al. 2013, 2014a). In recent times, it has been used for pulp and paper production, roof thatching as well as for energy feedstock.

China with an area of 40 million ha of wetlands and a reed biomass yield of 2.6–2.7 million tonnes (t) in 2004 is the biggest reed processing country in the world. Concentrated in the northwest, north, northeast and coastal east the harvested reed is almost exclusively used for paper production. By these estimates, reed usage contributes to local livelihood and, in particular, within rural areas. Wuliangsuhai Lake, Inner Mongolia, in the north of China, is a case in point for a rural utilisation of reed. Utilised for paper production, the reed economy is put under stress from rapid rising wages and tightening environmental standards. Some recommendations and an outlook on solutions and new applications are provided, focusing in particular on energetic applications.

Part of
Cirella, G. T. & Zerbe, S. (Eds.). (2014). *Sustainable water management and wetland restoration strategies in Northern China*. bu,press. https://doi.org/10.13124/9788860461094

8.2 Reed biomass potential: Analysis worldwide and in China

Species of the genus *Phragmites* Trin. are distributed around the world, except for the Artic. The most prominent species also worldwide is *Phragmites australis* Trin. ex. Steud. As a pioneer plant it is able to spread very fast into new areas and build mono-species stands. Highly tolerant against water level fluctuation and tolerant against salinity, in can grow on sites with a groundwater level of up to 3 m below surface (Thevs et al. 2007), periodically inundated sites, and along shorelines in 1–2 m deep water.

On sites with very favourable conditions, i.e. inundated by shallow water, high temperature and high solar radiation, *P. australis* reaches a NPP of 30 t ha^{-1} a^{-1} (Köbbing et al. 2014a). Thereby, as a natural plant it does not require treatment like irrigation, seeding, weeding or herbicide or pesticide treatment. Therefore, *P. australis* offers a huge potential as a valuable resource for rural people especially in developing countries, who use it for all kind of applications, e.g. mats, baskets, roofs, fodder, pulp production or as an energy source. *P. australis* biomass also might be used as a source for polymers and other chemical products (Fachagentur für nachwachsende Rohstoffe 2012; Smole et al. 2013).

The potentially available reed biomass is lacking reliable data and is difficult to quantify. As a natural plant it is not part of official statistics such as agricultural crops and residues. Moreover, many former reed beds were reclaimed for farmland, urbanisation etc. in the last decades which makes it even difficult to rely on literature data. Nevertheless, we have attempted an initial estimation based on the available data worldwide and on China, in particular (Köbbing et al. 2013).

Table 1 summarises the available data about reed beds. Some of the sources are rather old but, if we assume that only half of the total area identified still exists, it would exceed 4 million ha. If we could harvest only half of it, yielding 5 t ha^{-1}, the quantity of biomass made available would be 10 million t annually. Atchison (1995) estimated the worldwide available reed resources to be 30 million t in 1989.

Table 1 – Reed areas and yields from winter harvest in different countries. HB = Harvested biomass [t ha^{-1} a^{-1}] (Köbbing et al. 2013).

Site, region or country	Reed bed area [ha]	HB	Total yield [t]	Year	Reference
Europe					
Poland	60,000	-	-	-	Rodewald-Rudescu (1974)
South Finland	30,000 (15,000 harvestable)	10	150,000	2006	Komulainen et al. (2008)
South Sweden	230,000	5	1,150,000	2012	Iital et al. (2012)
Mecklenburg-West Pomerania, Germany	1,500	-	-	1997	Schäfer (1999)
The Netherlands	9,000 (2,850 harvested)	-	-	-	Sluis et al. (2013)
Lake Neusiedl, Austria	60,000 (36,000 harvestable)	7	28,500	-	Schuster (1985); Gamauf (2000) cited in Kitzler et al. (2012)
United Kingdom	7,700 managed for conservation	-	-	2013	Mills (2013)
Estonia	27,899 (12,970 harvestable)	7	88,368	-	Kask (2011)
Only lakes, Latvia	13,200 (10,826 harvestable)	7.2	69,000	2009/10	Cubars (2010)
Curonian Lagoon, Lithuania	4,995	-	-	2012	
Kaliningrad Oblast, Russia	200–300	-	-	-	Iital et al. (2012)
Regions and provinces of Russia	> 1,715,000	-	-	1959	
Kazakhstan	2,000,000	-	-	1959	Krivitzki (1959) cited in Rodewald-Rudescu (1974)
Uzbekistan	800,000–1,000,000	-	-	1959	
Turkmenistan	1,000,000	-	-	1959	

Azerbaijan	50,000–100,000	-	-	1959	
Danube Delta, Romania	190,000 (125,000 harvested)	5	625,000	1965	Rudescu et al. (1965) citied in Dela Cruz (1987)
Danube Delta, Ukraine	105,055	5	50,000	-	Rodewald-Rudescu (1974)
Hungary	26,200	-	-	-	Ruttkay et al. (1964) cited in Rodewald-Rudescu (1974)
America					
Brackish, salt and tidal marshes, USA	1,800,000	-	-	1991	Chambers et al. (1999)
Asia					
NW, N, NE and coastal east China	484,000	5.5	2,600,000–2,700,000	2004	Pöyry (2006)
North & South Korea	30,000 and 20,000	-	-	-	Rodewald-Rudescu (1958)
Iraq	17,300	-	-	2000	UNEP (2001)
Globally	>10,000,000	-	-	-	Allirand & Gosse (1995)

According to Pöyry (2006), which were the last available data, *P. australis* covered an area of 1 million ha (484,000 planted reed) outside of protected areas in China 2004. Large reed bed areas are concentrated along the east coast, in the Liaohe River Basin, and in the river basins of the Yangtze and Yellow River. Further contiguous areas are distributed in Inner Mongolia and Xinjiang (Pöyry 2006). The total annual harvested biomass was 2.6-2.7 million t of reed (5.5 t ha^{-1}, moisture content 15-18 %) in 2004, headed by Hunan with 650,000 t and Liaoning with 470,000 t (Table 2).

Table 2 – Reed area and yields (incl. 15-18 % moisture content) in the provinces of China 2004 (Pöyry 2006).

Province	Yields [t ha^{-1}]	Reed area [ha]	Total yields [t a^{-1}]	Reed price after harvest [€ /t^{-1}]	Reed price at end user [€ /t^{-1}]
Heilongjang	1.3	160,000	210,000	2-3	5-6
Hunan	10.0	63,000	650,000	-	-
Liaoning	7.5	66,000	470,000	4	-
Xinjiang	9.0	43,000	400,000	2.5-3	-
Hubei	9.7	36,000	350,000	5	-
Inner Mongolia	4.0	26,000	100,000	-	3
Jiangsu	0.7	113,000	80,000	5	-
Jilin	0.2	470,000	110,000	-	-
Shangdong	7.5	13,000	100,000	3	-
Anhui	5.3	15,000	80,000	-	-
Total	5.5	1,005,000	2,550,000	3.4	4.6

The area is estimated to reach 541,000 ha in 2010, dating back to 1998 this is an increase of 1.2 % per year with an annual biomass yield of 4.2 million t of reed (Zhu et al. 1998). A productivity increase from 4 t ha^{-1} to 10 or 12 t ha^{-1} was estimated to be possible until 2010 (Pöyry 2006; Zhu et al. 1998). Table 3 shows that reed can be an important raw material in China with big concentrated stands, which allows comparable easy harvest.

8.3 Reed products worldwide: Source for products

Reed has been used for centuries as raw material for construction, fodder, fertiliser and as an energy source. Today these four reed utilisations still exist and new applications, e.g. raw material as polymers, are investigated. On an industrial scale, reed is used in the field of house construction, paper production and as an energy source (as discussed in Chapter 7). As house construction material, reed plays a role for roofing.

Table 3 – Reed area and yields in China from 1985-2010. * Forecast from 1998, ** Pöyry (2006) (Zhu et al. 1998).

Year	Area [ha]	Yields in plantation [million t]	Yields in natural reed beds [million t]	Total yields [million t]	Supply for pulp [million t]	Pulp output [million t]
1985	442,670	1.36	-	1.36	-	-
1987	471,410	1.47	-	1.47	-	-
1988	483,300	1.62	-	1.62	-	-
1989	488,680	1.65	-	1.65	-	-
1990	481,650	1.66	-	1.66	-	-
1991	485,510	1.69	-	1.69	-	-
1992	488,000	1.73	-	1.73	-	-
1995	510,000	1.95	0.61	2.56	2	-
2000*	540,000	2.62	0.65	3.27	2.78	1.08
2004**	484,000	-	2.6-2.7	-	-	1.1
2010*	600,000	4.2	0.75	4.85	4.2	-

For a long time, reed has been the only roofing material in northern Europe. Until present, it is used for roof thatching in a wide part of northern Europe and Japan. The main consumers are The Netherlands, Germany, Poland, Denmark, United Kingdom, the Baltic countries and Japan (Hawke & Jose 1996; Stenman 2008). Production has shifted from local domestic production to large reed areas in the Danube Delta and recently China. Straight, dry, nutrient poor winter reed is required and pursued for € 2 to € 3 per bundle. In house construction reed can also act as material for insulation and reed panels (Holzmann & Wangelin 2009). Panels can be used to separate walls, fixed at walls for insulation and covered with clay. Such panels can be produced in a flexible way according to the sizes required. Cost vary from around € 6.50 to € 10 /m^{-2}, e.g. as in Austria (Reichel 2013).

Reed can also be chopped and compressed to granulate panels suitable for indoor construction (Reichel 2013; Holzmann & Wangelin 2009). Next to house construction material, paper mills are the other big consumer of reed at the industrial scale. The high cellulose content (i.e. 39-59 %) of reed biomass makes it a demanding source for pulp production (Rodewald-

Rudescu 1958). Challenges occur with the sewage treatment of non-wood pulp waste water (Paavilainen 1998), which are one of the reasons for the shutdown of reed paper mills in Sweden, Egypt, Romania, Iraq, Italy, the former German Democratic Republic and the former U.S.S.R (Wayman 1973; Sainty 1985). Today, such reed mills operate in China and parts of India (Savcor Indufor Oy 2006). One ton of paper pulp requires 5.3 m^3 of softwood, 4.1 m^3 of beech wood or 3.3–3.5 t of reed (Chivu 1968). The last introduced possible industrial utilisation is the use of reed as a basis for bio-based plastic. The high cellulose content makes it a possible material for functional polymers (Fachagentur für nachwachsende Rohstoffe 2012). Lignin, hemicelluloses and especially cellulose are extracted and used for different applications, e.g. viscose/rayon, plastic or ethanol (Holzmann & Wangelin 2009); though, this application of cellulose-biomass is still in its research stages.

Reed biomass is converted into energy through combustion, biogas or as a bio-fuel. All parts of a reed plant can be used for energy generation. For combustion purposes we find the dry reed, from winter harvested plants, the preferred choice. The dry reed biomass is fired in stoves or power plants. The bulk density (20–60 kg m^{-3}) of reed is low so that a use in a local scale is favoured, in order to avoid long distance transport. Still, reed biomass is pressed into bales, briquettes or pellets, in order to increase its density (Iital et al. 2012; White 2009). The average heating value of reed is 17 MJ kg^{-1} and the calorific value of wood pellets is 17 MJ kg^{-1} whereas that of oil is 42.5 MJ kg^{-1} (BIOMASS Energy Centre 2013), which is around half that of coal (Köbbing et al. 2014b). Biogas is produced in anaerobic digestion from green spring or summer reed, which have a high nutrient content (Kask 2011). One kilogram of reed produces 0.4-0.5 m^3 of biogas with a maximum methane content of 55-60 % (Komulainen et al. 2008). Reed as raw material for biogas digestion is suitable for domestic digesters as well as large-scale plants; the left over sludge, if not polluted, can be used as fertiliser (Hansson & Fredriksson 2004). The production of biofuels (bio-ethanol or bio-diesel) is possible from all kind of biomass with a high cellulose content, which can be pre-treated to glucose (Tutt & Olt 2011). For reed, this application is still in

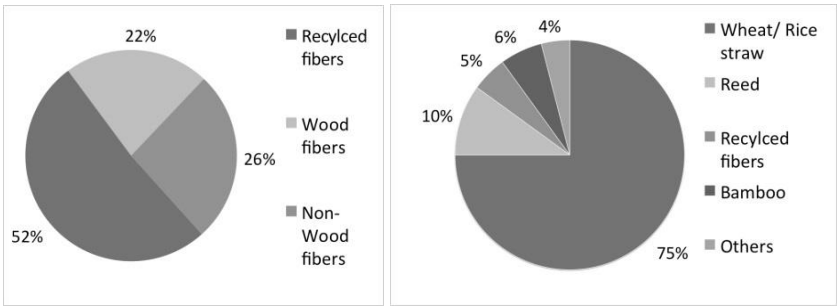
an experimental stage due to missing demand, high costs and lacking of availability. Reed can be eaten by water buffalo, sheep, cattle and goat either as fresh fodder or as hay (Häkkinen 2007; Thevs et al. 2007; White 2009). It is easy to digest (similar to hay or straw) and can be a roughage (especially K and Mn) for ruminants, but has a comparable low nutritional value (Baran et al. 2002; Rodewald-Rudescu 1974). As a fertiliser, only pre-treated reed is suitable, for example as sludge from biogas digesters. Preferably summer reed should be used as fertiliser, because it contains sufficient amounts of nutrients (Hansson & Fredriksson 2004). Untreated, only chopped reed biomass, is unsuitable as fertiliser due to its high C:N ratio.

Next to the applications of harvested reed biomass, reed beds have the ability to purify water. This function is used in many natural as well as artificial wetlands to treat nutrient pollution from nitrogen and phosphorus. The nutrients are removed by bacterial ammonification and dentrification processes initiated by reed stalks and by nutrients uptaken by the reed plants (Kronbergs et al. 2006). If reed biomass is harvested in spring or summer, the nutrients incorporated in the biomass are removed from the specific wetland. In autumn, the nutrients are relocated into the rhizome so that not many nutrients are removed through winter harvest. Thus, reed harvest as restoration technique removes nutrients from wetlands at the same time. The nutrient peak of the aboveground biomass is reached in July and August, whereas in winter the nutrients are stored in the root system. Experience from Sweden show an extraction of 20 kg N and 1 kg P in a reed yield of 5 t ha^{-1} in winter time (Graneli 1990).

8.4 Reed usage in China: Important feedstock

The utilisation of reed has a long tradition in China since centuries. Traditional uses are fodder, mats, baskets, huts, construction material, straw checker boards for sand fixation and fire starting material (Hansmann 2008b). Currently about 95 % of the harvested reed is used for paper production, minor uses are still mats or fodder. Reed is harvested in winter, in particular in north China where an ice cover allows a simple harvest. Mostly cut by local farmers, the reed is bundled, pressed and transported to

the end user, mainly paper mills (Photograph 9). Reed for fodder is grazed or cut by boat in late spring or summer (Photograph 10). Paper production, the most important application for reed in China is investigated. Approximately 2.6 to 2.7 million t of raw reed material has been used in 2004, corresponding to 1.1 t of pulp. This amount equals to 10 % of the non-wood fibre pulp production in 2004 (Figure 1). According to the estimations of Zhu et al. (1998), this would correspond to 4.2 million t of reed in 2010 (Table 3).



a b

Figure 1 – [a] Total pulp production and [b] non-wood pulp production in China in 2004 (Pöyry 2006).

Traditionally, China is using a high amount of non-wood raw materials like agricultural residues (e.g. straw or bagasse) for paper production due to a lack of domestic wood feedstock. Starting in the 1950s, numerous small, rural, collectively owned paper mills were founded, with an annual production of only a few thousand tons of pulp. Missing self-owned wastewater treatment facilities, most of them caused severe water pollution. Following more strict environmental regulations, many of these have been shut down since the 1990s and have been replaced by bigger wood-based paper mills (Lang 2007). This also influences rural labour markets where around 8 million generate parts of their income from harvesting, trading or transporting biomass (Lang 2007). This trend also led to a drop of reed price and to search for new reed applications. Due to the low bulk-density, long

distance transportation for reed is economically not viable and local utilisation should be favoured.

8.5 Reed use in China: Case studies

In this section, we introduce reed utilisation for four case studies: Liaohe Delta, Tarim Basin in Xinjiang, Yellow River Delta and Wuliangsuhai Lake. The Liaohe Delta and the Yellow River Delta represent two large reed areas with a continuous water supply in coastal regions. The Tarim Basin and the Wuliangsuhai Lake represent the reed use situation under arid climate in northern and northwestern China. An overview about the four case studies is illustrated in Table 4.

Table 4 – Overview about the four introduced case studies; RP = Reed price after harvest [€ /t^{-1}] (year) (Köbbing et al. 2014a).

Case study	Province	Reed area [ha]	Yields per ha [t]	Total yield [t]	RP	Reference
Liaohe Delta	Liaoning	100,000	4.5	450,000	40 (2004)	Pöyry (2006); Xiao & Li (2004); Ye et al. (2013)
Tarim Basin	Xinjiang	37,000	8	300,000	14 (2007)	Hansmann (2008)
Yellow River Delta	Shandong	100,000	15	150,000	-	Man & Croon (2007)
Wuliangsuhai Lake	Inner Mongolia	18,800	5.3	100,000	41 (2011)	Köbbing et al. (2014a)

8.5.1 Liaohe Delta

As mentioned above, the 400,000 ha Liaohe Delta (also Panjing) in northeast China (121 °10′– 122 °30′ E, 40 °30′–41 °30′ N) in the province of Liaoning is known as the biggest contiguous reed area worldwide, with an area of 100,000 ha of reed beds (Xiao & Li 2004). A sophisticated water management scheme enables people to regulate the water table according to the biological requirements of the reed beds. Reed beds are burned regularly, in order to eliminate eventual pests and other vegetation (Ji et al. 2009; Ye et al. 2013). All this had led to an annual increase of 600 ha of reed area between 1984

and 2006 (Ji et al. 2009) and levelled out the yields increases. In 2011, around 450,000 t of reed were harvested (Ye et al. 2013). The reed is harvested with traditional agriculture trucks during winter, bundled by hand, and transported by train or truck to the paper mills in the region (Ye et al. 2013).

The paper mills Yingkou Paper and Jin Cheng Paper in Yingkou and Jincheng, respectively, have an annual production capacity of 150,000 t pulp each, which corresponds to 700,000 t of reed raw material intake (calculated by a factor 2.3 from reed to pulp) (Pöyry 2006). In 2011, the two paper mills in Jincheng lacked 140,000 t reed biomass (Ye et al. 2013). In 2004, the harvested reed raw material price was € 40 /t^{-1} (Pöyry 2006), which is comparably high, probably due to the high competition between reed users. The whole management is focussed to gain high yields, other ecosystem functions and services such as habitat for birds are neglected.

8.5.2 Tarim Basin

The second case of reed use, introduced here is located in Xinjiang in the far northwest of China. Along the Tarim and its tributaries and at the Bosten Lake, reed beds are distributed. The latter has an area of 98,000 ha (Xia et al. 2001). Reed grows inside the lake, along the shores of the lake and the Tarim River and on irrigated or drainage fields. Reed at Boston Lake is exclusively used for paper production by Bohu Reed Company which is managing 30,000 ha inside the Boston Lake, plus 7,000 ha artificial planted reed at the shore (Hansmann 2008b). The reed beds are managed in terms of water table by the help of pumps and dams, in order to increase the productivity and enable an easy harvest. The harvest is done by tractors and harvesting machines or manually with sickles. The harvested reed serves as a source of cellulose for which is supplemented by 10 % wood cellulose. The paper mills has a current production capacity of 120,000 t of pulp which corresponds to 300,000 t of reed intake (Hansmann 2008b).

Apart from this one major user, reed is used in wetlands by local farmers as additional income. The reed business involves a specialised network of people dealing with cultivation, transportation, trading, manufacturing and purchasing. Final products are weaved (bora) mats (Photograph 11 and 12),

reed (Yuban) panels (Photograph 13 and 14), reed blinds and bundled strings. Bora mats are sold for € 1.40 to € 2.30 and € 2.80 to € 5.60 (in 2008) depending on the quality for small (1.8 x 3 m) and big (3 x 6 m) mats, respectively. The mats are used for traditional Uighur adobe house construction. Yuban panels in contrast are produced by compressing and binding reed in one meter wide and required length panels. They were sold for € 0.40 /m² in 2008. Reed bundled in 10-15 cm rope is used for roof construction and for fencing. These bundles were purchased for € 0.04 /m in 2008 (Hansmann 2008b). A rare use of reed is in the construction of blinds for construction or as insulation material. Separate reed culms of the same length bind together in chains. The size of 2.5 x 10 m length is sold for € 2.80 in 2008 (Hansmann 2008b). Moreover, especially on sites with low productivity, reed is used as a fodder plant for sheep, goats, cattle or donkeys in spring and early summer (Gahlert 2006; Hansmann 2008b).

8.5.3 Yellow River Delta

The third reed case study introduced here is the Hekou district, Shandong Province, in the Yellow River Delta. The delta expands over an area of 780,000 ha, with reed covering more than 100,000 ha (Man & Croon 2007). With an average yield of 15 t ha^{-1}, a feedstock of 150,000 t is available (Man & Croon 2007). It is used for paper production in traditional paper mills, though, these paper mills are shut down gradually due to water pollution. New alternatives for utilisations of the reed biomass are explored, e.g. environmentally-friendly paper mills, energy production in biomass power plants or panel production.

8.5.4 Wuliangsuhai Lake

As described in Chapter 2, the Wuliangsuhai Lake is a shallow, eutrophic wetland with a dense cover of *P. australis*. An area of 18,800 ha is covered with reed, corresponding to more than half of the lake area and producing around 100,000 t of reed per year (Köbbing et al. 2014a). Harvest ensures the regular removal of biomass, which otherwise would decompose inside the lake and accelerate the eutrophication process. In this respect, a market demand for reed is important for the lake maintenance and restoration. From

our investigations, Figure 2 illustrates the total lake area, reed area and yield from 1986 to 2010. In the areas bordering Wuliangsuhai Lake, roughly another 100,000 tons of reed are cultivated (Köbbing et al. 2014a).

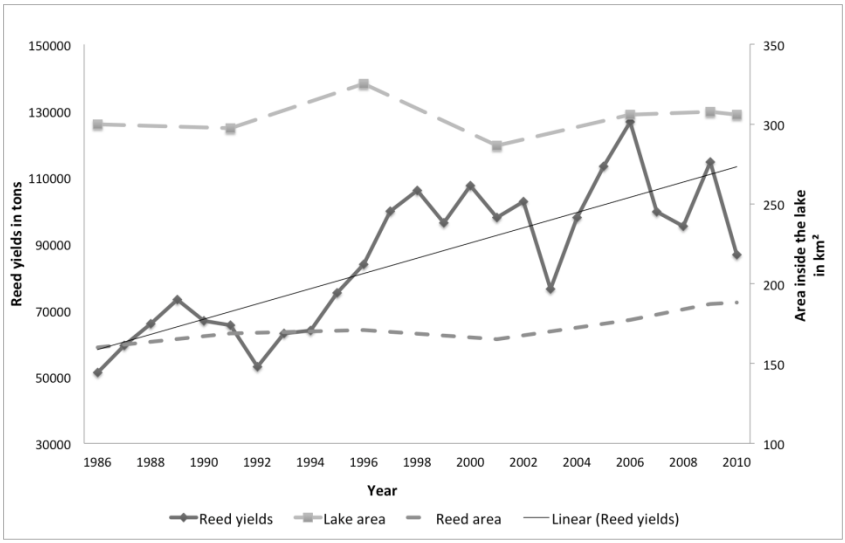


Figure 2 – Total lake area, reed area and yield from 1986–2010.

This huge biomass feedstock is an important income source for local people and for hired migrant workers. Until 2008, the reed resource was almost exclusively used for paper production in two paper mills in and near Urat Front Banner. Some minor parts were used to produce mats for construction and insulation of greenhouses (Photograph 15 and 16). More restrict environmental regulations and a missing wastewater treatment led to the shutdown of the paper mills and to two new consumers in Ningxia Province, 800 km away. The additional transportation costs had reduced the revenues of the responsible lake administration and lead to a search for new, local products.

The cut reed raw material is sold to the paper mills for € 41 /t, which includes € 22 /t paid to local fishers and farmers for the harvest. Before loading on trucks, the reed is compressed into bales (Photograph 17 and 18)

which costs around € 13 /t. Transportation costs another € 20 /t which results in a reed price at gate of around € 75 /t (Photograph 19); loaded reed trucks are weighed before leaving the area (Photograph 20 and 21). The costs for pressing and transportation corresponds to the reduced income of the lake administration and also affects the income of around 4,000 people engaged in the harvesting process (Table 5).

Table 5 – Reed network and value chain at Wuliangsuhai Lake in 2011 (Köbbing et al. 2014a).

Actor	Activity	Price per Units [€ /t^{-1}]	Total [€]
Lake administration	Revenue	-	41
	Harvesting	22	-
Paper mill	Raw material	41	-
	Pressing	13	75
	Transportation	20	-

New, higher valued applications are investigated by the Wuliangsuhai Lake administration to increase profitability of the reed business. As noted earlier in this chapter, only a few reed products are suitable for large-scale applications such as panels, thatching, paper and energy. In China, reed as construction material is seen as backwards, or old-fashion, and lacks market demand. A new, clean paper mill could be an option, but requires high investments and therefore seems not to be an option.

Facing the rapid increase in energy demand in China and the negative impacts of the intensive coal consumption, reed as an energy source, as investigated in Chapter 7, offers two novel scenarios. First, the replacement of rural, coal-based furnaces by biomass ones (Scenario 1) and second, the construction of a combined heat and power (CHP) generation in a dedicated gasification plant, that is, centralised heat and power generation (Scenario 2). A 30 MW CHP plant has been considered, which corresponds to a total reed

raw material consumption of 212,049 t. From Table 6, it can be seen that reed biomass furnaces can be competitive under the assumption that the energy efficiency of the new furnaces raises from 10 to 75 %. For a CHP plant, the reed price per MJ/kg will be around 1/3 more expensive. Also, the Net Present Value (NPV) valued calculated for 20 years was slightly negative. The calculation for both scenarios is based on a few assumptions. Change factors such as rising labour costs or increasing subsidies will, respectively, influence the result in a negative or positive way.

Table 6 – Heating value and prices for reed and coal at Wuliangsuhai wetland. * Inflation adjusted from February 2004 to February 2011 according the consumer price index in China reported in (OECD 2013). (Köbbing et al. 2014b).

	Present situation		Scenario 1	Scenario 2
	Rural coal	Coal plant	Reed biomass furnaces	CHP plant fed by reed
Heating value [MJ/kg]	23	23	15	15
Average purchasing price per kg * [€]	0.082	0.042	0.054	0.041
€ per MJ/kg	0.003	0.001	0.003	0.002

8.6 Conclusion

Reed as a source for multiple products has been important for China since human time. Long used as a construction material and a fodder plant, in the 1950s it was discovered as a valuable source for cellulose, which was short, due to lack of domestic forest resources. After markets opened in China the import of wood resources for paper production increased, but at the same time most of the domestic non-wood paper mills came under pressure due to their smaller size. Supply and demand, forced these smaller industries into financial despair as costs of maintaining their own water treatment facility became less supportable.

Today, reed bed managed all over China continues to innovate and change with market demands – seeking new consumer ends for reed resources. The most promising use is energy production by combustion or ethanol production, novel environmentally-friendly paper mills, natural water treatment plants and, in some cases, reed panels. But all of these products are often hardly or not profitable and need governmental support. If not, the situation will become similar to the one in Europe. Some reed beds will be reclaimed for more profitable uses like agriculture or urbanisation, others have to be costly managed (incl. harvest production) by environmental management schemes.

Key References

Dela Cruz, A. 1987. The Production of pulp from marsh grass. Economic Botany, 32: 46–50.

Köbbing, J.F., Beckmann, V., Thevs, N., Peng, H. & Zerbe, S. 2014a. Investigation of a reed economy (*Phragmites australis*) under threat: pulp and paper market, values and netchain at Wuliangsuhai Lake, Inner Mongolia, China. Technical Report. Greifswald, Germany: Institute for Botany and Landscape Ecology, University Greifswald.

Köbbing, J. F., Patuzzi, F., Baratieri, M., Beckmann, V., Thevs, N., & Zerbe, S. 2014b. Economic evaluation of common reed potential for energy production: A case study in Wuliangsuhai Lake (Inner Mongolia, China). Biomass and Bioenergy, 70, 315–329. doi:10.1016/j.biombioe.2014.08.002

Köbbing, J.F., Thevs, N. & Zerbe. 2013. The utilisation of Reed (*Phragmites australis*) – A review. Mires and Peat, 13: 1–14.

Pöyry. 2006. Technical Report, Modules 2-7. In: China: Technical Assistance for the Sustainable Development of the Non-wood Pulp and Paper Industry. Shanghai: Pöyry Forest Industry Co. Ltd.

Rodewald-Rudescu, L. 1974. Das Schilfrohr (The reed stalk). E. Schweizerbart´sche Verlagsbuchhandlung (Nägele u. Obermiller) Stuttgart.

Savcor Indufor Oy. 2006. China. Technical Assistance for the Sustainable Development of the Non-Wood Pulp and Paper Industry. Impact assessment. UNEP.

Thevs, N., Zerbe, S., Gahlert, E., Mijit, M. & Succow, M. 2007. Productivity of reed *(Phragmites australis* Trin. ex Steud.) in continental-arid NW China in relation to soil, groundwater, and land-use. Journal of Applied Botany and Food Quality, 81(1): 62–68.

Ye, S., Brix, H. & Sun, D. 2013. Large-scale management of common reed, *Phragmites australis*, for paper production: a case study from the Liaohe River Delta, China. In: International Conference "Reed as a Renewable Resource" 14-16 February 2013. 2013, Greifswald, Germany: Institute for Botany and Landscape Ecology, University of Greifswald.