

Biogas from landfills in China ? ... implications on Solid Waste Management

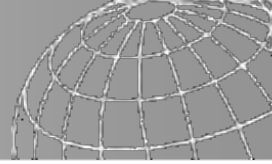
Prof. Dr. phil.-habil. Bernhard Raninger

Shenyang Aerospace University (SAU)

***Institute of Clean Energy and Environmental Engineering (ICEEE) and
Liaoning Key Laboratory of Clean Energy & Environmental Engineering (LNKLCE)***

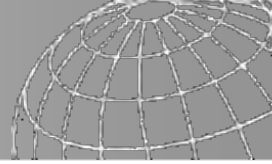
**** GTZ - German Development Cooperation, China Biomass Utilization Project***

Biogas technology: Status and Trends in Asia, 24 May 2011, Bangkok, Thailand



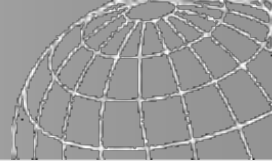
Agenda

- ✓ ***China Waste Management Facts***
- ✓ ***Support policy and drivers***
- ✓ ***Why Landfill Gas collection fails in China***
- ✓ ***Alternatives to landfills***
- ✓ ***Conclusions***



Waste Management Drivers in China 废弃物管理在中国的驱动力

- 1) Environmental Protection (ground-, surface waters, soil, air,)**
环境保护（土地、地表水、土壤、空气）
- 2) Landfillspace is running out (eastern - coastal provinces)**
填埋土地正被耗尽（东部-沿海省份）
- 3) Circular Economy (Material- and Energy recycling,)**
循环经济（材料和能源的回收利用）
- 4) Greenhousegas mitigation (climate change, Kyoto Protokol, low carbon economy), 40-45% CO₂ emission reduction in 2020**
温室气体减排（气候变化、京都议定书、低碳经济），到**2020**年二氧化碳减排**40%-45%**。
- 5) Renewable Energy (substitution of fossil energies, energy safety, sustainable development,), 3 GW from MLSBPs in 2020**
可再生能源（替代化石能源、能源安全、可持续发展），到**2020**年大中型沼气厂产能**3GW**

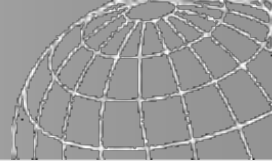


China's GHG Emission Reduction Policy

- 1) **2002 'GHG Emission Reduction voluntary obligations' & China's 2006-2010 mitigation actions: to reduce the intensity of CO₂ per unit of GDP in 2010 by 20 % compared with the level of 2005**
- 2) **2009 the State Council announced that China in a "voluntary action" taken by the Chinese government, is going to reduce the intensity of CO₂ emissions per unit of GDP in 2020 by 40 to 45 % compared to 2005.**

.....international inspections should only cover emissions cut achieved with capital assistance of developed nations under the UNFCCC mechanism (CDM) and must be "measurable, reportable and verifiable".

37 Kyoto protocol signatory countries agreed to reduce their collective greenhouse gas emissions by 5.2% from the 1990 level till 2012 (which can hardly be achieved, see Austria). The Post-Kyoto regime is still pending. CDM to outsource this obligations!!



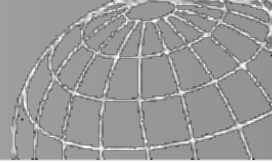
Climate Relevance and estimated savings in GHG emissions of different waste management options

不同的废弃物管理模式下温室气体减排量估算与气候变化相关性

废弃物管理技术	温室气体排放基线	温室气体排放	温室气体排放潜在减排量
WM Technology	Baseline GHG emission (tons CO ₂ e/t of waste)	GHG emission (tons CO ₂ e/t of waste)	Potential saving in GHG emissions (tons CO ₂ e/t of waste)
Landfill with LFG flaring	2.46	0.74	1.72
Landfill with LFG utilization	2.46	0.68	1.78
Composting	3.54	0	3.54
Anaerobic digestion 厌氧发酵	3.54	-0.055	3.6

.....not considering the indirect savings from utilization of generated energy from Biogas.
没有考虑通过使用由沼气所产能源而出现的间接减排量。

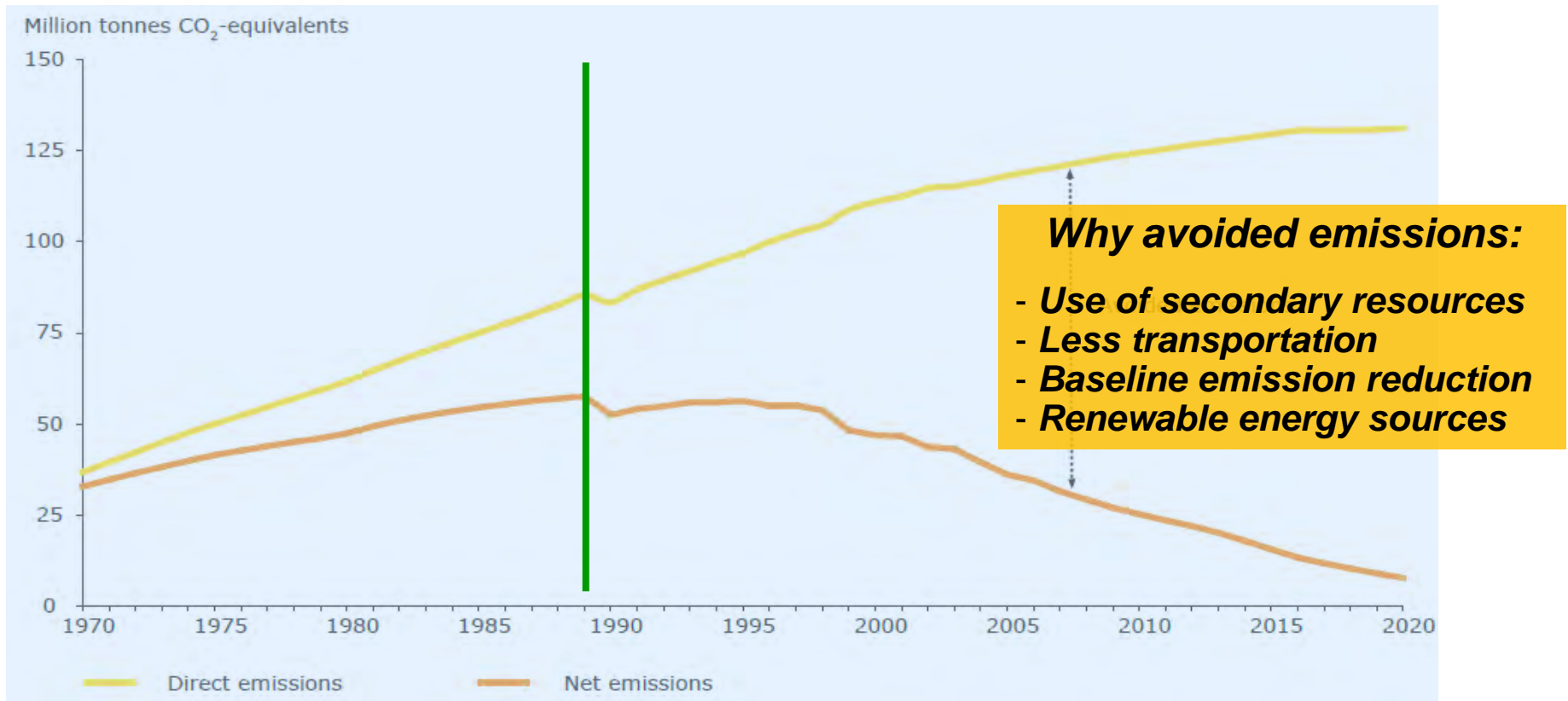
(Source来源: World Bank世界银行)

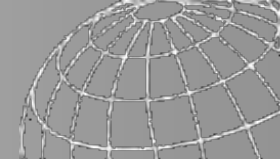


Changes in EU-15 GHG emissions by sector 1990 - 2006 - 2020 在1990-2006-2020年欧洲15种温室气体排放变化

- The EU net GHG emission from SWM are declining from a peak of 55 mn t CO_{2eqv} in the 1980s to an estimated 10 mn t CO_{2eqv} by 2020.

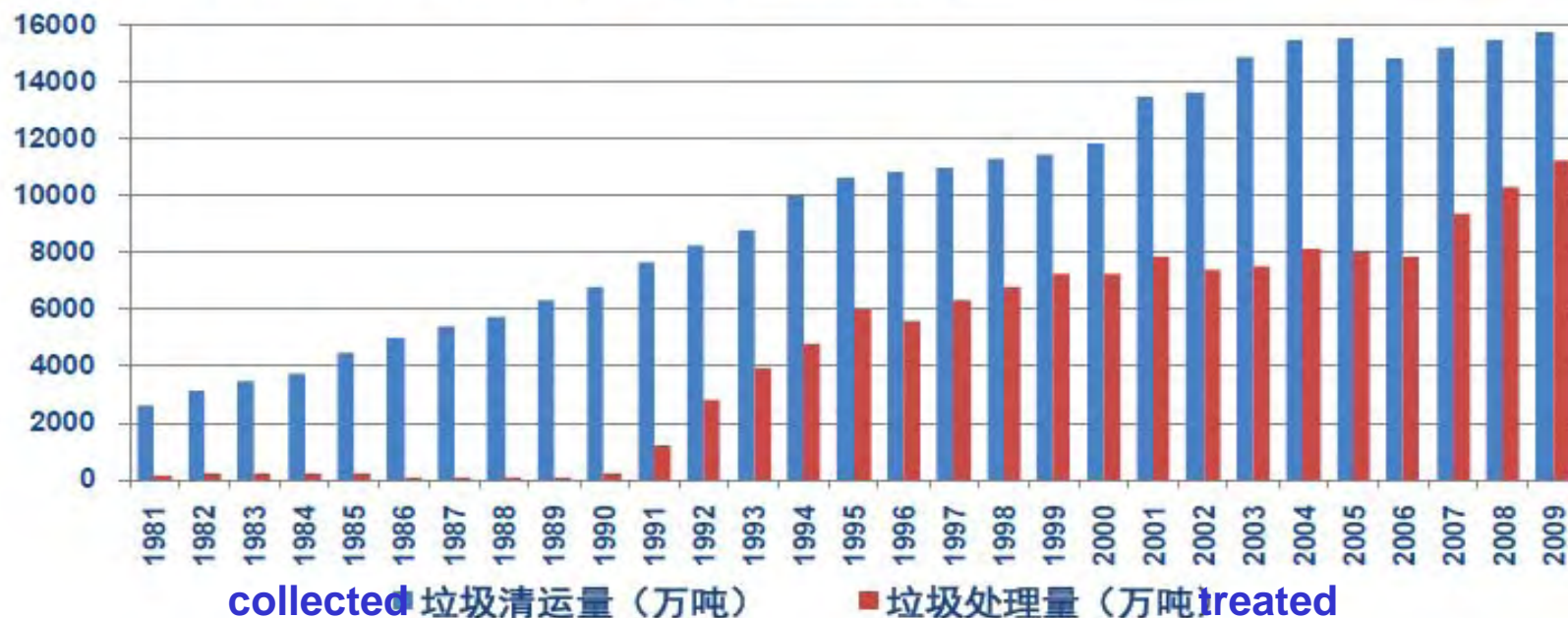
欧洲固体废弃物温室气体净排放量将从1980年5500万吨CO_{2eqv}逐步降低到2020年1000万吨CO_{2eqv}。在1990到2006年期间

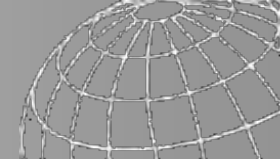




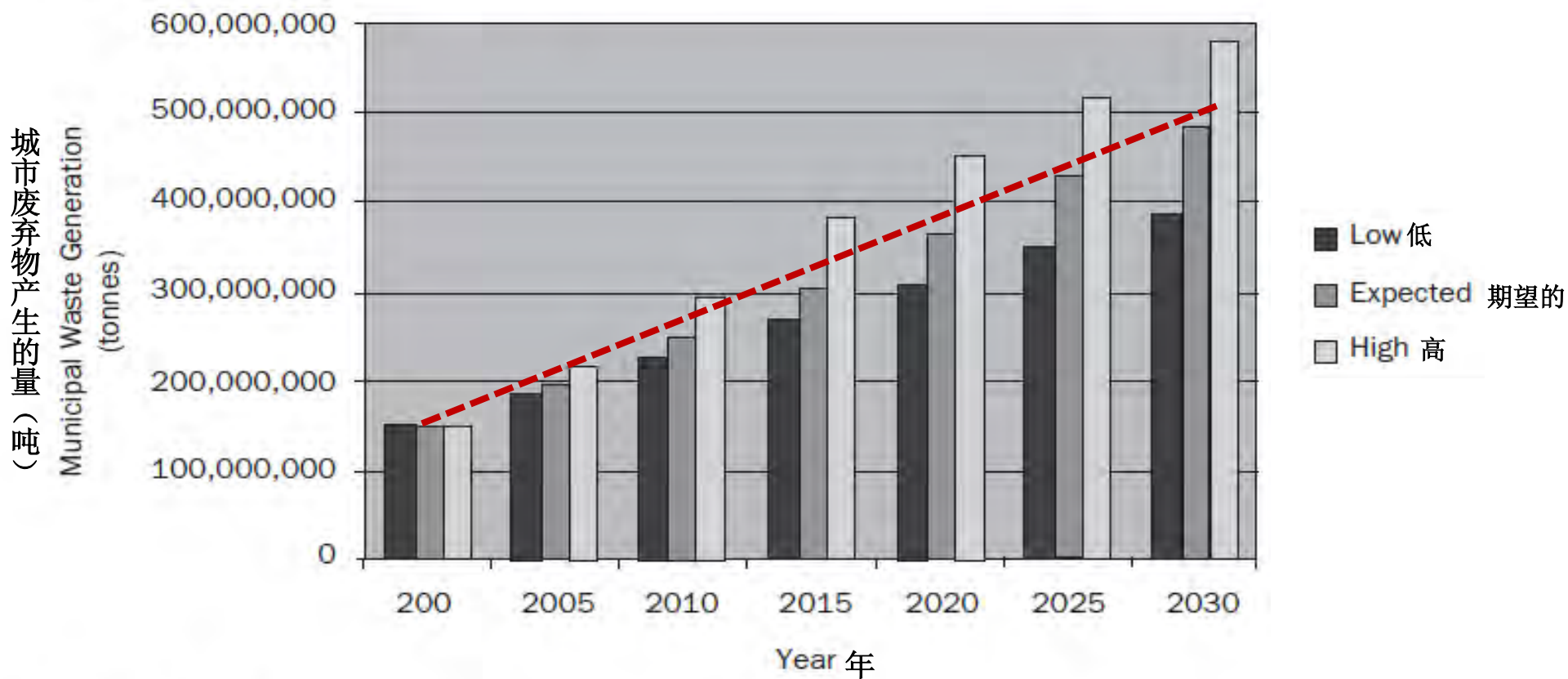
Development of Waste quantities collected and treated 1981 - 2009 1981年-2009年废弃物收集和処理量的发展

- 目前，我国城市生活垃圾清运总量稳定在1.5~1.6亿吨/年。2005~2009年，平均清运量为1.54亿吨/年，合约42.1万吨/日。2009年我国城市生活垃圾清运量为1.57亿吨，合约43.10万吨/日。
- 近几年来，我国城市生活垃圾无害化处理总量显著增加。从2005年的8051万吨增加到2009年的11220万吨，增加了39.36%。

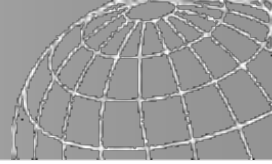




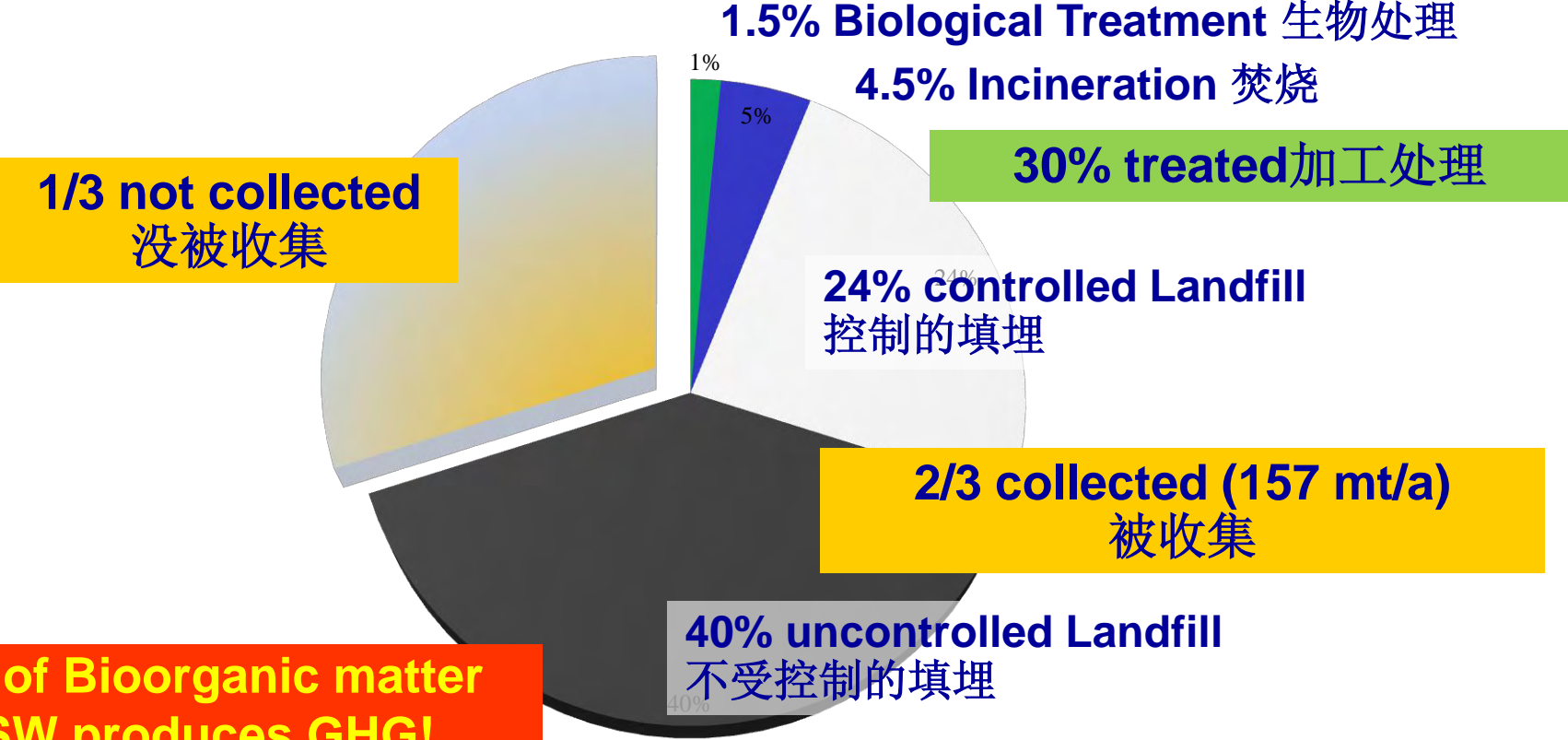
Development of Waste quantities in China till 2050 到2050年中国废弃物数量发展 (World Bank 世界银行 2005)



Source: AMEC

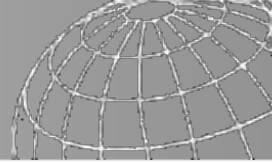


**China Solid Waste Management 2010,
>360mt/a MSW after recycling from 654 cities,
中国固体废物管理2009, 对654座城市进行回收后城市固体废物大于3.6亿吨/年**

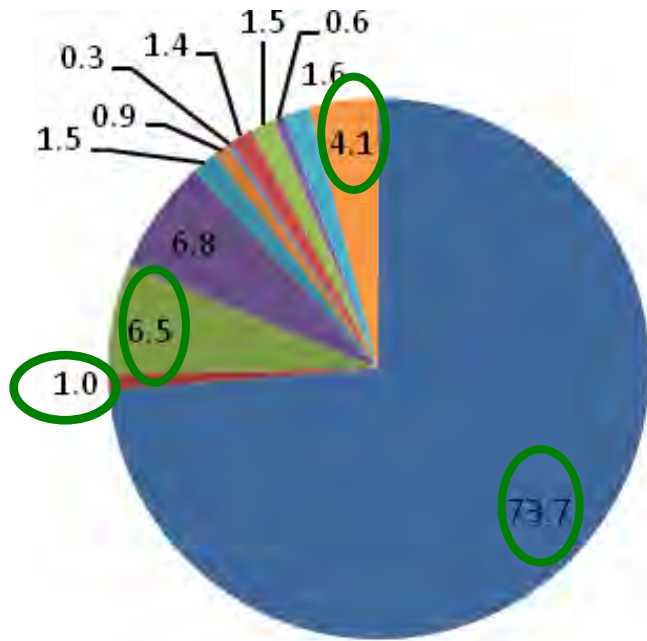


**60-90% of Bioorganic matter
in MSW produces GHG!
城市固体废物中有60-90%的
生物有机质分解产生温室气体**

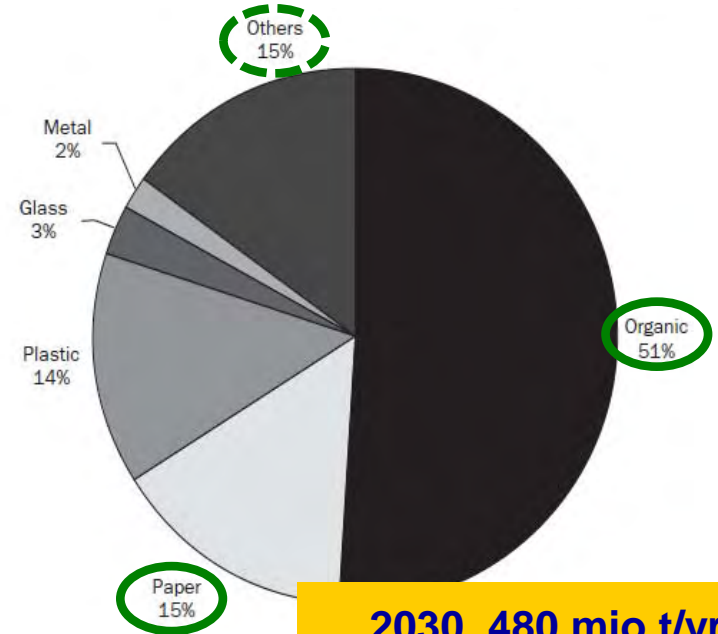




China MSW Composition 2005 – 2030 中国2005-2030年城市固体废弃物组成



- BMW 城市生活垃圾
- Wood/Bamboo 木材/竹
- Paper 纸
- Plastics 塑料
- Glass 玻璃
- Textiles 纺织品
- Metal 金属
- Hazardous waste 危险废
- Complex prod. 复合产品
- Minerals 矿物质
- Others 其他
- Fines <10mm 细粉<10mm



2030, 480 mio t/yr
(Weltbank, 2005)

RRU-BMW pilot areas average of monthly analysis (n=69) Shenyang 2005/09
资源回收利用-城市可生物降解垃圾试验区每月分析汇总 (n=69) 沈阳

Average BMW content of MSW
城市固体废弃物中的生物可降解垃圾成分
China 中国 = ± > 66 % up to 80% (average from 27 cities in China, 1998 – 2006 数据来源于中国27座城市)
Europe 欧洲 = ± 33 %

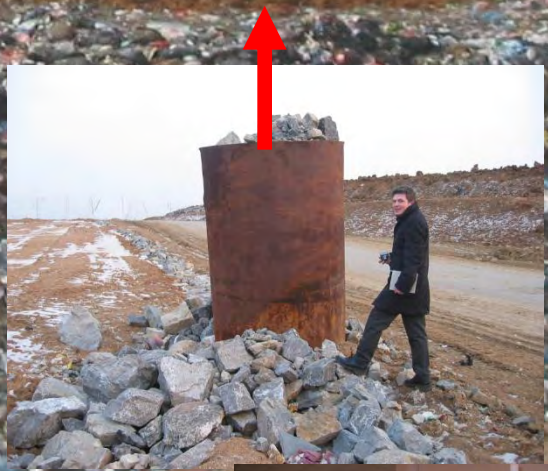
Sanitary Landfills in Liaoning (Daxin & Laochuchung)

(18% of anthropogenic GHG from LFG emissions)

2 Landfill sites in Shenyang

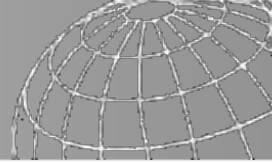
Laochuchung & Daxing > 4,500 t p.d., lifetime till app. 2030,
LFG collection under CDM credits anticipated

CH_4 CO_2 ↑
Gaseous emissions



Liquid emissions

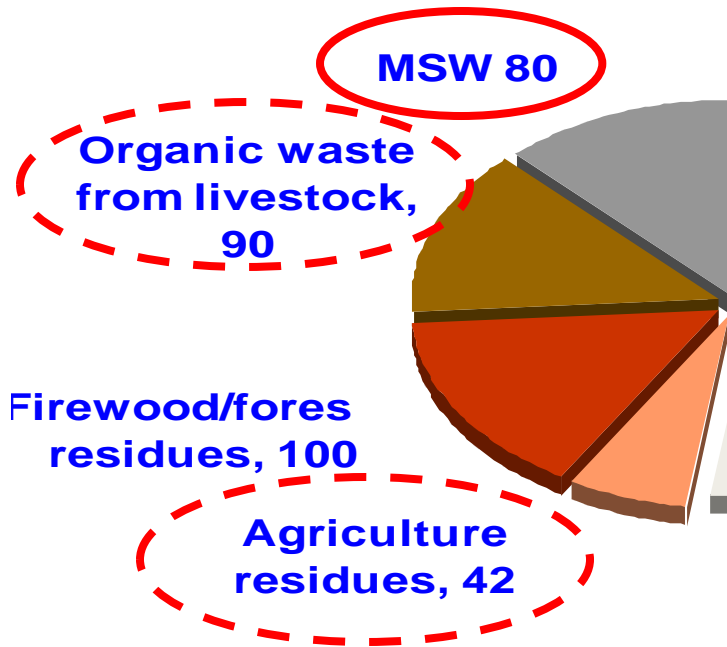




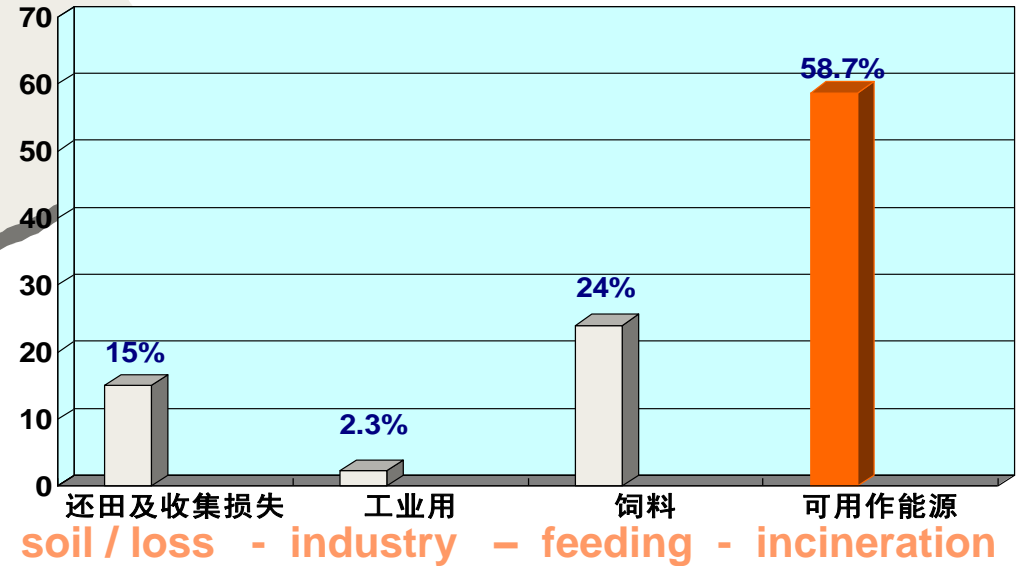
Abundant Biomass-Waste Resources in China 2005

NDRC 2008: 2050 1 bn t of coal can be replaced by biomass energy = 100GW

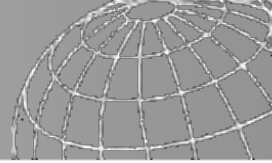
2006: 650 mill tce/a, potential 2050: 1 bn tce/a



Agricultural straw, 340



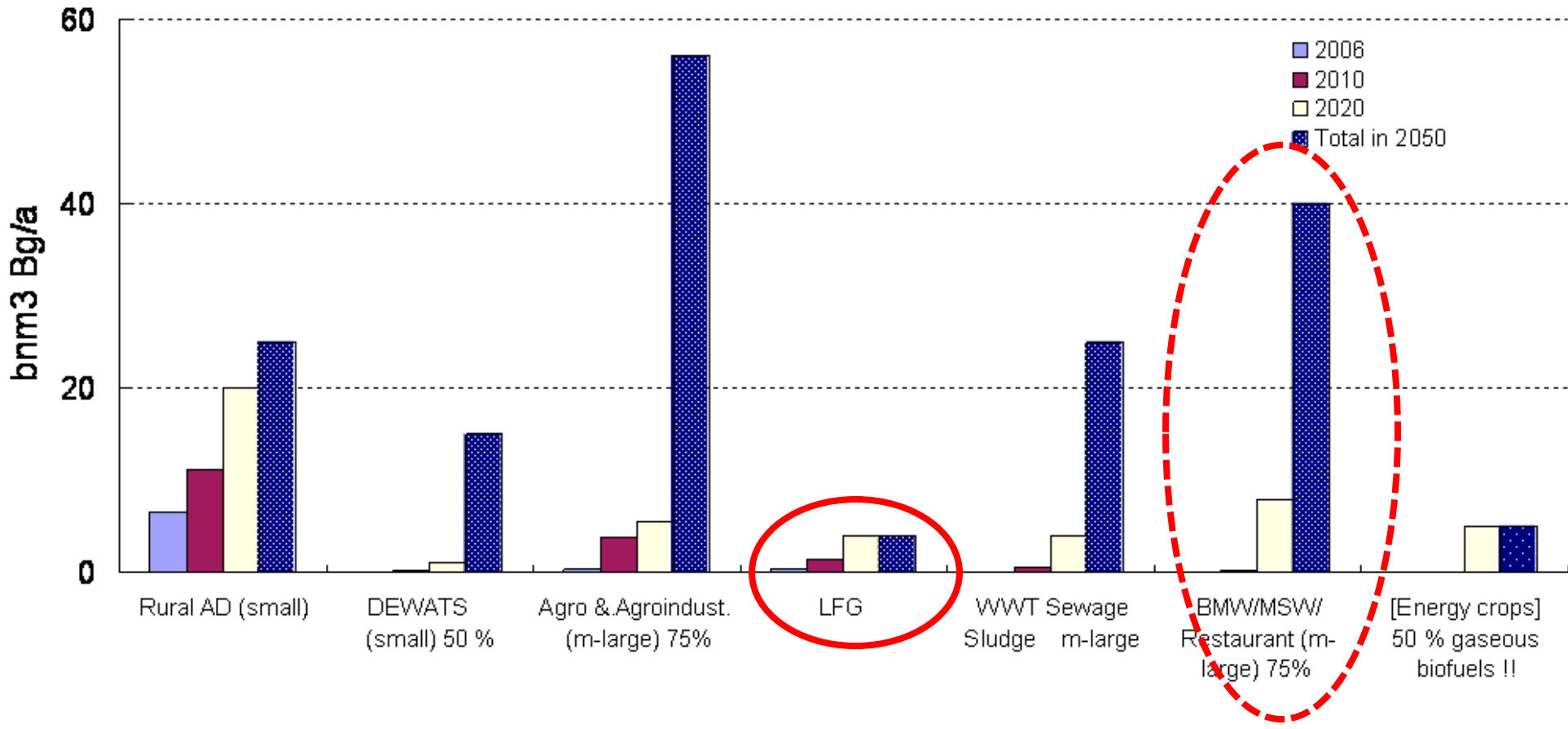
Source: Zhejiang University 2007

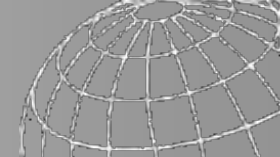


Chinas Biogas Production & Potential



China: Biogas Potential from Wet- Bioorganic Wastes





58 CDM Landfill Projects in China registered 20 CERS issued as at 09/2009 by UNFCCC

					CERs issued total (t CO ₂ e)	CERs calculated in PDD (t CO ₂ e)	Capture efficiency (%)	Issuance success rate (%)
Nanjing Tianjingwa Landfill Gas to Electricity Project	18 Dec 2005	246,107	1 May 2005-29 Jun 2008		120550 *(171981)	701,585	55	17.2
					101908 *(194201)	520,273	85	19.6
					13295	60,237	68	22.1
Recovery and Utilization Project	06		2005-30 Apr 2006		*(142684)	223,007	24	63.4
					53509 *(161262)	198,525	48	27.0
Recovery and Utilisation Project	07		2007-31 Oct 2008		*(16,544)	205,757	65	8.0
					28,333 *(56,351)	152,852	60	18.5
					25,236	93,114	70	27.1
					*(24,081)	256,720	30	9.4
Landfill Gas Recovery and Electricity Generation CDM Project	07		2008-31 Mar 2009		*(32,106)	309,197	75	10.4

... and so far only half of them can provide monitoring reports with app. 25% CERs

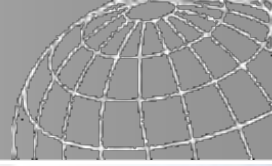
**Expected Emission Reduction:
> 6.9 mn t/a CO₂equ. X < EUR >8 - 24
(>11 - 33 USD)**

**LFG recovery rate:
Western Countries = <60 %**

China = <13 %* (<10 % of the LFG potential)

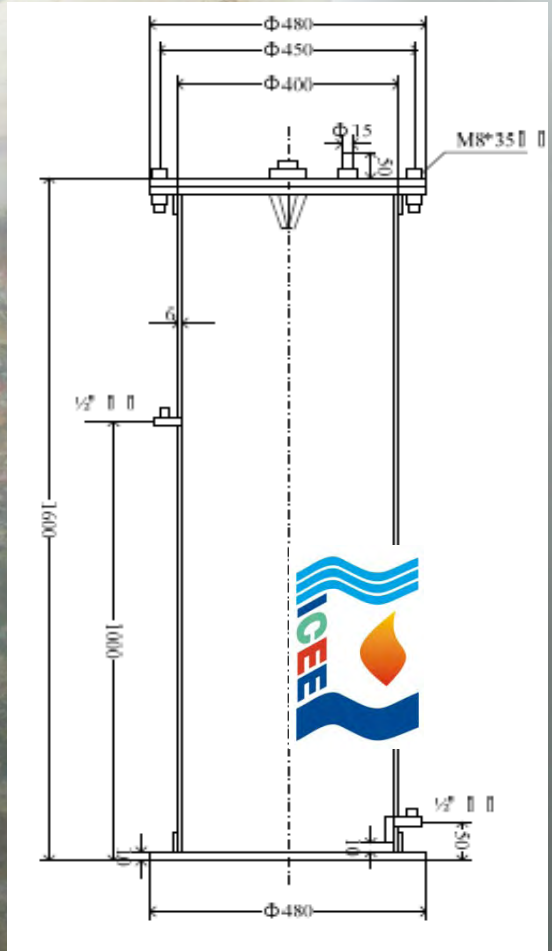
* Not included projects which are performing so badly that they are not in the position to submit a monitoring report

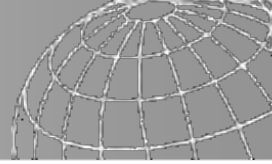
* including the ER that ongoing expected issuance request



Landfill Simulation Research

Climate Chamber conditions: 37 °C, compression 3.5 t/m², anaerobic, Inoculum, rainfall, 37°C,





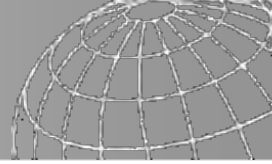
Comparison of Organic Matter Biodegradability of Chinese and European MSW

对中国和欧洲城市固体废物有机物质生物降解能力的对比

城市固体废物特点		中国		欧洲	
MSW characterization		China [m/m%]		EU [m/m%]	
Rapidly & moderately degrading 快速与中速分解	Bioorganic municipal waste BMW (food- and kitchen waste, green garden waste)	78		12	
Slowly degrading 低速分解	Organic matter with a higher semi- and lignocelluloses content (wood, yard waste, paper, textiles, composite material,)	10	∑88	47	∑59
Non degrading 不分解	Inert organic and inorganic matter (plastic, metal, glass, ash,)	12		41	
Total	总数	100		100	

(Sino-German RRU-BMW project, Raninger & Li, 2008), (in m/m% FM)
(中德资源回收利用-城市可生物降解垃圾项目2008)





MSW LF Simulation Research (ICEEE) 城市生活垃圾填埋模拟实验 (ICEEE)

Up to 550 days Shenyang MSW LF Simulation 2009

2009沈阳城市生活垃圾填埋模拟实验 (实验周期: 550天)

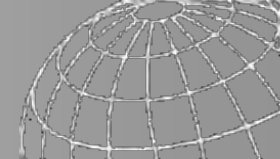
Climate Chamber conditions: 37 °C, compression 3.5 t/m², anaerobic, inoculum,

恒温箱: 37°C, 压缩3.5 t/m², 厌氧, 接种体

	150 days		300 days		550 days	
	CHN	EU	CHN	EU	CHN	EU
pH *	4.2 - 6.4	5.5 - 6.0	5.2 - 6.3	5.0 - 6.1	4.7 - 6.1	--
Density (kg/l FM)	0.79	0.46	0.80	0.47	0.83	--
Volume reduction	38%	5%	41%	9%	44%	--
Mass reduction	22%	3%	26%	6%	>38%	--
TOC reduction **	15%	2%	18%	4%	22%	--
VFA (g/l) *	--	--	26 - 30	28 - 41	30 - 39	--
CH₄ (% v/v) ***			5		18	

* in the leachate ** through leachate emissions *** in the landfill simulation container B





Comparison of 3 Landfill gas calculation models

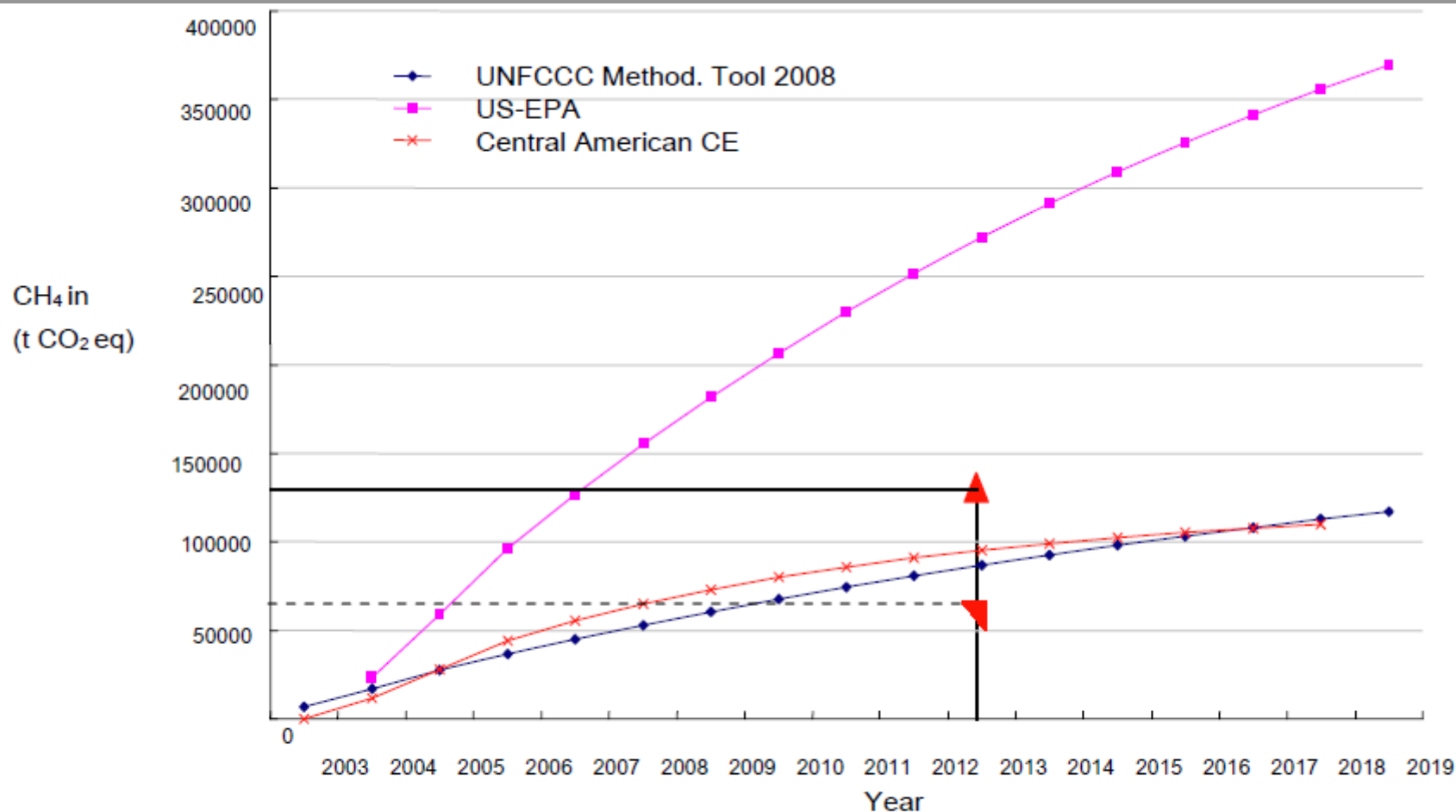
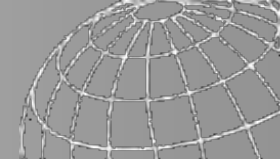
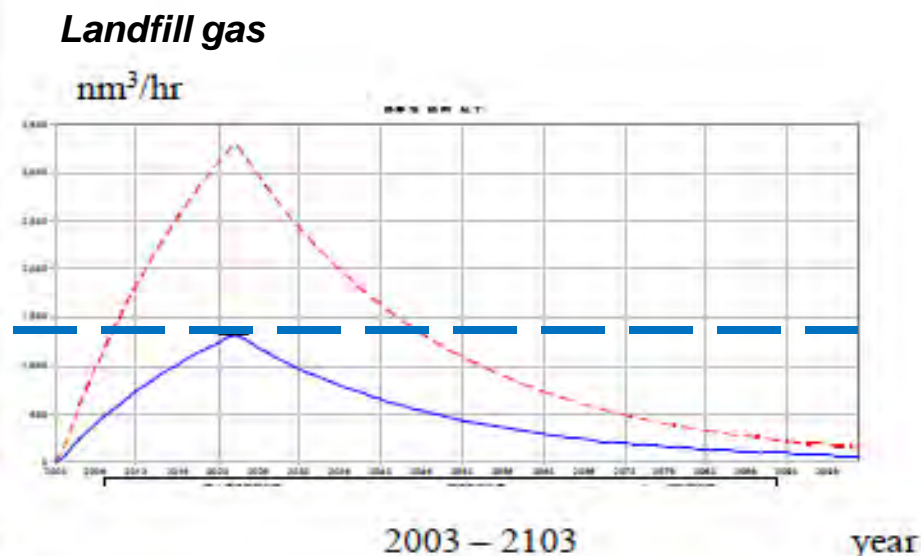
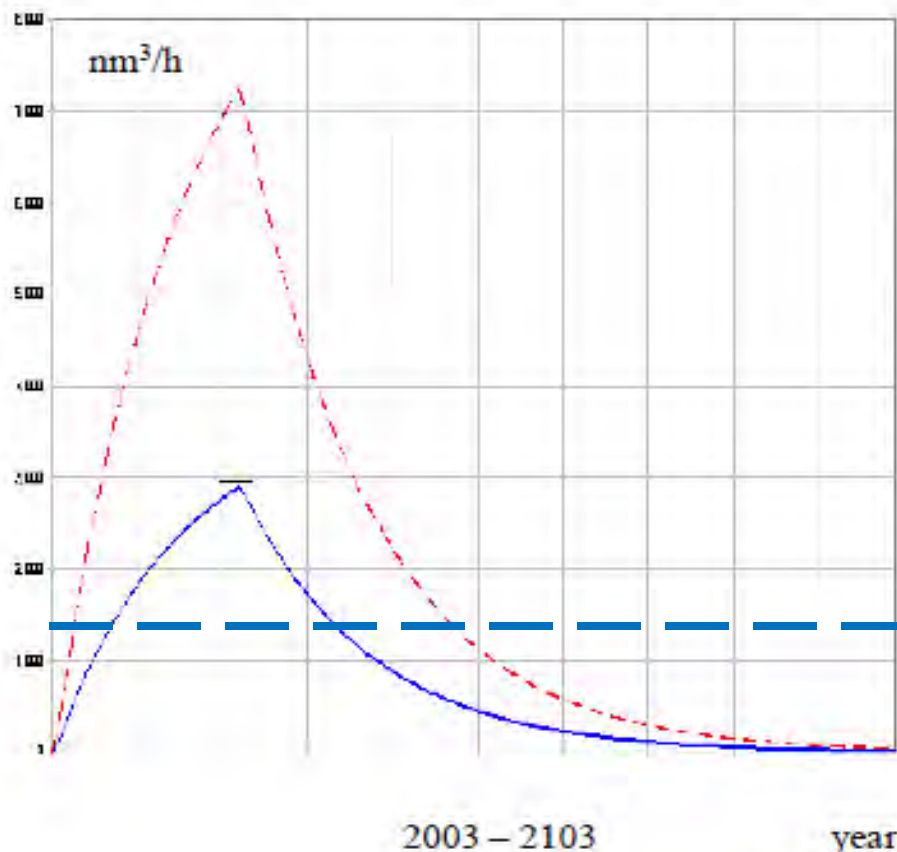


Fig. 3: Comparison of three landfill gas calculation models (US-EPA 2005, US-EPA Central American Model 2007 and UNFCCC 2008) on the example of Shenyang, Laochuchong Landfill, ▲ PDD estimation and ▼ expected CER result

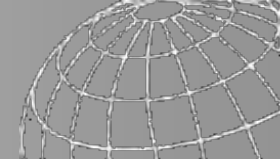




Case: Shenyang Laohuchong landfill applied the LFG forecast model special for China, (EPA, May,2009)

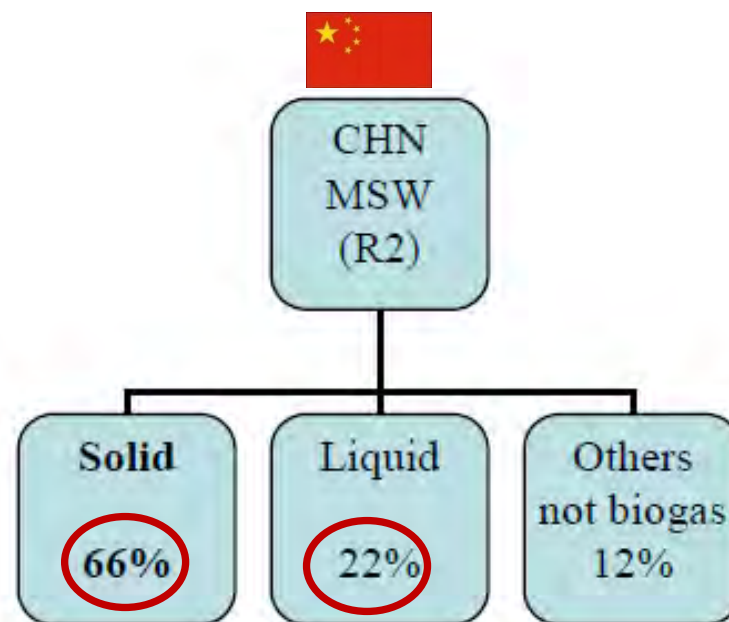
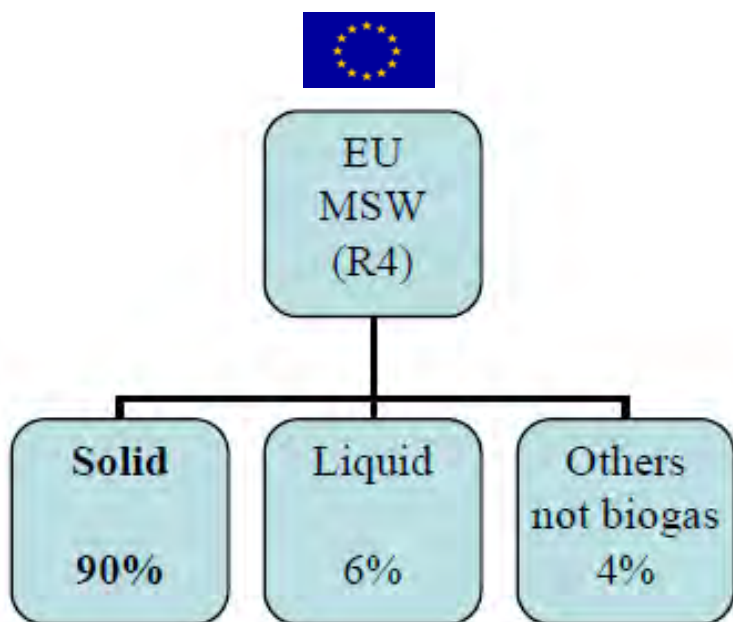


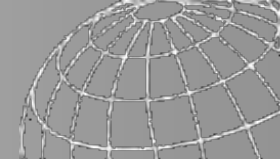
- a) left: $k = 0.0668$, $Lo = 116 \text{ t/m}^3$ (as in the UNFCCC methodology, PDD)
- b) right $k = 0.04$, $Lo = 70 \text{ t/m}^3$ calculated according the real waste composition and Climate
- c) red = for casted, blue = actual yield



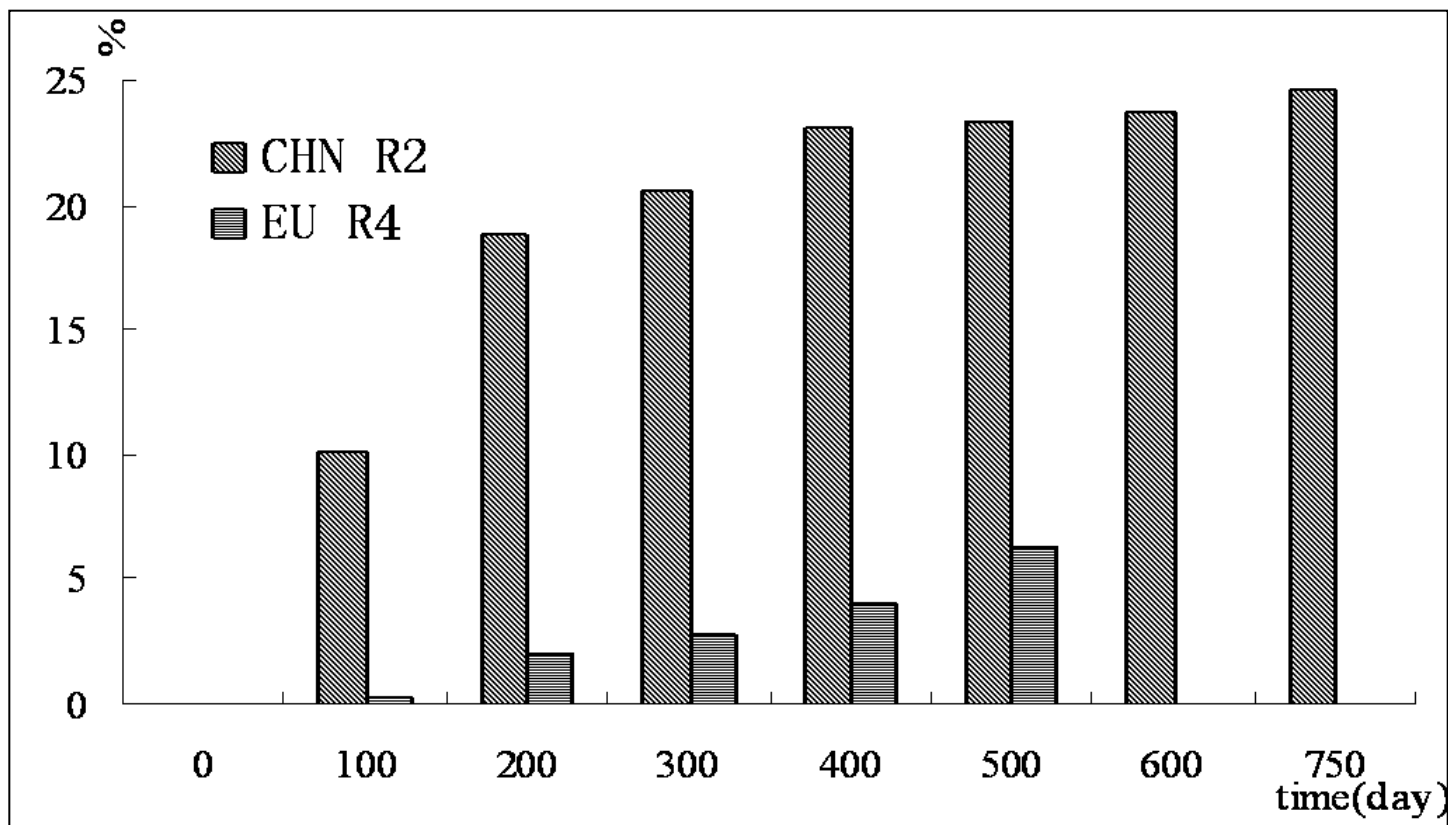
TOC mass balance of the EU and Chinese MSW

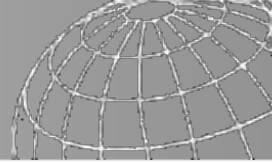
after 500 days landfill simulation
(rainfall 600 mm/year, 37 °C, pressure load of 3.5 tons/m², inoculum)





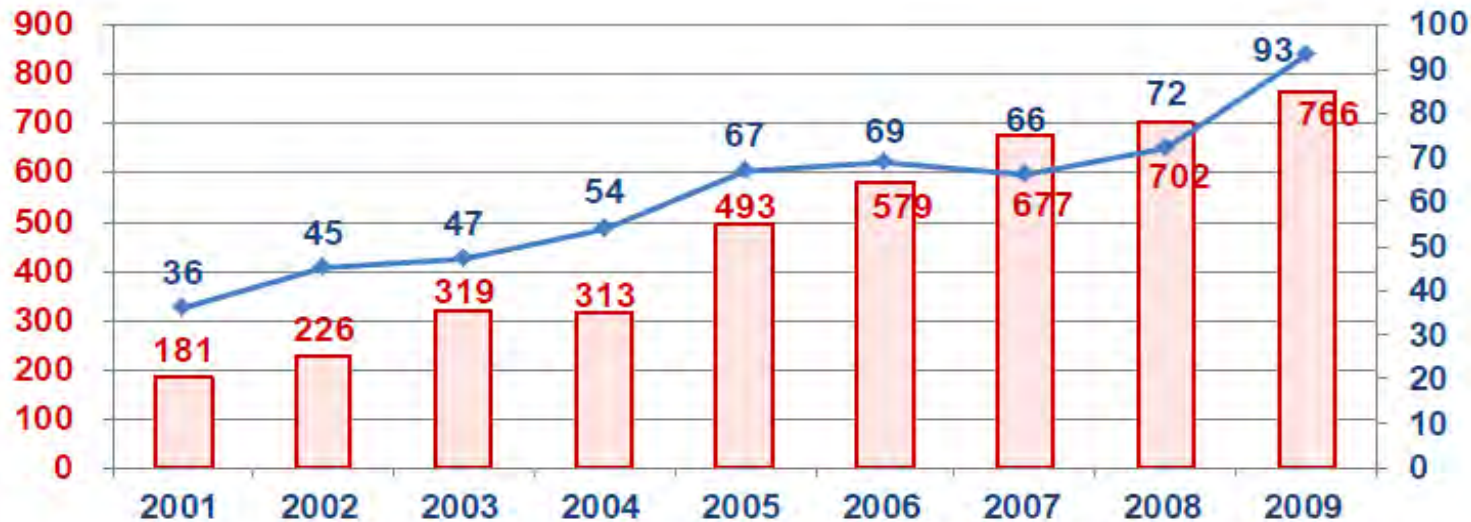
Comparison of TOC loss of EU and Chinese MSW during landfill simulation, exposure time up to 750 days





MSW Incineration 城市固体废物焚烧

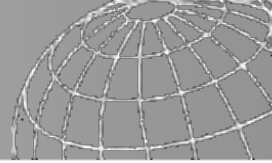
The MSW incineration shall be developed fast in the coastal, municipal but also rural areas (about 600 new incineration plants till 2020 with a total capacity of 103 mn t/yr, which would be about 1/3 of the collected MSW). 城市固体废物焚烧将不仅在沿海及地方城市发展，同时在农村地区也会发展迅速（到2020年将建成600个焚烧厂，处理能力达到1.03亿吨/年，占收集的城市固体废物总数量的1/3）



2005-2009
Heat value热值:
3.600 kJ/kg FM
Co-incineration with coal!
与煤炭混合焚烧!

average treatment capacity 平均规模(吨/日) 焚烧厂数量(number of plants)

Development of MSW Incineration in China 2001 – 2009, treatment capacity (in 2010 71,200 t/d was not reached). 中国2001-2009年城市物体废物焚烧发展，在2010年，没有达到71200吨/天的处理能力）



MSW Incineration 城市固体废物焚烧

Emissions limit values according GB18485-2002, draft GB18485 and EY2000/76/EEC
 限量排放值是根据GB18485-2002, GB18485草案和EY2000/76/EEC

Item	烟尘	HCl	SOx	NOx	CO	Dioxin
EU2000/76/EEC	10	10	50	200	50	0.1
中国GB18485-2002	80	75	260	400	150	1
GB18485-修订中	10/30?	50/60?	80/100?	200/250?	50/100?	0.1

Problems with Hg and Dioxin emissions

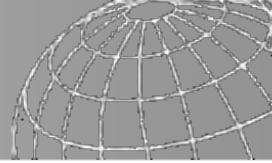
汞和二噁英的排放问题
(WB世行, 2005)

2011: New emission standards are proposed.
 2011: 新的排放标准被提议



MSW Incineration plant Chongqing, Tong Xing
 重庆同兴城市固体废物焚烧厂,
 1200t/d, 2x 10 MWeI, Investment:
 CHY 450 mn
 投资: 4.5亿元, 2005年

Xu Wenlong, Outlook of energitization of Biomass of municipal waste in China, EU-Forum on Clean Energy 2011



Composting 堆肥

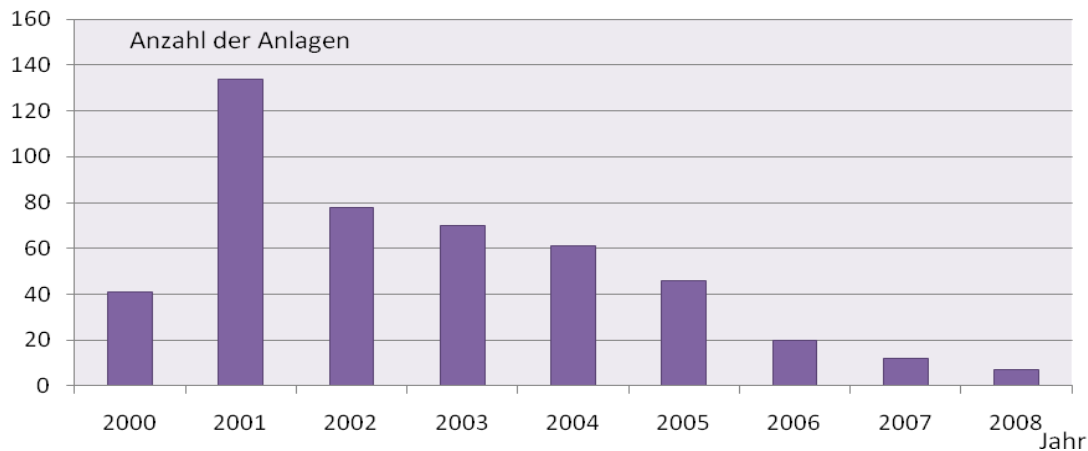
Composting was increasing in the 90th but is decreasing since 10 years to currently 7 plants, because of the bad end product quality derived from mixed waste and/or sewage sludge processing, though the market for organic fertilizer is good (< 30 EUR /t).

堆肥在上世纪90年代被广泛应用，但是由于从混合废弃物和/或污泥中得到的肥料质量低下，近10年来堆肥厂数量减少了7家，尽管有机肥的市场很好（< 30欧元/吨）

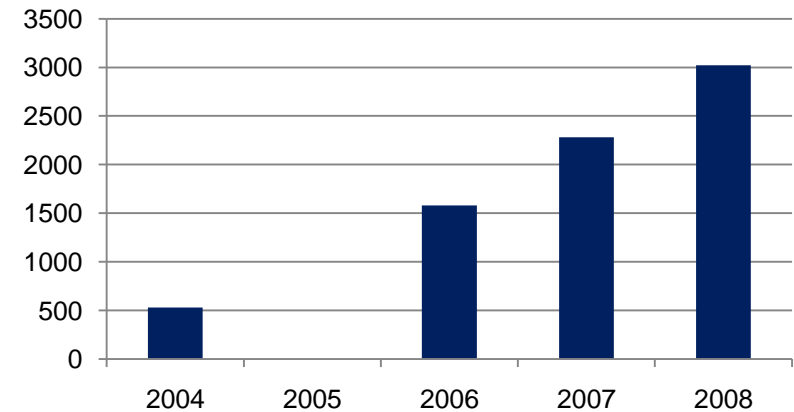
(Compost quality requirements acc. World Bank 2005 堆肥质量要求根据世行2005)

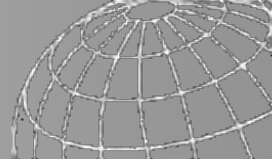
Mg/kg dried matter	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Heavy Metal standard	10	3	50	80	150	1	50	300

Number of MSW Composting plants in China 中国城市固体废物堆肥厂数量



Agriculture Composting Plants (Li Ji, CAU 20011)





RRU-BMW 4 Pilot Areas in Shenyang

2. Dong You

SYIAE/ICEE

1. Beifang Yuan

~~3. Minglian~~

5. Quan Yuan

4. Van Ke

SHENYANG CITY

If you have any questions please contact the
Telephone Help Line

如果你有任何问题，请联系我们
沈阳航空工业学院电话：024-86141598
绿色辽宁电话：024-86625211
皇姑区电话：024-86141598
东陵区电话：024-24218796
Email: greenliaoning@sina.com



BMW Source Separation in Shenyang

沈阳市生物垃圾源头分类

Public Communication – Biowaste bin – Separate Collection – Lab investigations

公众获取垃圾分类信息-生物垃圾桶-垃圾分类收集-实验室分析

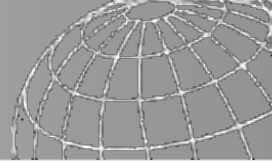


3 Bins:

- **BMW** (wet, kitchen waste)
- **RMW** (dry, RDF waste)
- **MSW** bin (for ignorant, but higher costs on a long time)

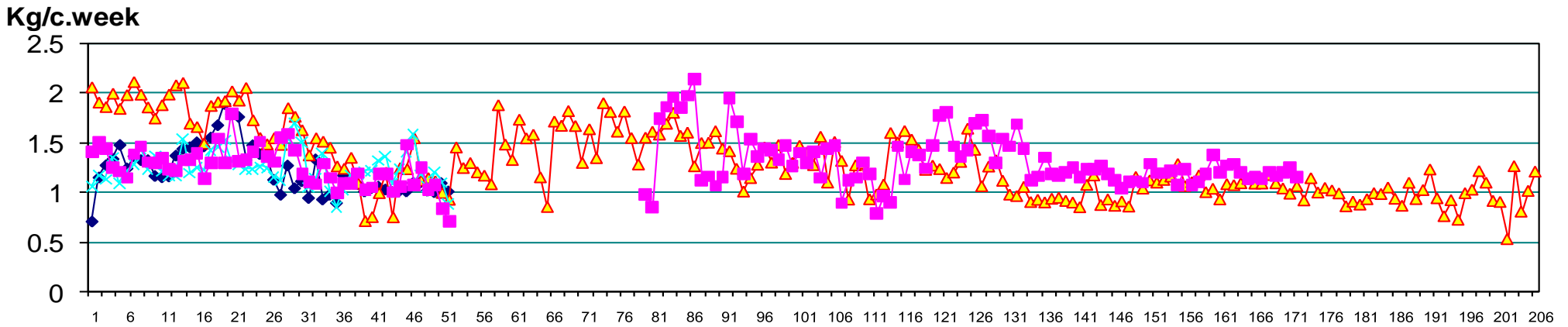
- **Recycling** bin not necessary they are sold



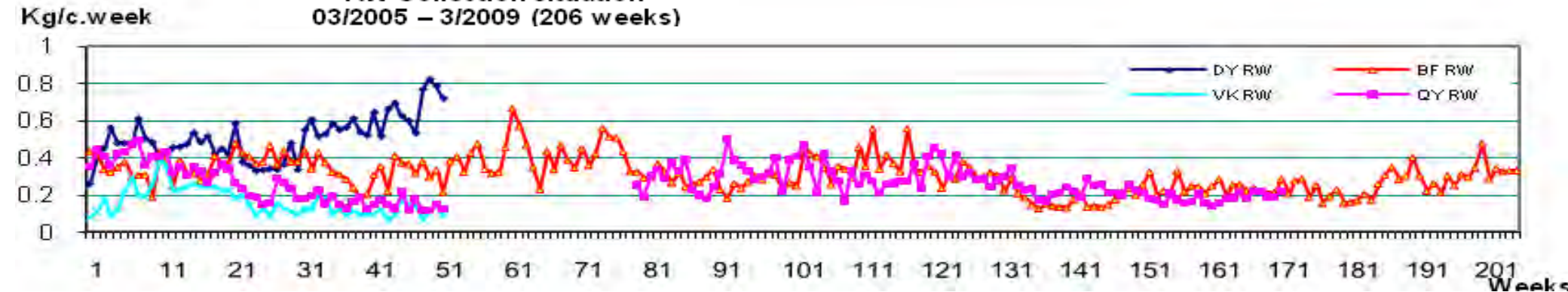


BMW/RMW Source Separation 城市可生物降解垃圾/回收的城市垃圾分类

Shenyang 沈阳, BMW & RMW from PSS pilot areas, 505 participants, 城市可生物降解垃圾/回收的城市垃圾来自实验区域505名参与者, 4 years (206 weeks) 2005-09, [kg/c. week], 4年(206周) 2005-09

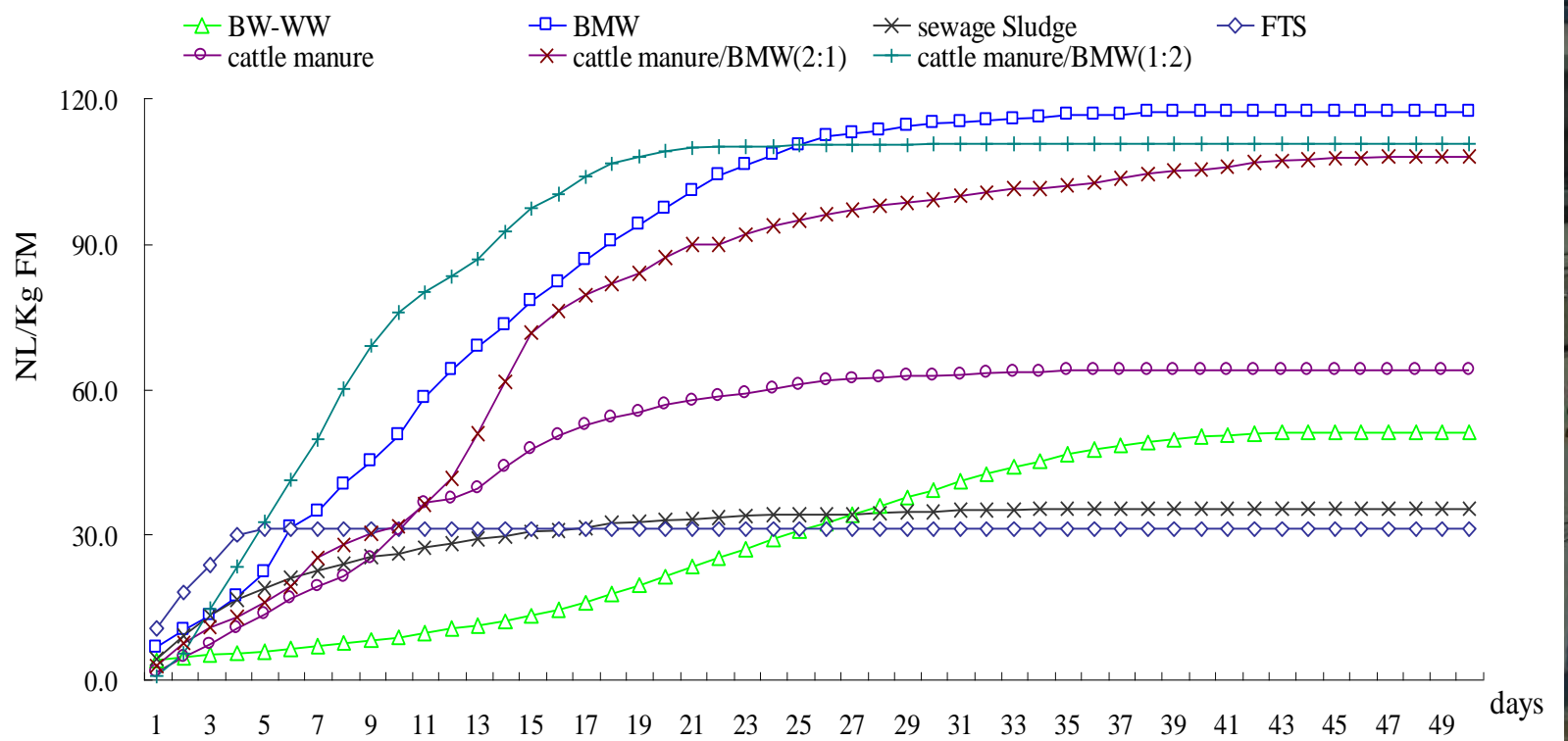


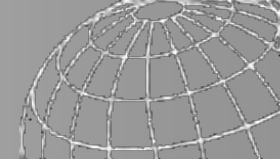
RW Collection situation
03/2005 – 3/2009 (206 weeks)



The new AD Lab equipment at ICEEE

4x 30l automatic controlled CSTR AD fermenters, co-funded by CIM (D)





Livestock Sector China

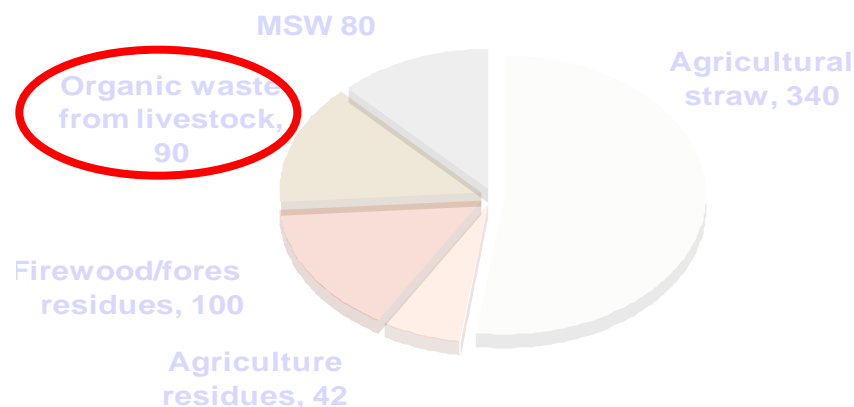
Commercial livestock farms: 4.3 mn in 2008
Large and medium-sized livestock farms: 20,000 in 2007
but only 3% are equipped with appropriate waste treatment facilities.

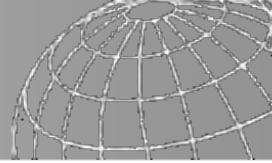
Livestock Waste:

1.9 bn t/yr in 2004
2.1 bn t/yr in 2005
2.7 bn t/yr in 2006
3.4 bn t/yr in 2015

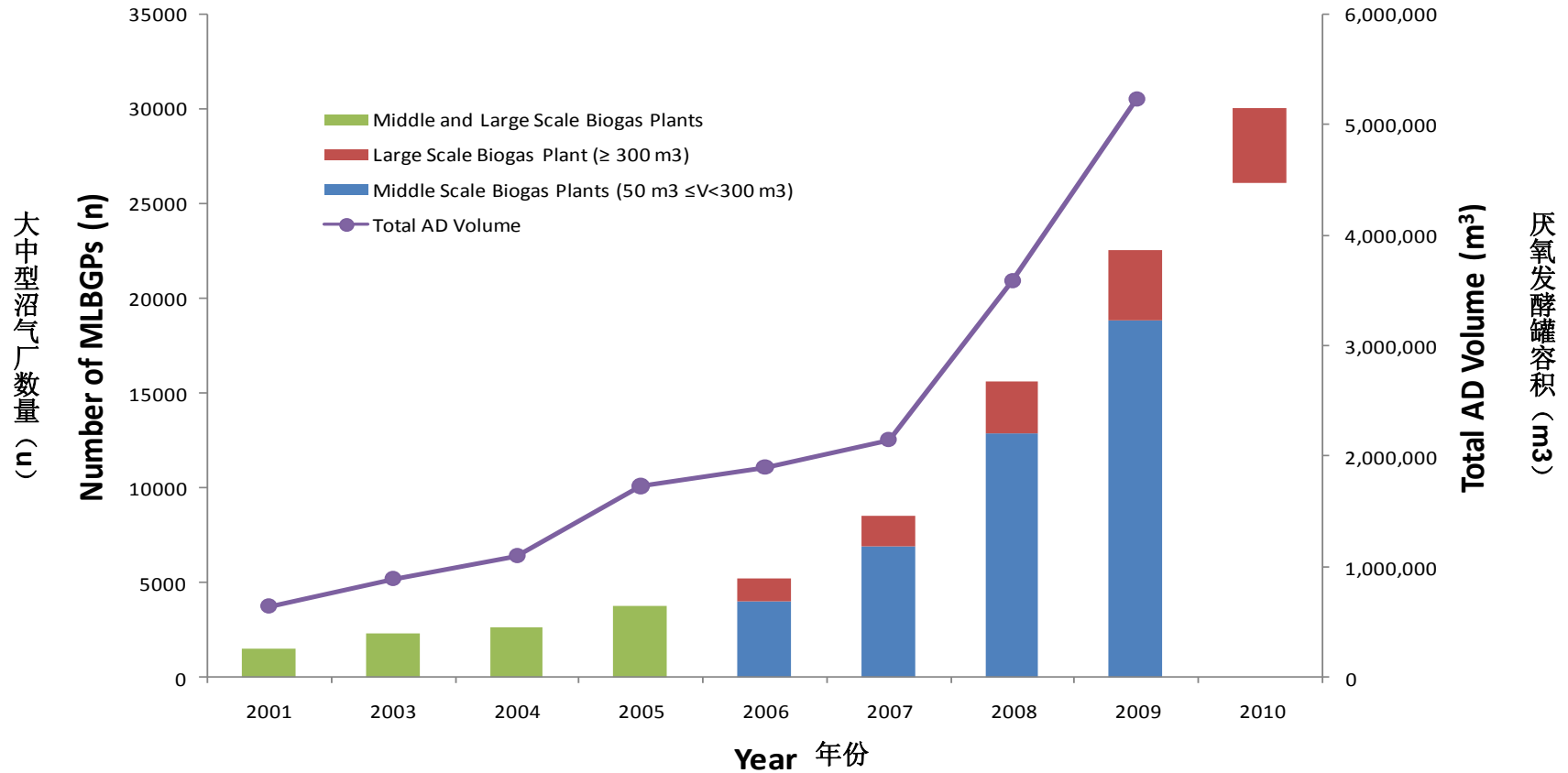
ML Biogas Plants: 4,000 in 2006
10,000 (with 1 bn m³ biogas /year) in 2020

2006: 650 mill tce/a, potential 2050: 1 bn tce/a



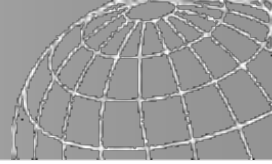


Agricultural Biogas plant development in China 2001 – 2010 中国2001-2010年农业沼气厂发展



2009: 56,856 BG plants 沼气厂 > 50m3 fermenter volume 发酵罐容积, 42 MWe!

(Source: China Biogas Association, BIOMA and NDRC Medium and Long Term Program of Renewable Energy Development Plan (2006 - 2020))
(来源: 中国沼气协会, 成都沼气研究所和国家发改委可在能能源中长期发展规划 (2006-2020))

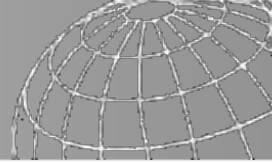


MSW in the 12 FYP, 第12个5年计

During the 12th-FYP period, the investment in this sector will be doubled, reaching CNY800bn and new concepts will be adopted. New integrated SWM solutions, appropriate to the local conditions, have to be approached.

在即将到来的十二五期间，这个领域的投资将翻倍，达到8000亿元人民币，并会采用新的理念。新的结合了当地条件的固体废弃物管理方法将被实施。

- Further increase of the MSW **treatment ratio** to 80%, 增加城市固体废物处理比例
- support the electricity generation from landfill gas and another 1600 **landfills** required till 2050
- improve MSW incineration capacity by another 600 **MSW Incineration plants** till 2020 支持填埋气的电力生产和改进城市固体废物的处理能力, emission standards will be increased
- **50 Kitchen waste AD plants** in 33 cities,在33个城市建立50个处理餐厨垃圾的沼气厂
- target for the cement **industry to treat 42 mn t/yr in 2015** (RDF and Biogas!)
水泥产业目标为到2015年处理 4200万吨 /年 (固态废弃物衍生燃料和沼气)
- Source separation of wet and dry waste in major cities (Beijing, Shanghai, Guandong, Harbin, Shenyang,)



Integrated waste treatment model with RDF use in the cement industry 在水泥产业中将垃圾处理模式与垃圾衍生燃料相结合

BMW processed in the way of MSW (with or without sewage sludge), leads to a digester effluent which after dewatering and biological drying, can be land filled or used as refuse derived fuel (RDF).

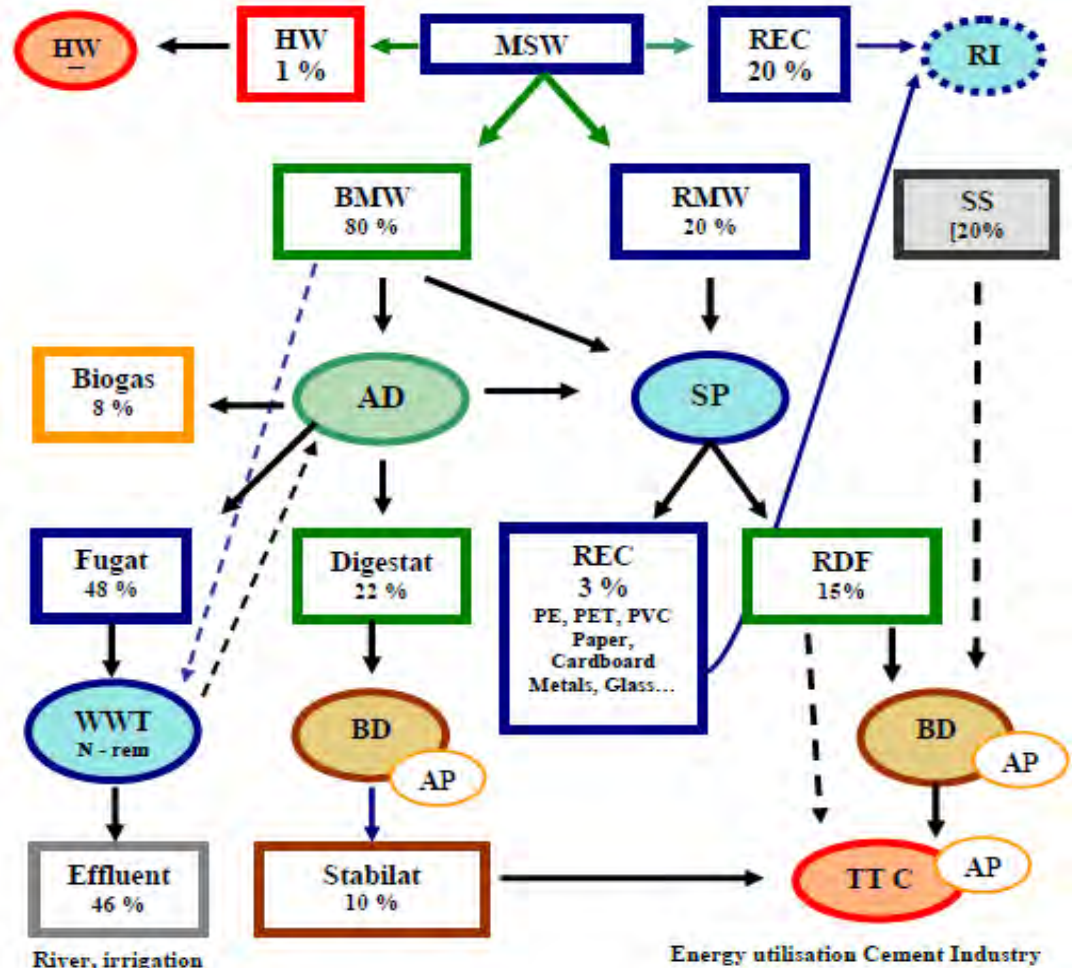
The high calorific waste is converted into RDF too.

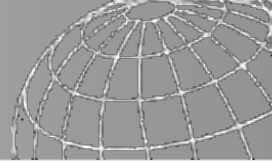
To realize this concept the Chinese cement industry got the target to establish a MSW treatment capacity of 42 mn t/a in the 12th-FYP till 2015.

城市生物可降解废弃物按照处理城市固体废物的方法进行加工（含有或不含有污泥），发酵排放物通过脱水和生物干燥便可用于填埋或者固态废弃物衍生燃料。

高热值的废弃物也可转化成固态废弃物衍生燃料。为了实现这套加工理念，中国水泥产业需在十二五期间（截止于2015年）达到处理42 mn t/a 城市固体废物的目标。

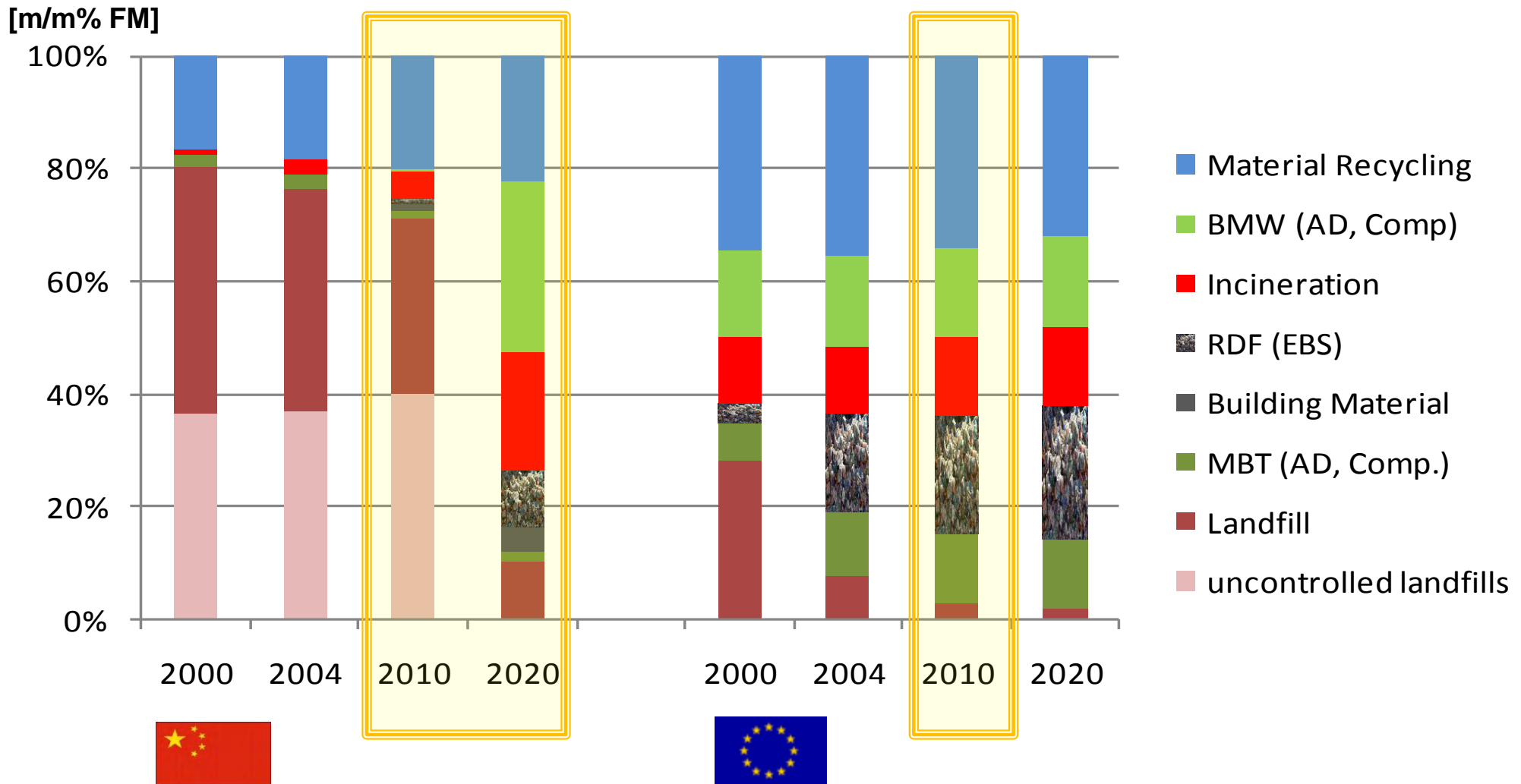
- AD Anaerobic Digestion 厌氧发酵
- AP Air Purification 气体净化
- BD Biological drying 生物干燥
- BMW Biological Municipal Waste 城市生物可降解废弃物
- HW Hazardous Waste 有毒有害废气物
- SS Sewage Sludge 污泥
- MSW Municipal Solid Waste 城市固体废物
- RDF Refuse Derived Fuel 固态废弃物衍生燃料
- REC Recycling 回收
- RI Recycling Industry 回收产业
- RMW Remaining Municipal Waste 剩余城市废弃物
- SP Sorting Plant for Recyclables 回收分类站
- TTC Thermal Treatment Cement 水泥热处理
- WWT Waste Water Treatment Plant 污水处理厂

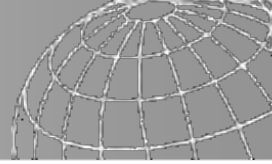




MSW Disposal & Treatment - China & Germany/Austria 2000 – 2020

中国和奥地利对生活垃圾的处置及处理情况





International SWM measures with limited success in China 国际固体废物管理测量在中国不是很成功

-Material recycling of secondary raw materials is performed via a informal, but well organised marketing system, which is based on market prices and functioning well (about 25% of waste is avoided for disposal), and bioorganic waste is not included.

二次原材料在中国的回收利用并不正轨，但是拥有一个建立在良好的市场价格和功能的市场体系（大概25%的废弃物避免了处理），但是不包含生物有机废弃物。

- Landfill gas collection was from limited success, as the CDM landfill gas projects in China shows (17% CERs). And landfill space- and leachate problems remain 从中国CDM填埋气项目（17% CERs）来看，填埋气的收集并不完全成功。填埋空间和渗沥液问题仍然存在

- Composting capacity was decreased seriously during the last decade, as

在过去的十年里堆肥能力快速下降，因为

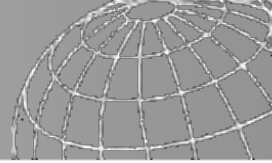
(i) composting is not really understood as a biotechnological process (temperature, moisture, oxygen supply, CO₂ removal,)

堆肥过程没有被正确理解为一个生物技术过程（温度、湿度、氧气供给、CO₂去除）

(ii) poor and unsufficient equipments 仪器装备落后

(iii) contaminated feedstock from ASW and sewage sludge 从城市固体废物和污泥中得来的原料被污染

(iv) Little financial inncentives to produce a quality product 对后端产品的经济补助很少



International SWM measures with limited success in China 国际固体废物管理测量在中国不是很成功

-Waste **incineration** plants with low emission standards (Hg, Dioxin,) and with low calorific value 3500 kJ/kg FS of MSW (high water content of bioorganic waste), new standards are proposed.

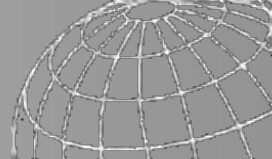
垃圾焚烧厂的排放标准低（汞、二噁英），并且其城市固体废物的燃烧热值（3500千焦/千克固体物质）低（生物有机废物的含水量高）

- **Biogas plants** in the municipal sector (so far not successful because of low competence of the companies involved , see biomass projects in China) 市政部门的沼气厂（由于企业间的竞争力小所以并不成功，参见中国生物质项目）

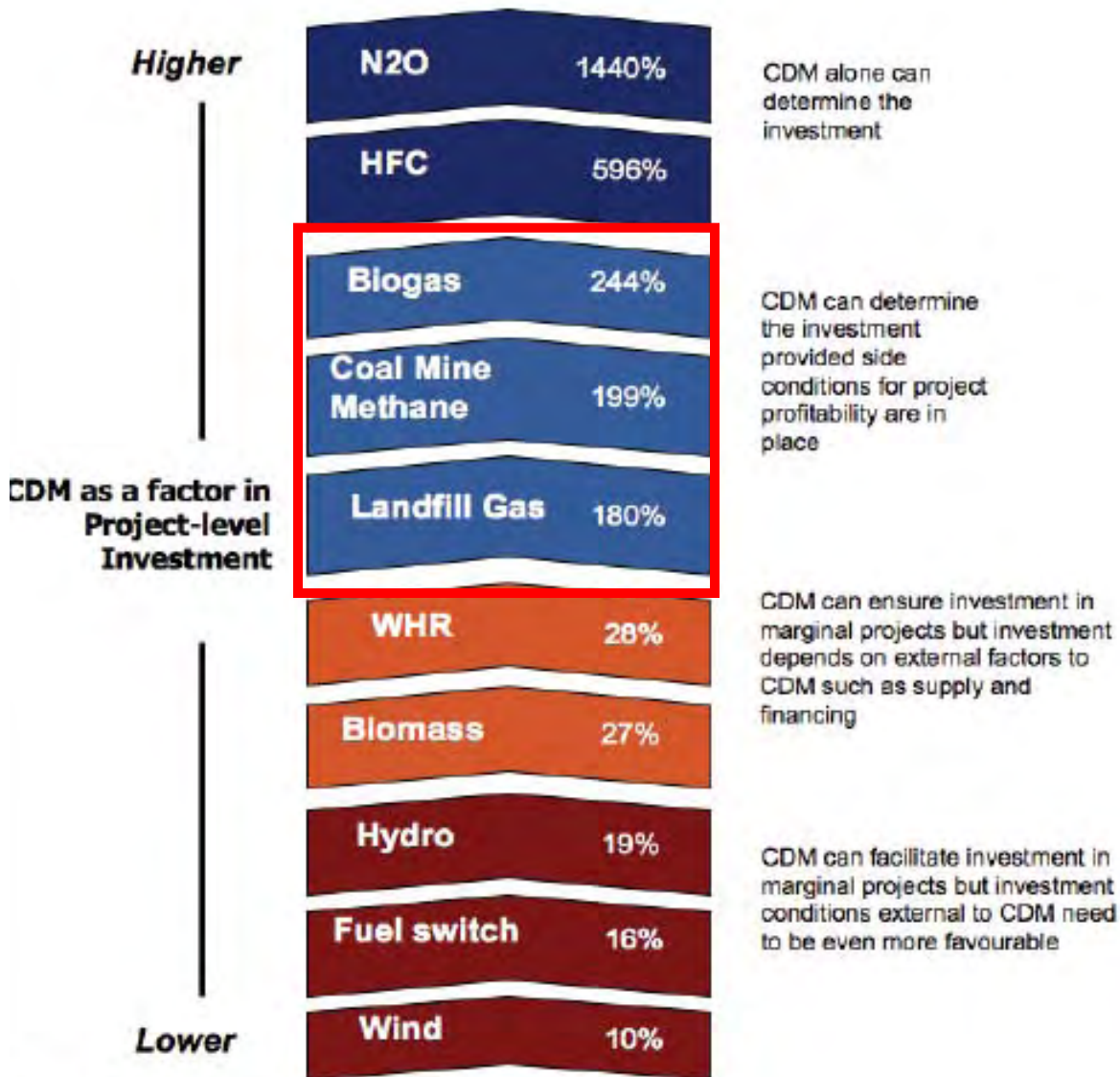
-**Agricultural Biogas plants** were built based in governmental investment subsidies , but they are often not operated well as no sufficient incentives for performance exist (feed in tariffs too low, fertilizer prices, no gate – fees , low competence of technicians operating those plants, no entrepreneur thinking, difficult interdisciplinary communication,)

农业沼气厂是基于政府投资补贴建立，但是其运行并不好。这主要是因为目前没有关于运行绩效方面的补贴（入网补贴少、肥料价格低、没有入门费、沼气厂运营技术人员的竞争小、企业领导者对此关注少、学科间交流困难）

-CDM not fully used

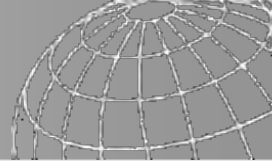


Total CER income to 2012 / Total investment

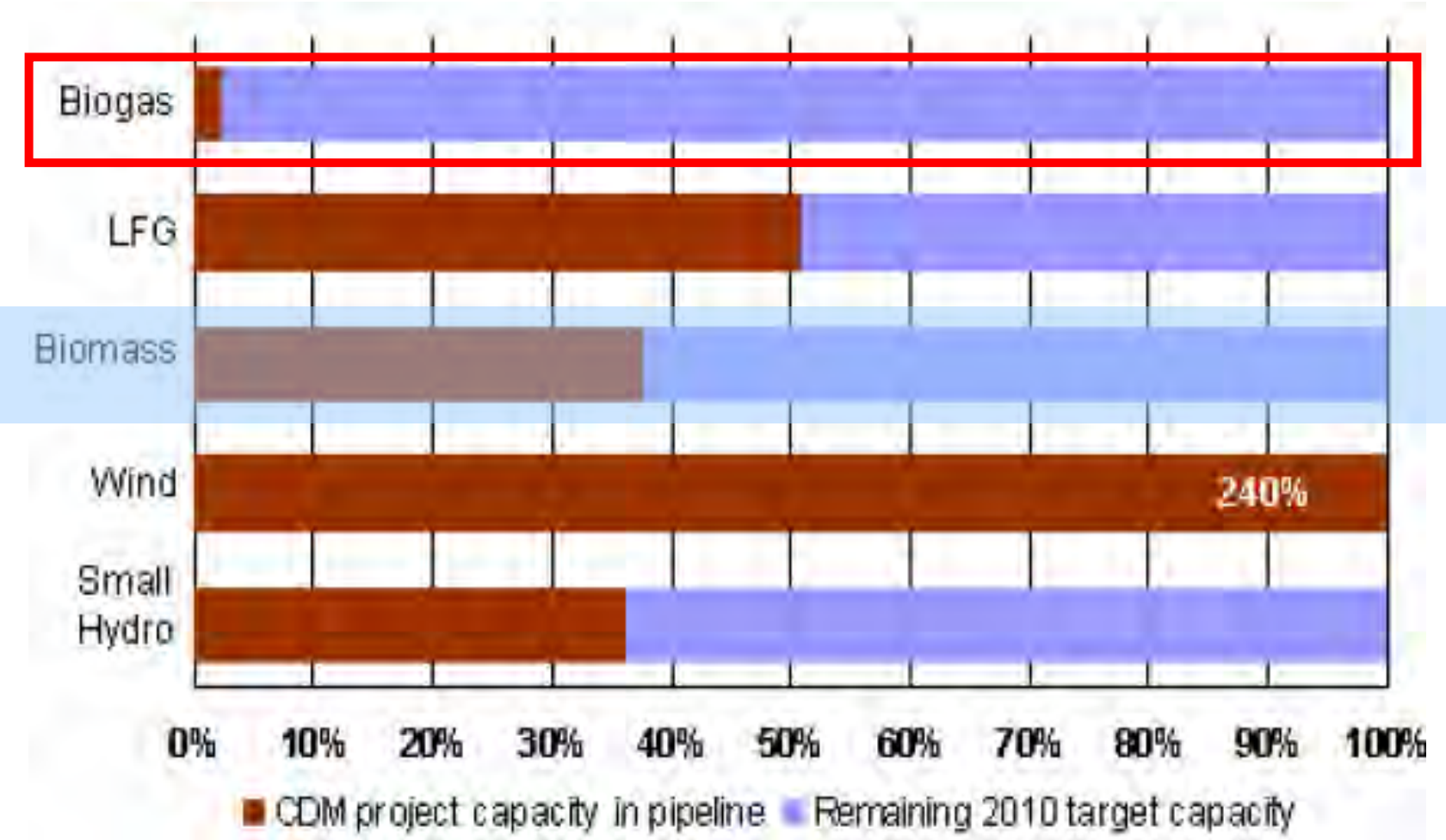


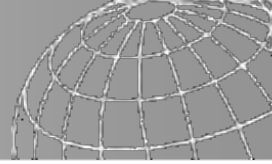
**CDM
Additionality
to facilitate
CDM projects
and Total
CERs to 2012**





Renewable Energy CDM Projects 2010 NDRC Targets





Conclusions

The Governmental policy and legislation in China is supportive to development a low carbon society considering waste management!

The biogas potential from solid biomass waste is 155 bn nm³/yr in 2050 but not leveraged !

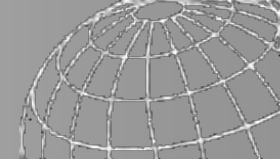
If MSW contains a high amount of fast decaying biodegradable substances the biogas potential cannot be used through landfill gas collection!

BMW can generate biogas under controlled conditions in biogas plant!

A 'landfill-free' China is getting a realistic long term vision!

The subsidy policy should be changed from investment support to longterm rewarding the operation!!

CDM as a tool to make the BG projects economically sustainable is NOT sufficient considered!



Thank You! Vielen Danke!



**Technical Director
Optimization of Biomass Utilization Project
生物质能项目主任：
Prof. Dr. Bernhard Raninger**

bernhard.raninger@gtz.de

Ranin@gmx.at

www.china-biogas.org