

The background of the slide is a photograph of the Paris skyline at dusk. The Eiffel Tower is visible on the left, and several modern high-rise buildings are illuminated against the blue twilight sky. The city lights reflect on the water in the foreground.

# 城市水系统可持续低碳发展思路

## Sustainable & Low Carbon Development of Urban Water System

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**2014年9月5日**

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住房和城乡建设部，城市建设司，张悦

# 目录

1

水资源与气候变化

**Water Resources & Climate Change**

2

城市水系统中的能源问题

Water-Energy Nexus in the Urban Water System

3

城市水系统的低碳理念：以污泥资源化为例

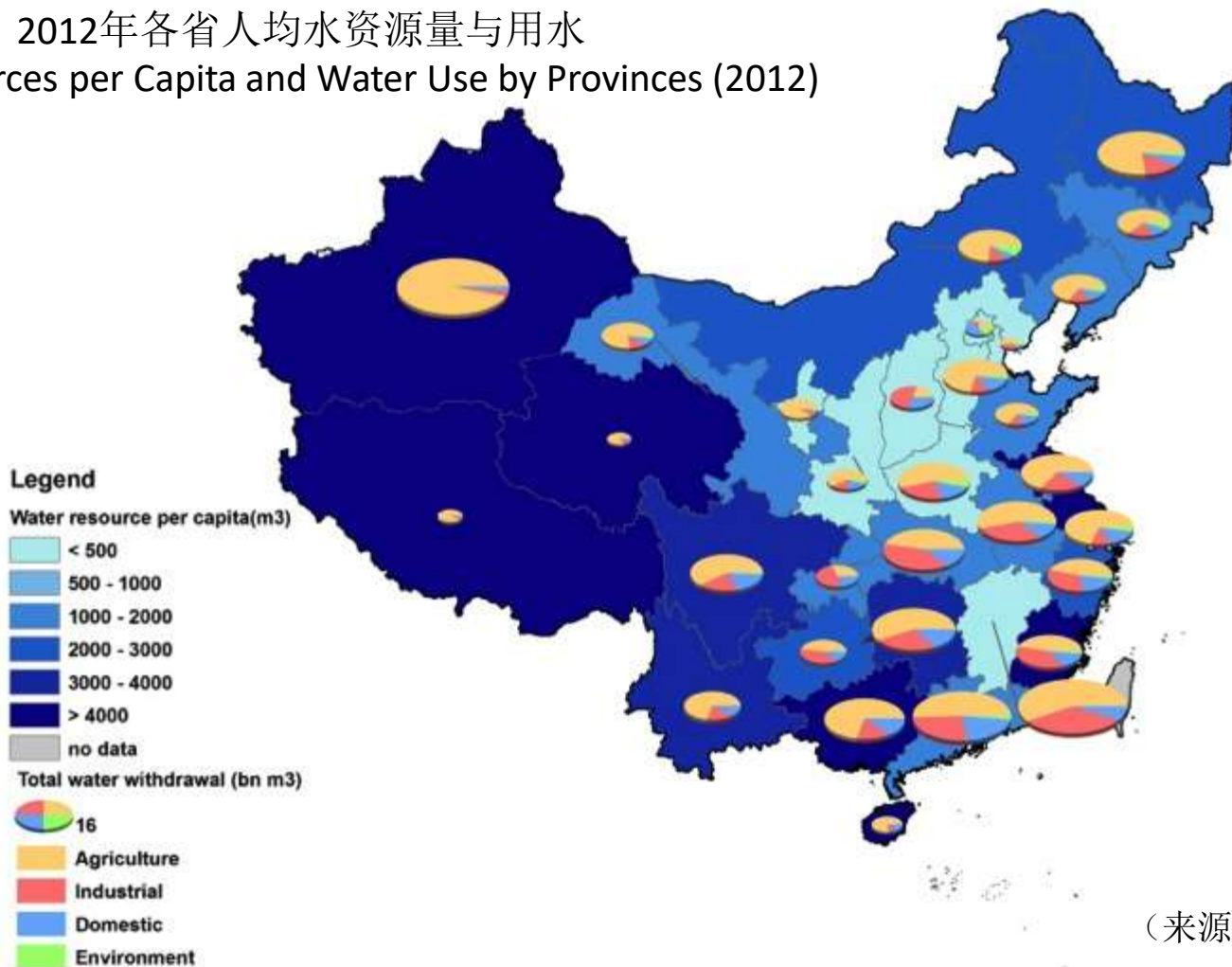
Low-Carbon Urban Water System: Sludge Reclamation

# 中国的水压力问题：水资源禀赋和用水

## WATER STRESS IN CHINA: Water resources and water use

2012年各省人均水资源量与用水

Water Resources per Capita and Water Use by Provinces (2012)

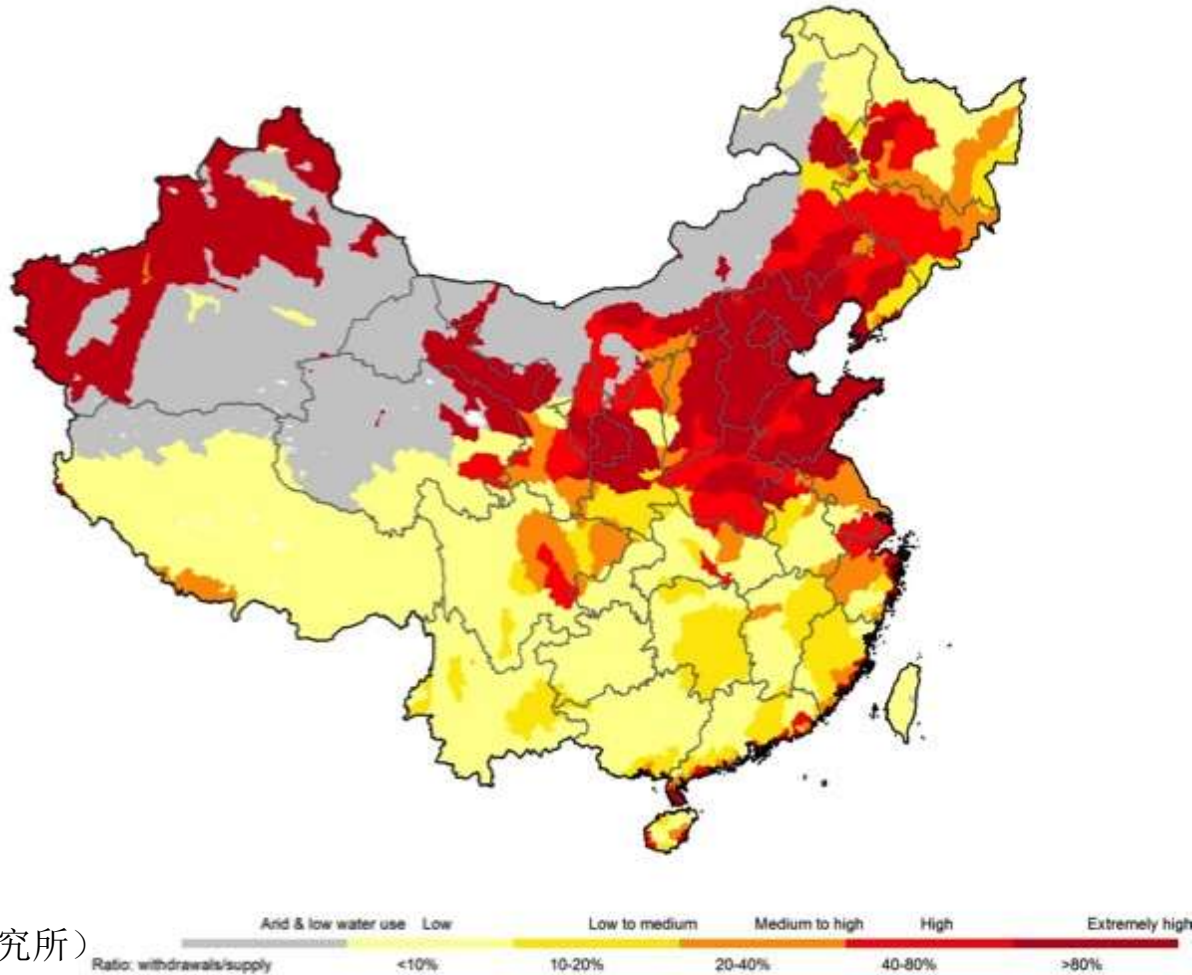


(来源：世界资源研究所)

中国人均水资源量是世界平均水平的1/4（2012年），同时用水和水资源禀赋不平衡  
China's water resources per capita is 1/4 of the world's average level. Unbalance between water resources and water use.

## 中国的水压力问题：基准水压力（取水量/多年平均可用水资源量）

### WATER STRESS IN CHINA: Baseline water stress



超过1/3面积面临较高的水压力，而且1/5以上面积面临极高的水压力（世界资源研究所）

According to World Resources Institute Aqueduct Baseline Water Stress, Roughly one thirds areas are facing serious water stress, and over 20% areas are in extremely high water stress



# 气候变化对城市水系统的冲击：暴雨与城市内涝

## Climate Change & Urban Water System: Rainstorm & Urban Flooding



2014年5月, 江西、湖南、广东、广西、贵州5省(自治区)23市77个县(市、区)出现大范围持续性强降雨过程,导致121.6万人受灾

In May 2014, 5 provinces were subjected to persistent and heavy rainfall, leading to 1.2 million people facing with urban flooding

## 气候变化对城市水系统的冲击：干旱与供水短缺

## Climate Change & Urban Water System: Droughts & Water Supply Shortage



2014年6月以来，河南、山东、陕西、内蒙古、山西、新疆等13个省区遭遇严重干旱，820万人面临饮水困难。

Since July 2014, 13 provinces were subjected to severe droughts, leading to 8.2 million people facing with water shortage



# 城市水系统对气候变化的影响：现存问题

## Climate Change & Urban Water System: Existing problems

在水资源选择战略、污水处理中缺乏对能源的考虑

Lacking consideration of energy as a factor in water resource selection and wastewater treatment

技术研发不足、基础设施投资不足（如管网）

Insufficiency in R&D and infrastructure investment (e.g. pipes construction)

从割裂的角度看待城市水系统和气候变化

Considering water and climate change as separate issues

对城市水系统对气候变化的影响关注不足

Ignorance of the impacts of urban water system on climate change

缺乏对水资源供给和污水处理能耗的相关统计数据

Lacking statistics on the energy consumption of water supply and wastewater treatment

# 目录

1

水资源与气候变化

Water Resources & Climate Change

2

城市水系统中的能源问题

**Water-Energy Nexus in the Urban Water System**

3

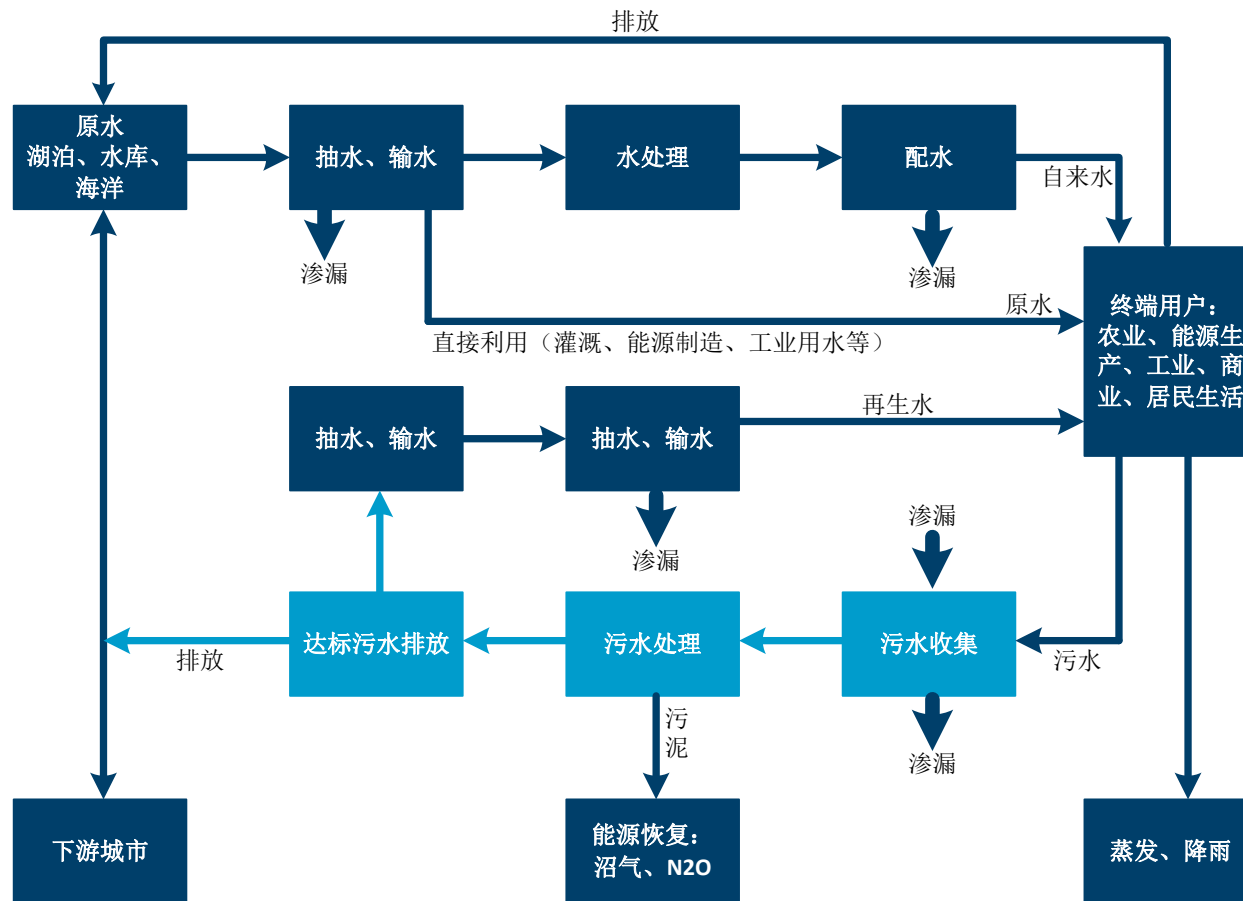
城市水系统的低碳理念：以污泥资源化为例

Low-Carbon Urban Water System: Sludge Reclamation



# 城市水系统中的能源：能源消耗与温室气体排放

## Energy in Urban Water System : Energy Consumption & GHG Emission

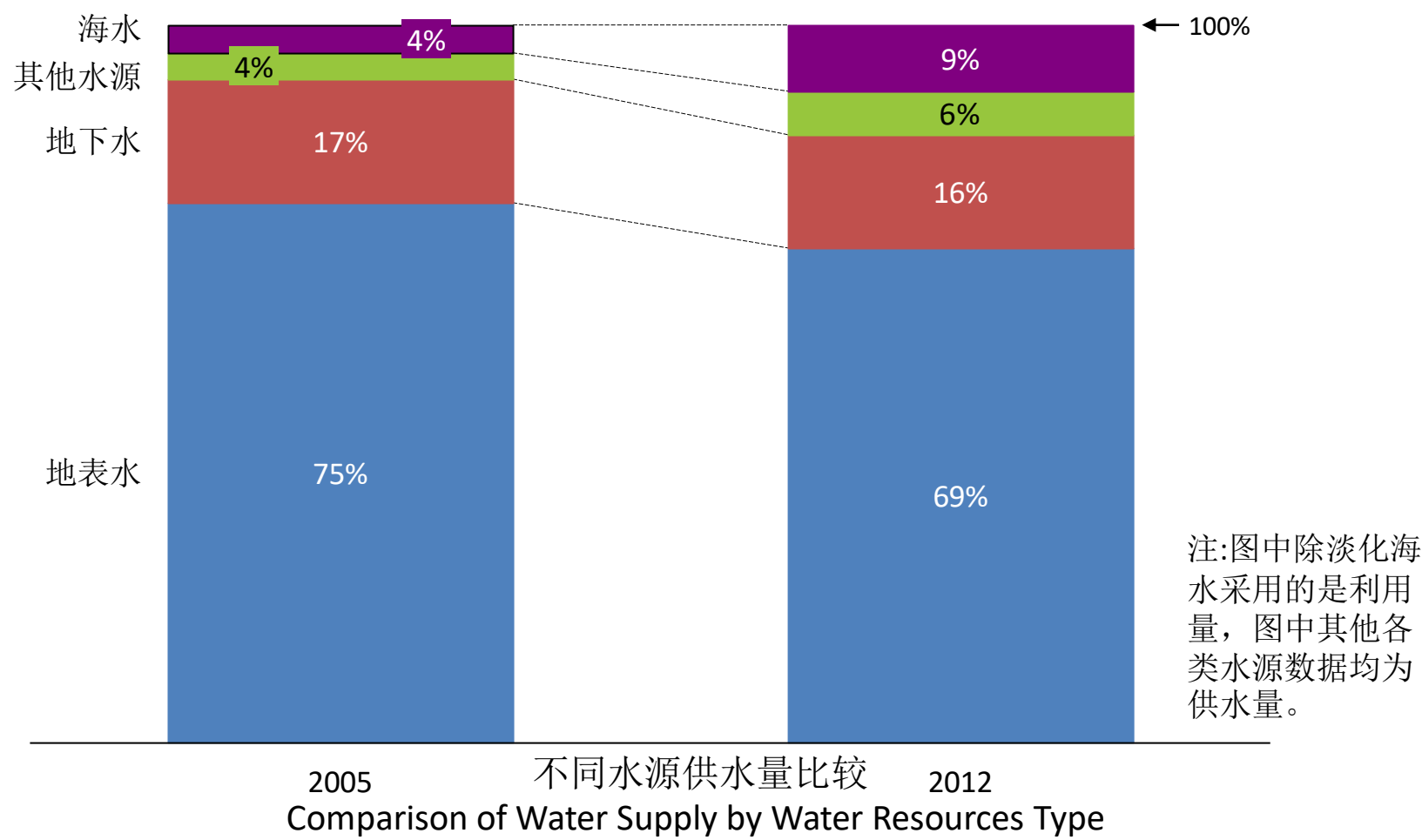


随着用水需求 and 水质要求的提高，城市水系统的能源密集属性愈发强烈，随之而来的温室气体排放的增加对气候变化带来直接影响

With the increasing demand on water resources and water quality, urban water system becomes more energy intensive, with higher GHG emission contributing directly to the climate change

城市供水：非常规水资源（淡化海水）利用量显著增长

Water Supply: Significant growth in the use of non traditional water resources (desalinated water)

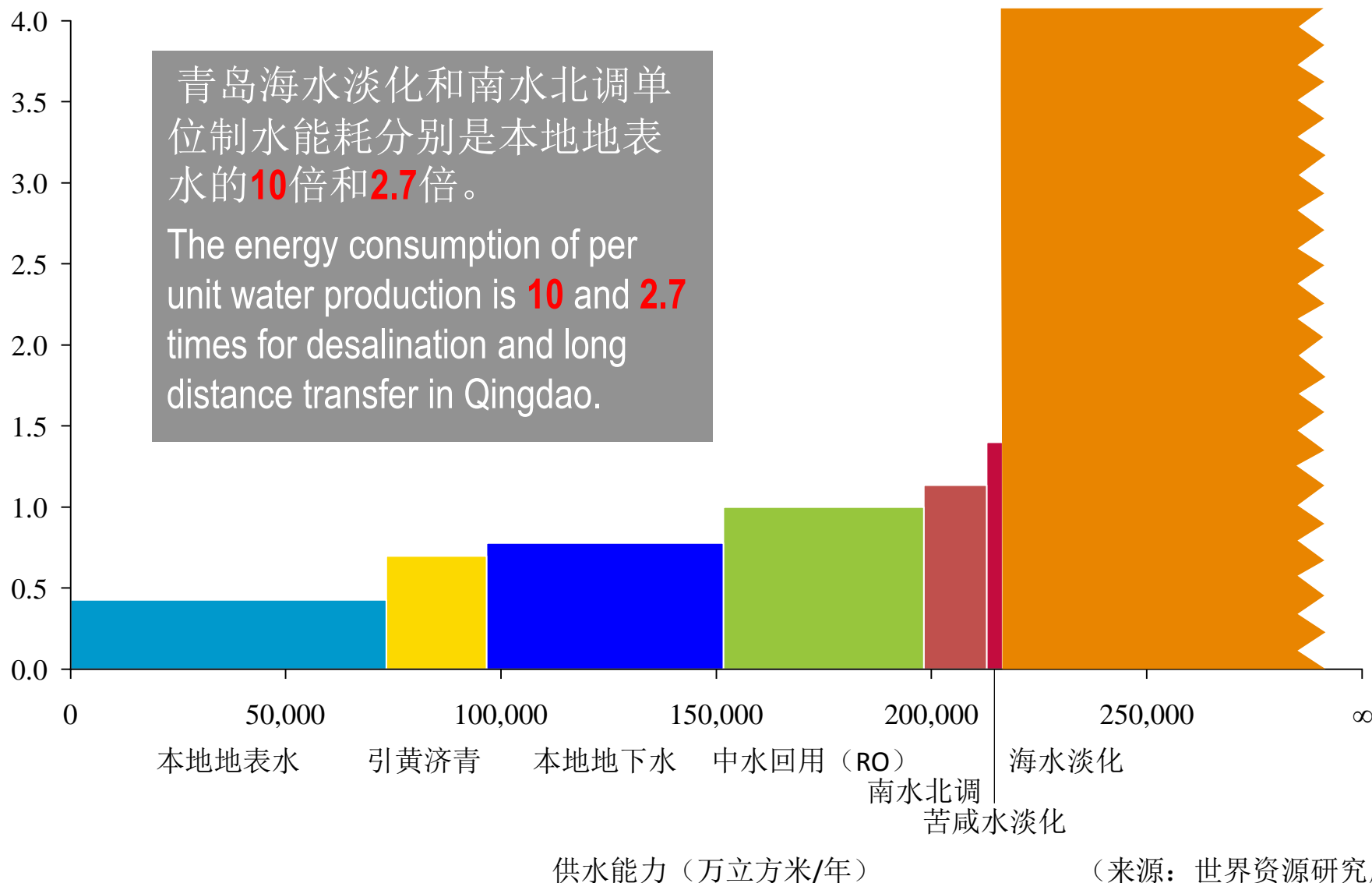


2012年全国供水总量比2005年增长了10%，而淡化海水利用量增长了180%，  
In 2012, the water supply increased 10% while the use of desalinated water increased 180% compared with 2005

# 城市供水：非传统水资源的利用带来城市供水能源强度的迅速增长（青岛）

## Water Supply: Increased energy intensity with the use of non traditional water resources

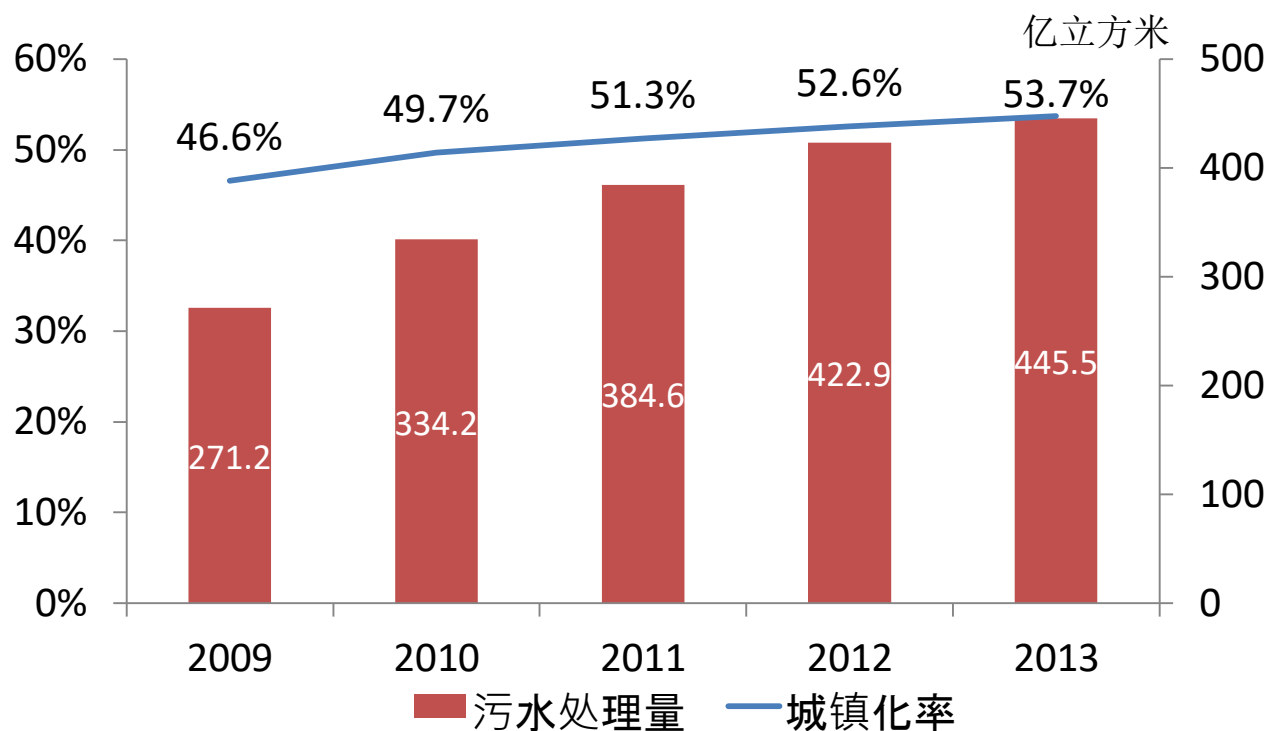
能耗（kWh/m<sup>3</sup>）





## 城市污水处理：城镇化进程和污水处理量迅猛增加

## Wastewater Treatment: Urbanization and increase in urban wastewater treatment



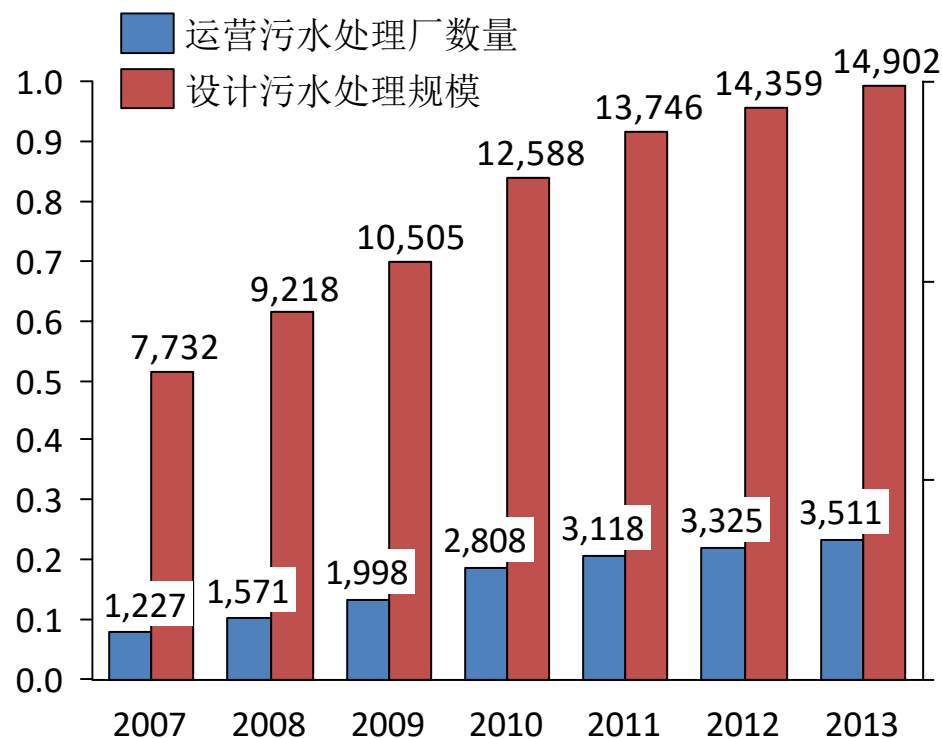
城镇化率与城镇污水处理量  
Urbanization Rate & Wastewater Treatment

为了解决中国城市污水处理空白问题，十一五以来污水处理设施数据增加迅速，污水处理量得到增加，2013年与2009年相比污水处理量增长64.3%

To address the big gap of wastewater treatment, China has a great increase in WWTP constructions. The treated wastewater in 2013 was increased by 64.3% than that of 2009

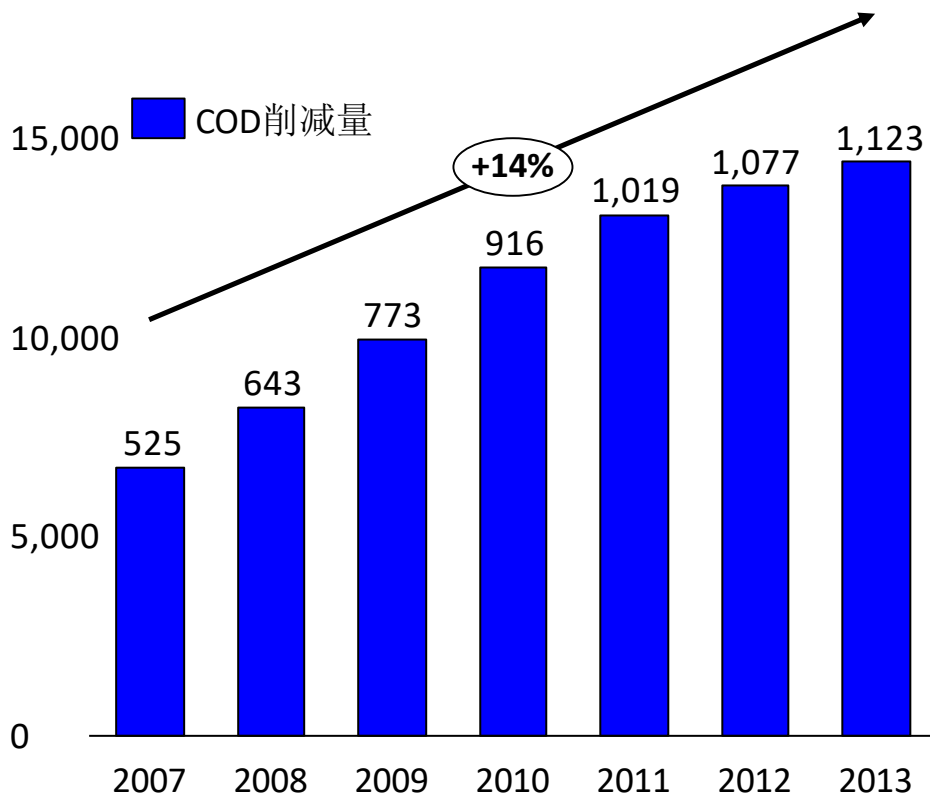
## 城市污水处理：城镇化进程推进带来污水处理量增多和系统能耗的增加

## Wastewater Treatment: Urbanization and associated increase in urban wastewater



历年城镇污水处理设施建设情况

Urban Wastewater Treatment Development in China



历年城镇污水处理设施建设COD削减量

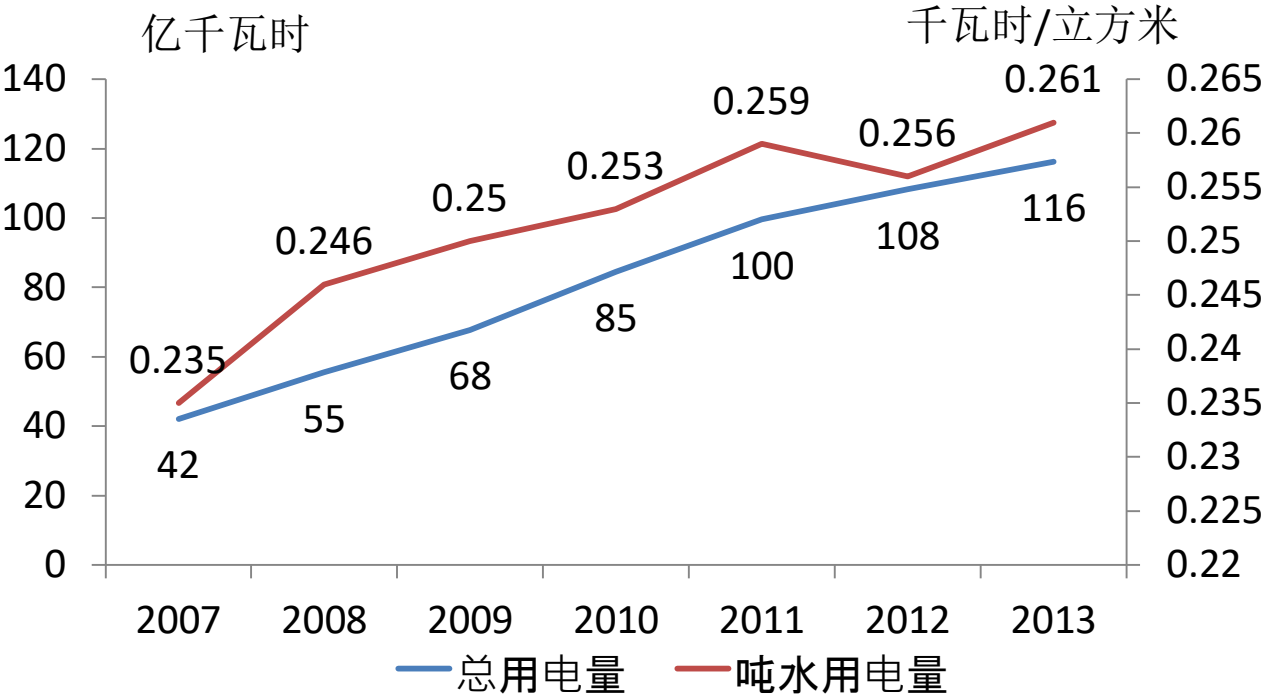
COD reduction for Urban Wastewater Treatment in China

污水处理厂数量已经处理能力得到快速提升，对于COD削减做出重要贡献

An sharp increase in the construction of wastewater treatment plants and the treated wastewater, contributing to the COD reduction directly.

城市污水处理：水质要求提高带来污水处理能源强度的显著增长

Wastewater Treatment: Increased energy intensity with higher water discharge standards



城镇污水处理电耗

Energy Consumption of Municipal Wastewater Treatment

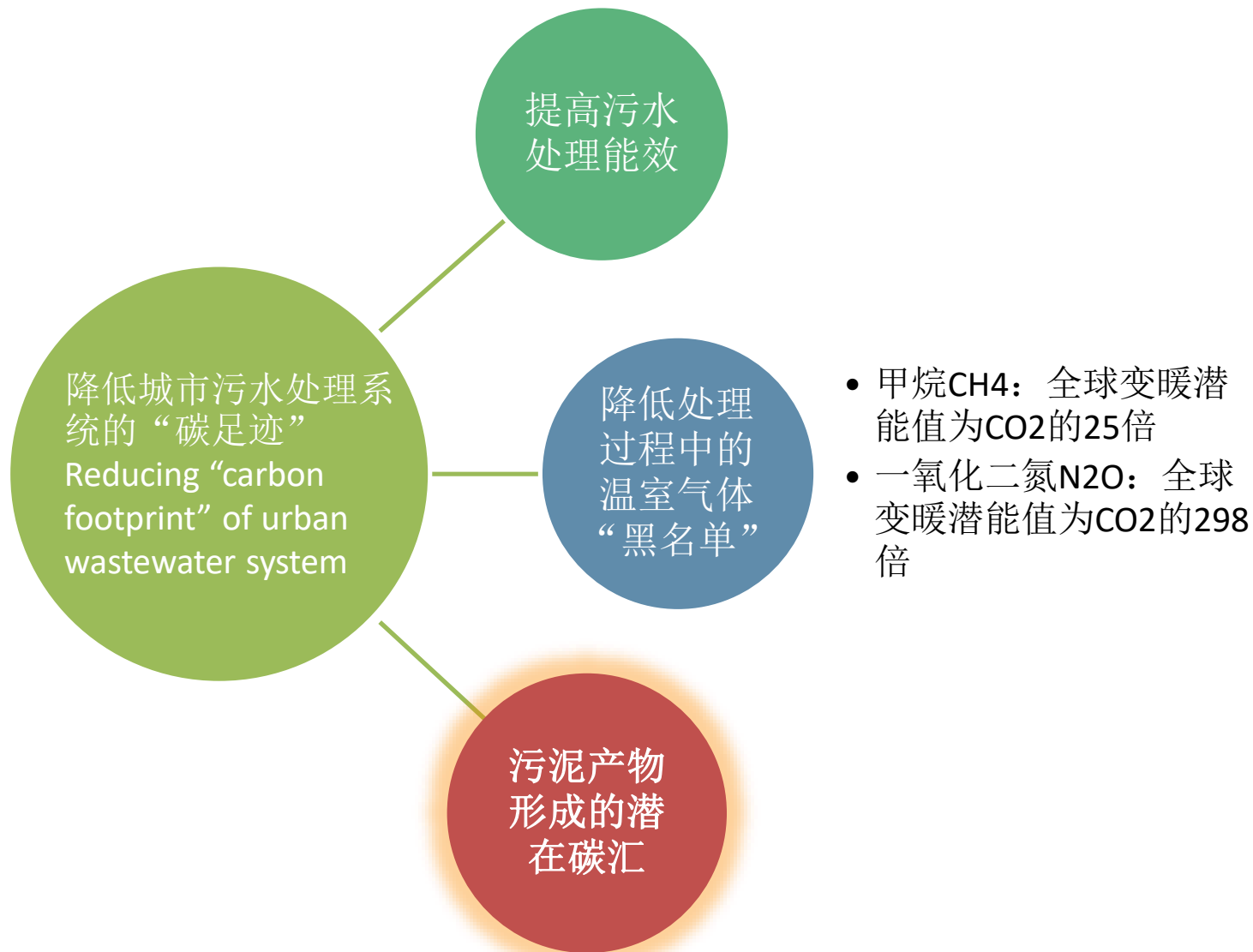
水质要求的提高以及污水再生循环利用的需求，污水处理的能源强度出现激增。2013年我国城镇污水处理厂处理总能耗较2007年增加了1.8倍，吨水污水处理能耗也提高了11%。

With the higher requirements on water quality and reclaimed water reuse, the energy consumption of urban wastewater system increased 80% compared with 2007. The energy intensity of per unit wastewater treated increased 11%.



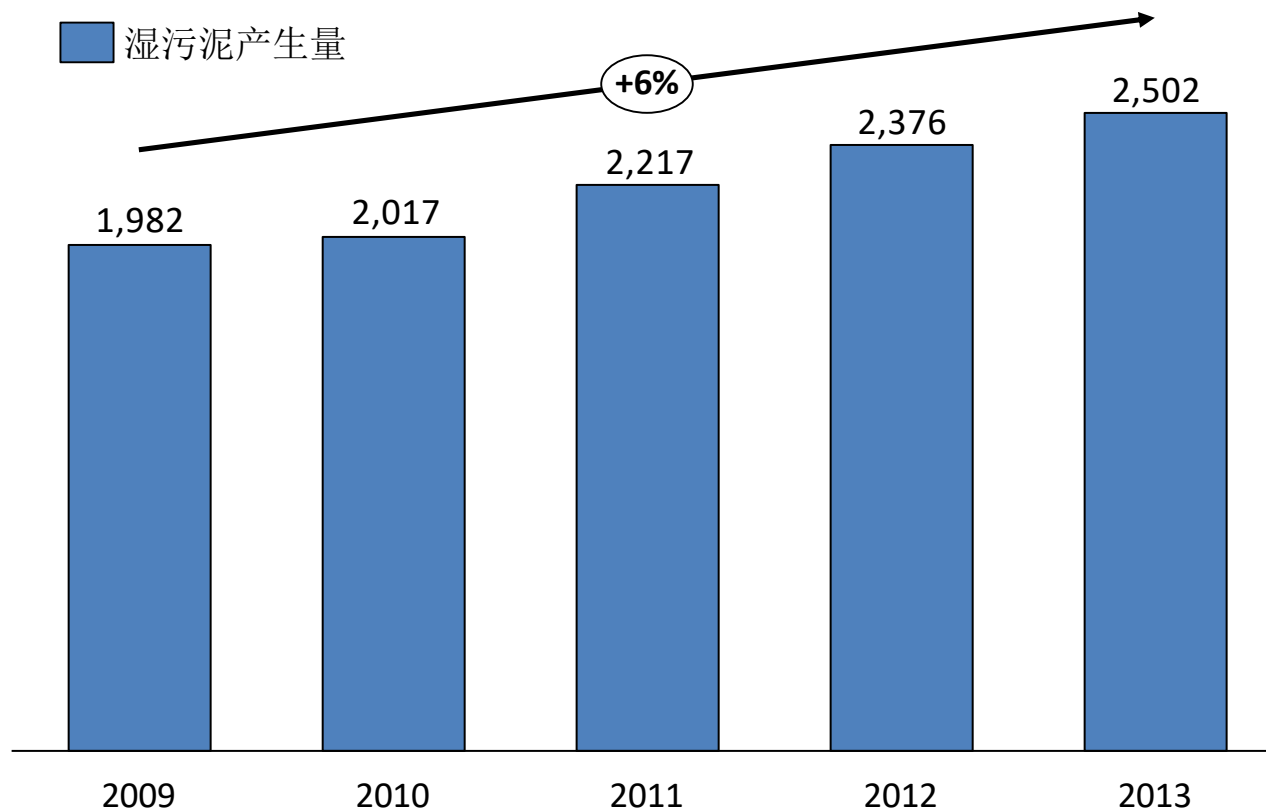
# 城市污水系统的温室气体减排：节能以外的新思路

## GHG Emission Reduction of Urban Wastewater System: New solutions



## 城市污水处理：污水处理量增多导致污泥产生量显著增长

## Wastewater Treatment: Wastewater treatment and sludge production



城镇污泥产生量与增长率  
Sludge Production vs Sludge Growth Rate

2013年我国城镇污水处理厂产生湿污泥2500万吨（含水率80%），与2009年相比年均增长率为6%。

In 2013, 25 million tons of sludge (80% water content) was produced from urban wastewater treatment plants, a annual growth rate of 6% from 2009 to 2013.

## 污泥的环境影响：二次污染和温室气体排放

### Environmental Impact of Sludge: Secondary pollution & GHG emission

污泥含有有毒有害物质，带来二次污染，威胁环境安全和公众健康。

The secondary pollution caused by hazardous matters in sludge poses risks to the environment and pub health.



污泥含有的有机物质发生厌氧消化反应排放温室气体效应为CO<sub>2</sub>25倍的甲烷。

The organic matters in the sludge decomposes into CH<sub>4</sub>, the GWP of which is 25 times of CO<sub>2</sub>.

城镇污水处理厂污泥已经因为“量变”而引起“质变”，成为城市发展中不可忽视的环境问题

With more sludge produced from urban wastewater treatment plants, sludge has become one of the unavoidable environmental problem in cities.



## 城镇污泥处理处置：随意堆置导致各地环境事件频发

**Sewage Sludge Disposal:** Environmental crises happened frequently in cities



城镇污水处理厂污泥问题在我国长期受到忽视，北京、上海、广州、合肥等大中城市都曾发生过因为污泥随意倾倒引起的环境污染和环境纠纷事件。

Sludge from urban wastewater treatment plants has long been ignored in China. Big cities in China such as Beijing, Shanghai, Guangzhou, Hefei and etc. have all undergone pollution and crises caused by sludge being dumped at discretion

# 目录

1

水资源与气候变化

Water Resources & Climate Change

2

城市水系统中的能源问题

Water-Energy Nexus in the Urban Water System

3

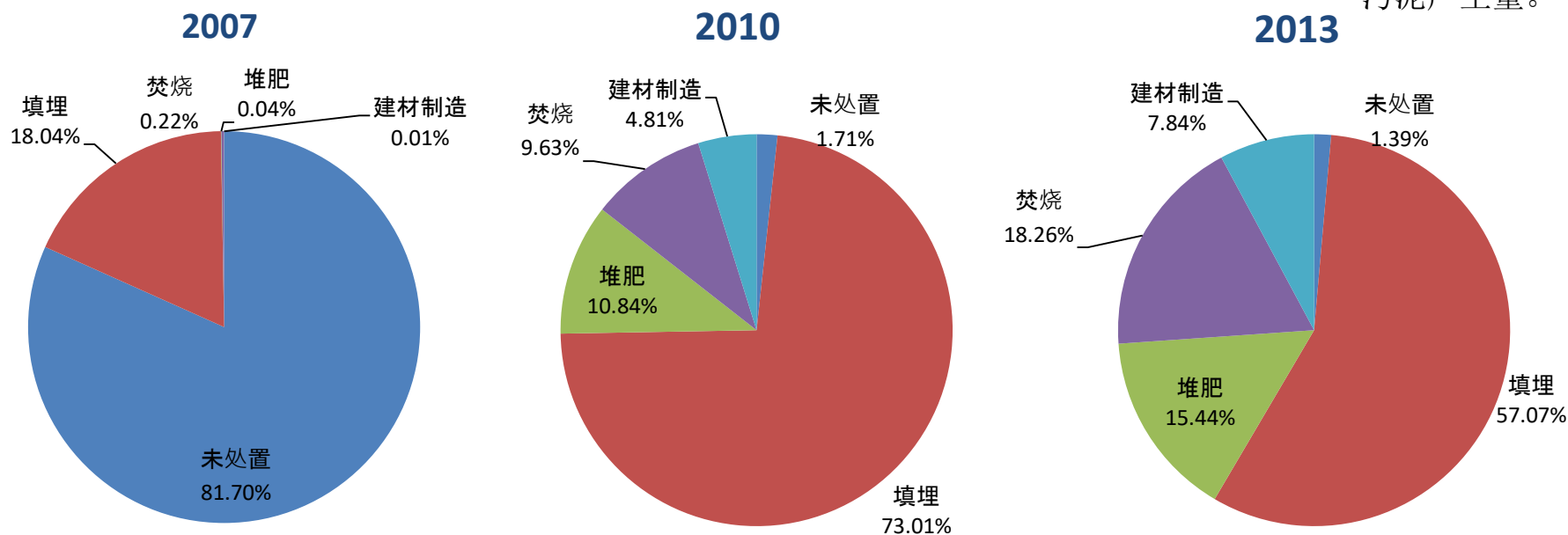
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**Low-Carbon Urban Water System: Sludge Reclamation**

# 城镇污泥处理处置：简易填埋仍为主导方式

## Sludge Treatment & Disposal: Landfill as the major disposal method

注：图中总量为污泥产生量。



中国 城镇污水处理厂污泥处理方式比较（2007-2013）  
Comparison on Sewage Sludge Disposal Methods in China (2007-2013)

随着国家对污泥处理处置的重视，越来越多的污泥得到处置，但简单填埋仍然是目前我国污泥处理处置的主要方式，占到污泥处置总量的46%

Sludge disposal has become one of the critical works of the government with more sludge being disposed. However, landfill is the major sludge disposal method in China with a share of 46%

## 城镇污泥处理处置：挑战与机遇

## Sludge Treatment & Disposal: Challenges & opportunities

挑战 Challenges	机遇 Opportunities
污水厂基本没有污泥消化处理，仅限于机械脱水处理 Few wastewater treatment plants have digestion equipment	已出台污泥处理处置专项政策 Sludge related policies issued
污泥有机质含量低，含沙量大 Low organic matter in sludge	污泥处理处置投资逐年增加 Growth in sludge disposal investment
污泥成分复杂，土地利用被严格限制 Limit the use of sludge on arable land	污泥处理处置需求不断提高 Increasing demand for sludge disposal
污泥焚烧开始兴起,但已引发社会关注 Public objection to incineration	



# 城镇污泥处理处置路线选择：废弃物还是资源

## Sludge Treatment & Disposal Method: Waste or resource

### 废弃物还是资源 Waste or Resource



除了含有有毒有害物质，污泥中还含有有机质和营养物质。采用不同的处理处置方式，决定了污泥是否能变废为宝。

Besides hazardous matters, sludge also contains lots of organic matters and nutrients. Selection of disposal methods decides if sludge exist as waste or resource.

发达国家污泥处理处置路线选择：从填埋到厌氧消化

Sludge Disposal in Developed Countries: from landfill to anaerobic digestion

发达国家污泥厌氧消化发展情况

Sludge Anaerobic Digestion in Developed Countries

国家 Country	年份 Year	厌氧消化装置 Anaerobic Digestion Equipment		发电量 Electricity Production
		进料为污泥 Sludge as Feed	进料为餐厨垃圾/ 农场废物 Kitchen/Poultry Waste as Feed	
		座数 Number	座数 Number	吉瓦时/年 Gwh/yr
英国 UK	2011	147	166	7883
瑞典 Sweden	2011	135	116	1709
挪威 Norwegian	2010	25	95	500
德国 Germany	2010	1400	NA	3100
美国 US	2010	3500	162	4530

# 襄阳污泥资源化项目：项目信息 CO<sub>2</sub>平衡图

## Xiangyang Sludge Project: Project information



- 规模：300吨/日（污泥、餐厨垃圾混合消化）
- 技术：高温热水解+中温厌氧消化 主要产出:沼气
- 产品：车用CNG、生物炭土、移动森林
- 运营模式：BOO
- Capacity: 300tons/day (sludge and kitchen waste co-digestion)
- Method: thermal hydrolysis + anaerobic digestion
- Product: CNG, biochar, seedling cultivation
- Operation mode: BOO

# 襄阳污泥资源化项目的能源效益：不同处置方式的碳排放比较

## Xiangyang Sludge Project's Energy Benefit: Carbon emission

襄阳项目污泥项目与焚烧、填埋的碳排放比较  
Comparison on GHG Emission of Xiangyang Project, Incineration, and Landfill

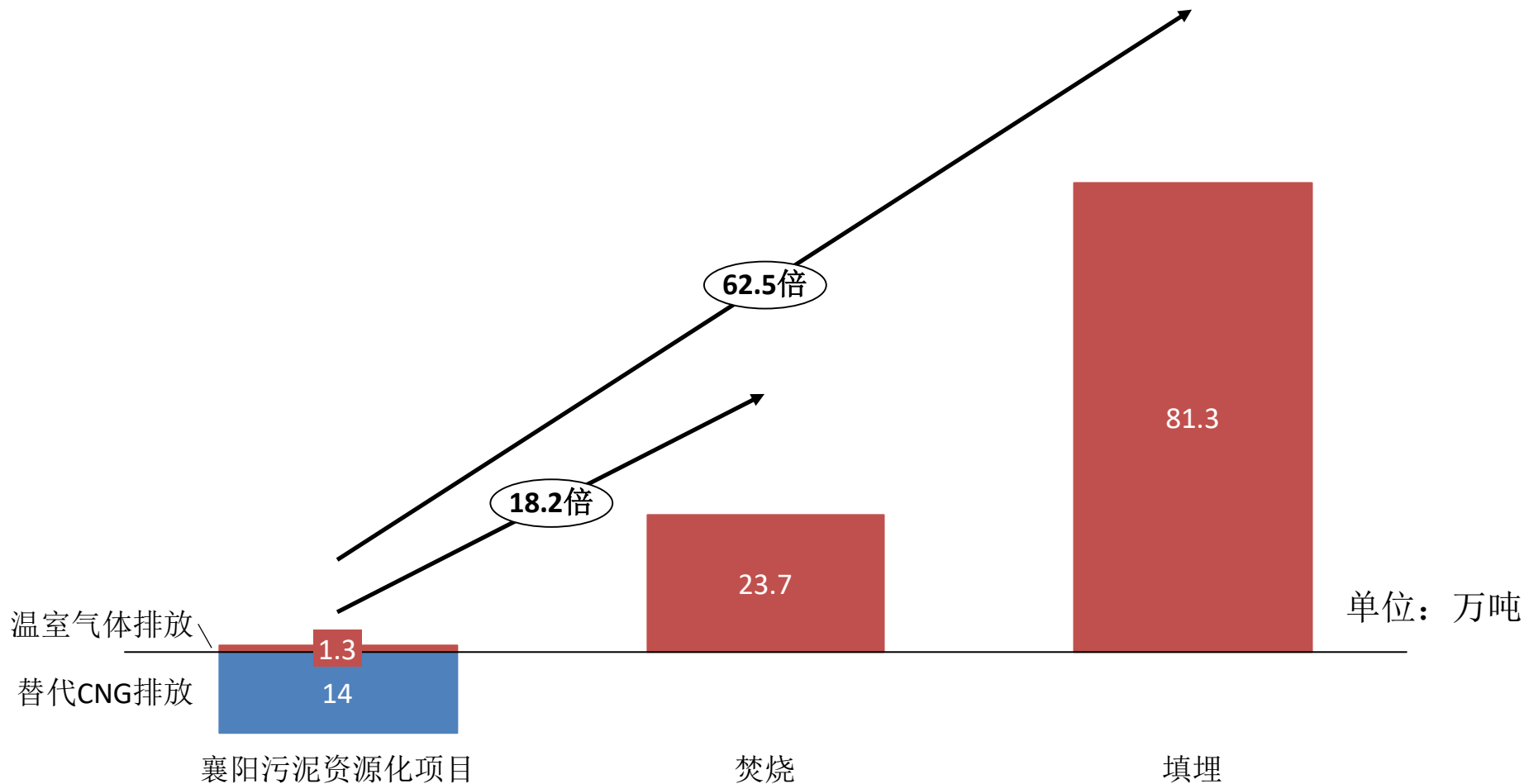
单位：万吨 Unit: 10,000 tons	襄阳项目 Xiangyang Project	焚烧 Incineration	填埋 Landfill
碳排放 Carbon Emission	1.3	23.7	81.3
中性碳（备案项，不计入排放） CO2 Emission from Bio fuel (Backup Item)	18.4	54.8	3.9
车用CNG替代化石能源排放 Emission from Fossil Fuel Replaced by CNG	14.0	0	0

相对于填埋或焚烧，襄阳项目在21年的运行期中实现了98%或95%的温室气体减排；同时可产生约4500万立方米CNG，替代近6万立方米车用汽油，实现约14万吨CO<sub>2</sub>e的额外减排

Compared with landfill and incineration, Xiangyang project can reduce 98 or 95% GHG emission. Meanwhile, 4500 m3 CNG is produced daily to replace 60000 litres gasoline, which avoids an extra 0.14 million CO<sub>2</sub>e emission.

# 襄阳污泥资源化项目的能源效益：化石能源替代和温室气体减排

## Xiangyang Sludge Project's Energy Benefit: replacement of fossil fuel & GHG emission reduction

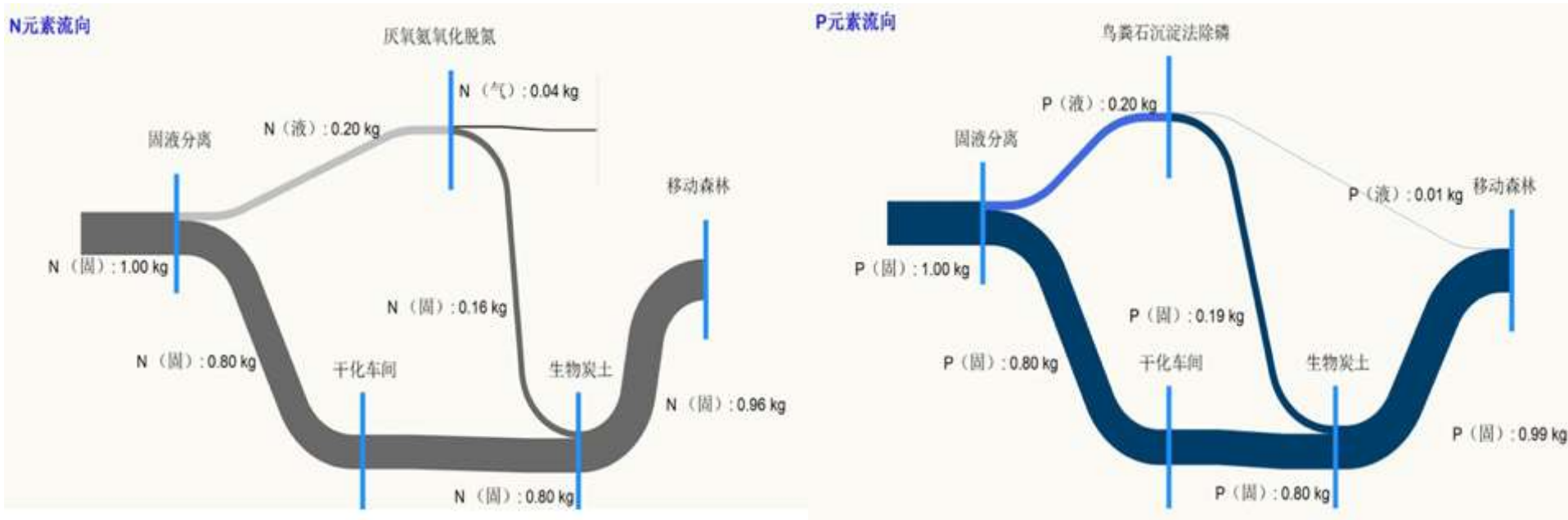


襄阳项目污泥项目与焚烧、填埋的温室气体排放比较  
Comparison on GHG Emission of Xiangyang Project, Incineration, and Landfill



# 襄阳污泥资源化项目的环境效益：污染物减排和营养物质回收

## Xiangyang Sludge Project's Environment Benefit: Pollutant removal & nutrient recovery



襄阳污泥处理处置N、P物质流图

Sankey Diagram of N,P Flow in Xiangyang Sludge Disposal Project

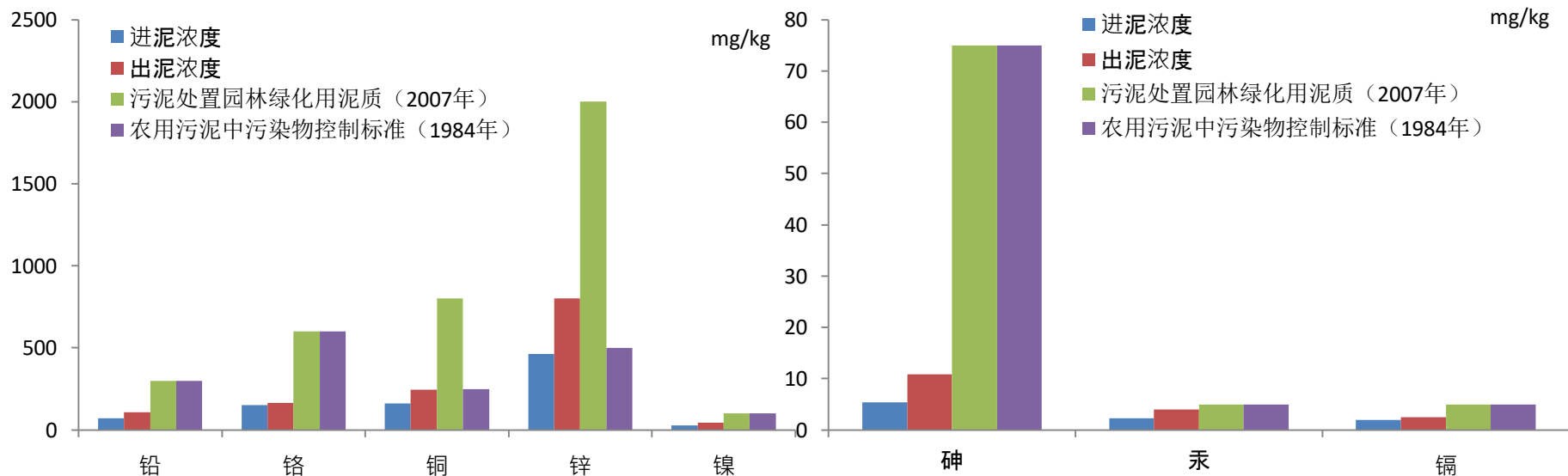
(来源：世界资源研究所)

实现了对N、P营养物质最大程度的回收再利用，其中96%的N和98%的P以可利用的方式进入了生物炭土。

Nutrients (i.e. N,P) in the sludge are recovered from sludge with 96% N and 98% P enter into biochar in the form of usable matters.

## 襄阳污泥资源化项目的环境效益：重金属稳定化

## Xiangyang Sludge Project's Environment benefit: stabilization of heavy metals



襄阳项目污泥处理前后重金属浓度与国家标准的比较

Comparison on Heavy Metal Concentration of Raw Sludge, Sludge disposed of Xiangyang Project and National Standards

在厌氧条件下利用硫酸盐还原菌将污泥中的硫酸盐转化成硫化氢，与重金属形成稳定产物，削减90%的不稳定态重金属。同时仅有少量 $H_2S$ 排出，解决了困扰多年的污泥臭气问题。

Xiangyang project utilizes the sulfate-reducing bacteria (SRB) to convert soluble metal sulphates into insoluble metal sulphides to stabilize 90% heavy metals in the sludge. As  $H_2S$  is the reactant reacted with sulphates during the SRB reaction process, it can avoid foul odor pollution as well.

## 襄阳污泥资源化项目的资源化效益：生物炭土和“移动森林”

Xiangyang Sludge Project's Economic Benefit: biochar & seedling cultivation



将厌氧消化后的污泥制成生物炭土，用于培植树木，创立“移动森林”理念，为污泥的最终无害化、稳定化开辟了思路

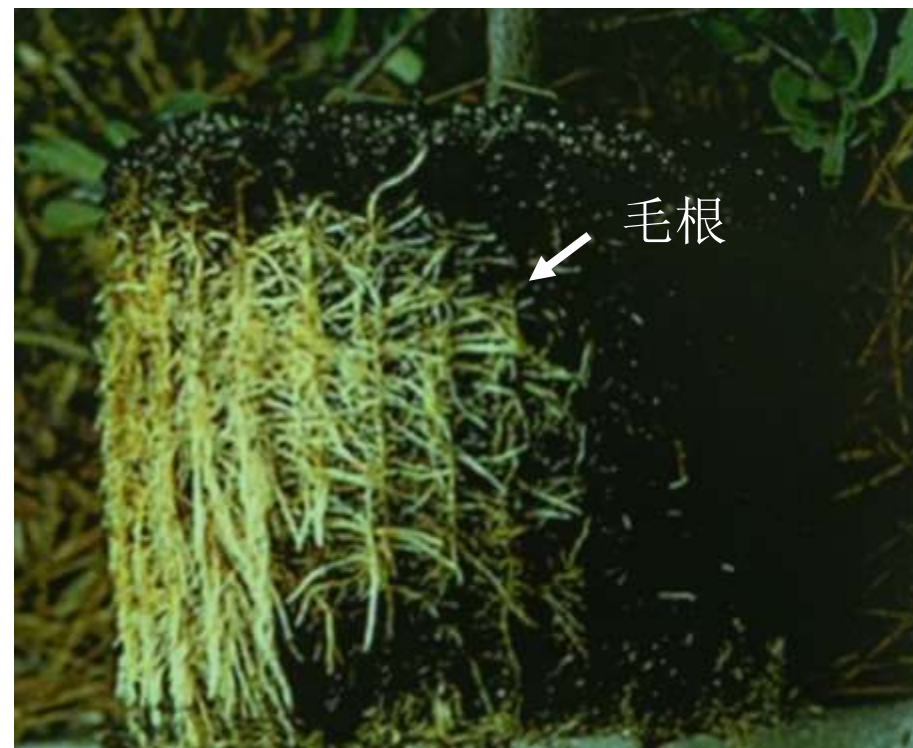
The biochar is used for seedling cultivation which brings new concept for the harmless, stabilizing disposal of sludge.



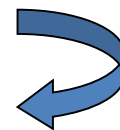
# 移动森林



连年落叶入地 腐殖质增加  
植树只予不取 改良荒废地



卖树不卖土 标准我做主  
植树再吸收 见根不见土



襄阳污泥资源化项目的成本效益分析：蕴含庞大的潜在收益

Xiangyang Sludge Project's Cost-Benefit Analysis: Huge benefit embedded

收入 (+) Revenue		成本 (—) Cost	
污泥处理补贴 Subsidy for sludge disposal	1825	污泥处理成本 Cost for sludge disposal	1584
餐厨垃圾处理补贴 Subsidy for kitchen waste disposal	270	餐厨垃圾处理成本 Cost for kitchen waste disposal	270
CNG销售收入 Sales for CNG	972	清洁能源调节基金 Clean energy adjustment fund	—216
生物炭土 Sales for biochar	675	税金 Tax	90
移动森林 Seedling cultivation	5400	财务费用 Financial fees	245
合计 Total	2770	合计 Total	2189

注： 1.按一年计（单位:万元）； 2.绿色表示未来可能实现的收入



# 襄阳污泥资源化项目：环境-能源-经济效益综合评价（襄阳案例）

## Xiangyang Sludge Project: Overall evaluation of environment-energy-economic benefit



（来源：世界资源研究所）

## 襄阳污泥资源化项目：城镇污泥处理处置的可持续低碳有益尝试

Xiangyang Sludge Project's : Good practice for sustainable & low-carbon sewage sludge disposal



襄阳项目实现了“污泥全消纳、能量全平衡、资源全回收、过程全绿色、费用可接受”的多效目标，将污泥对环境负面影响可以转化为正面贡献，探索出一条有效的污泥资源化途径。

Xiangyang project achieved the complete, balanced, green disposal of sewage sludge with recovering energy from sludge with acceptable cost. It provides an effective solution for sludge reclamation.

谢谢！

Thank You!