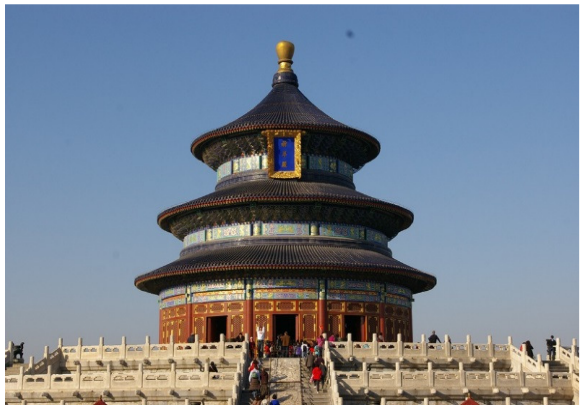
The 8th National Workshop of Technology & Applications of

Urban Sanitation Sludge Treatment and Disposal

中国城镇污泥处理处置技术与应用高级研讨会

2017年 5月 26日, 长安大饭店, 北京



Resource Oriented Treatment and Disposal of Urban Sanitation Sludge in Singapore

面向资源回用的新加坡城市污泥处理和处置

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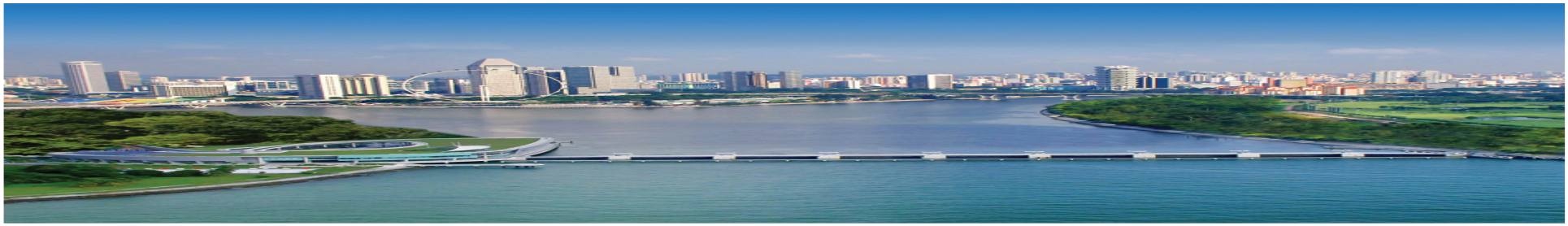
Former Chief Specialist (Used Water), PUB, Singapore



Outline
提纲

- Wastewater Treatment in Singapore
  新加坡的废水处理
  - Priorities of resource recovery 资源回收的优先顺序
- Current statues of sludge treatment and disposal
  污泥处理与处置现状
  - Technology and process and Operating data 技术工艺和运行数据
  - Quantitative management: mass flow an balance: 量化管理: 物质流和平衡
  - Road map of energy self-sufficient and positive 路线图
- Future: Energy Self-sufficient/positve for DTSS II 2025
  第二阶段深隧道系统 2025: 能源自给和盈余
  - Carbon pre-harvesting and PN/A: 碳的前捕获和主流部分亚硝化和厌氧氨氧化
  - Synergies of food waste co-digestion: 食物垃圾和污泥共厌氧消化
  - Synergies of urban solid and sludge co-incineration: 脱水污泥和城市固体废弃物的联合焚烧
- Summary 总结

Current used water treatment plants in Singapore
新加坡现有污水(回用水)处理厂

Background Information and Figures
背景讯息和数据

- Separate sewer system

  分流式下水道
- Raw sewage COD: 550 – 650 mg COD/L

  污水中有机碳: 550 – 650 mg COD/L
- Used water : ~ 1 500 000 m3/day

  污水处理量: ~ 1 600 000 m^3/day
- Activated sludge process

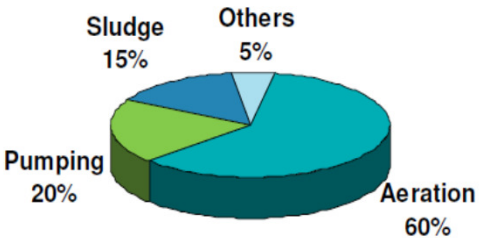
  脱氮活性污泥过程
- Dewatering Sludge: 150 m3/day

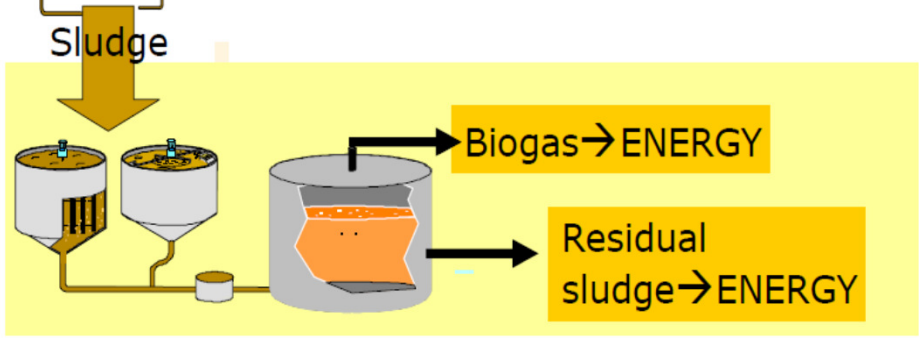
  脱水污泥量: ~800 m^3/day (20%含固量)

Priorities of resource recovery
资源回用的优先顺序

- Water
  水 (新生水: 世界上规模最大的食用水级回用)
- Energy
  能源
- Saving land
  土地
- Other reuse
  其他

Relevant factors
相关因素





COD fed (mass rate) x VSS_{dest} (%) x Electricity converting factor (%)

- PST and Bio unit: more and high VSS/TSS ratio sludge
  高效率初级沉淀池
- Digester operation: high VSS destruction 高效率厌氧消化
- Generator: high conversion efficiency 高效率发电机
- mize solids return from dewatering 减少固体从脱水返回

Current statue of energy recovery (Version 1)
能量回收: 现状 (第一版)

- Mesophilic anaerobic digestion with 40% of VSS destruction. 中温厌氧消化, ~40% 挥发性固体去除
- 23% of convert efficiency generator for electricity generation. 23%转换效率发电机
- 0.13 KWh/m3 sewage of electricity generation, 30% of process energy consumption 污水发电0.13 KWh/m3, 相当于工艺能源消耗的30%.
- All dried and dewatered sludge are incinerated prior to reuse/land disposal. 所有干燥、脱水污泥焚烧处置.

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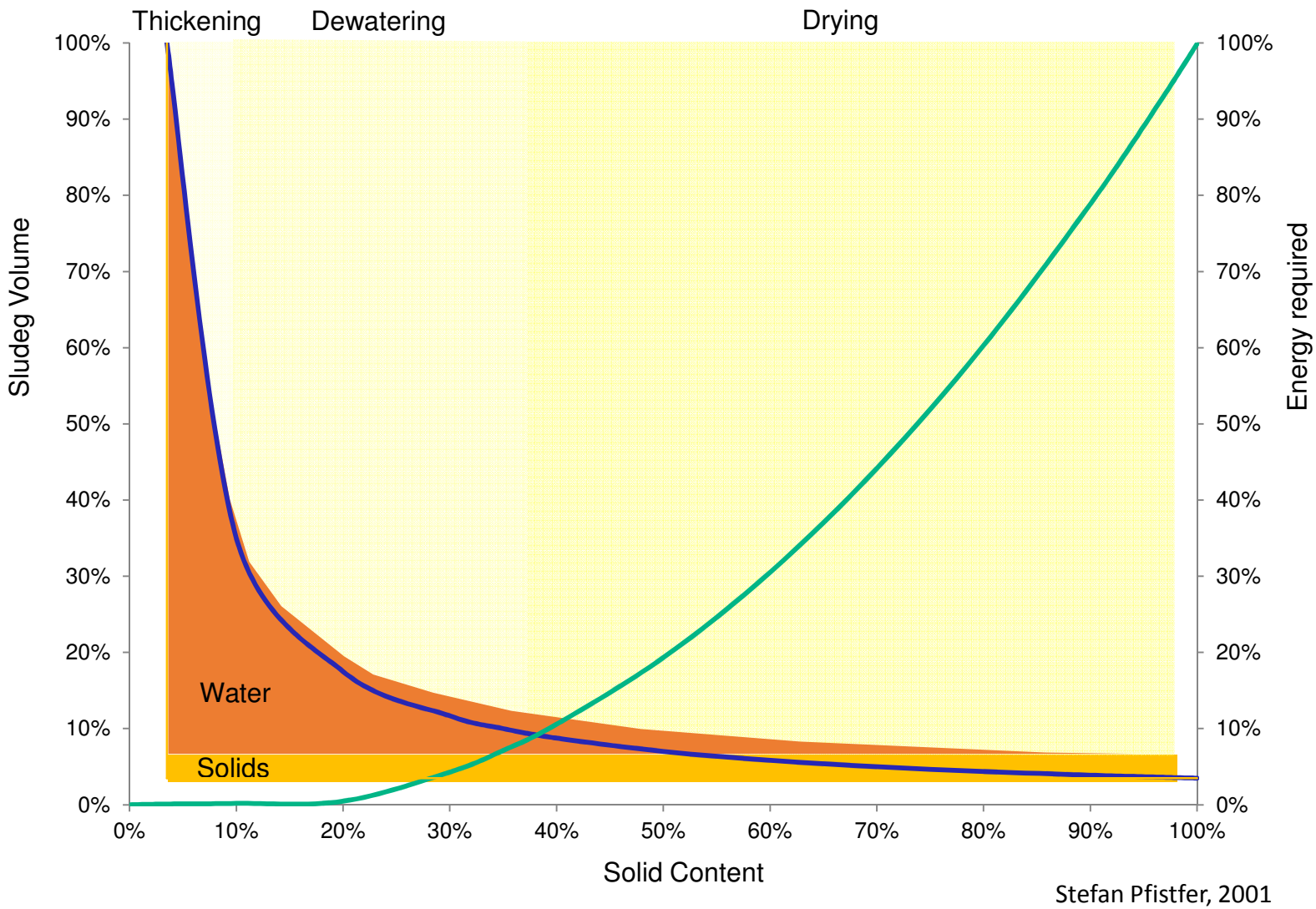
From landfill to inceneration: decrease of Volume

从填埋到焚烧: 减少体积

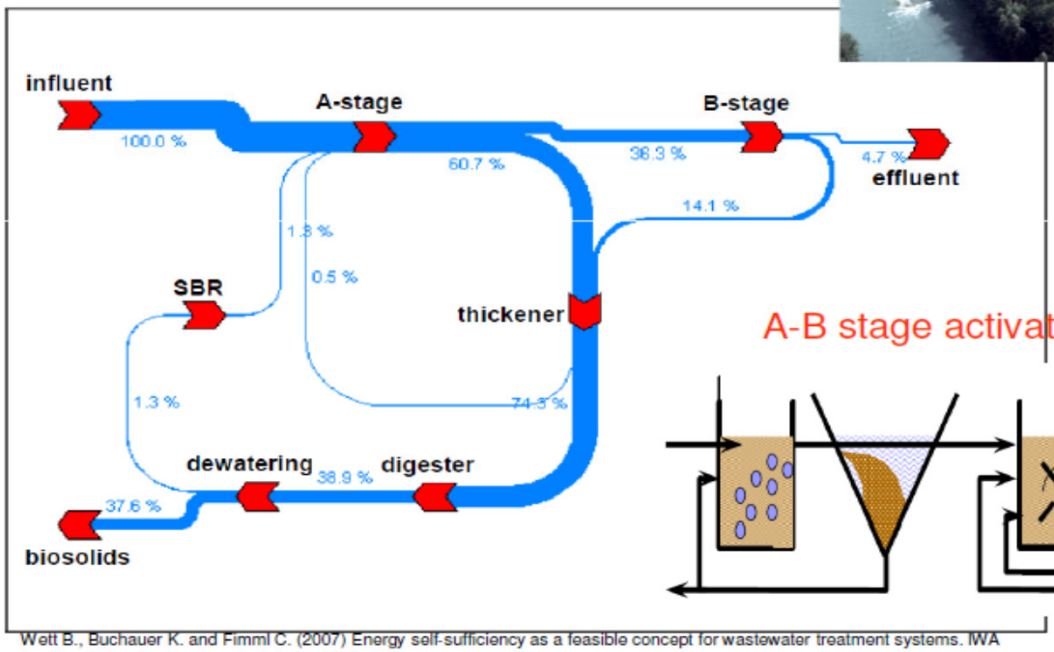


Stefan Pfistfer, 2001

Quantitative management: mass flow, energy efficiency auditing and benchmarking
量化管理: 物质流, 能源效率审计和标竿学习

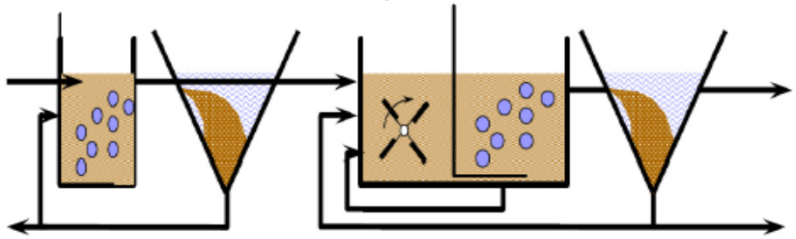
Strass WWTP, Austria (cont)

COD mass flow and balance in mass flow and balance



Wett B. (2011) Strategies towards improved energy balances of activated sludge systems -Austrian case studies, 8 Jan 2011, Miami .

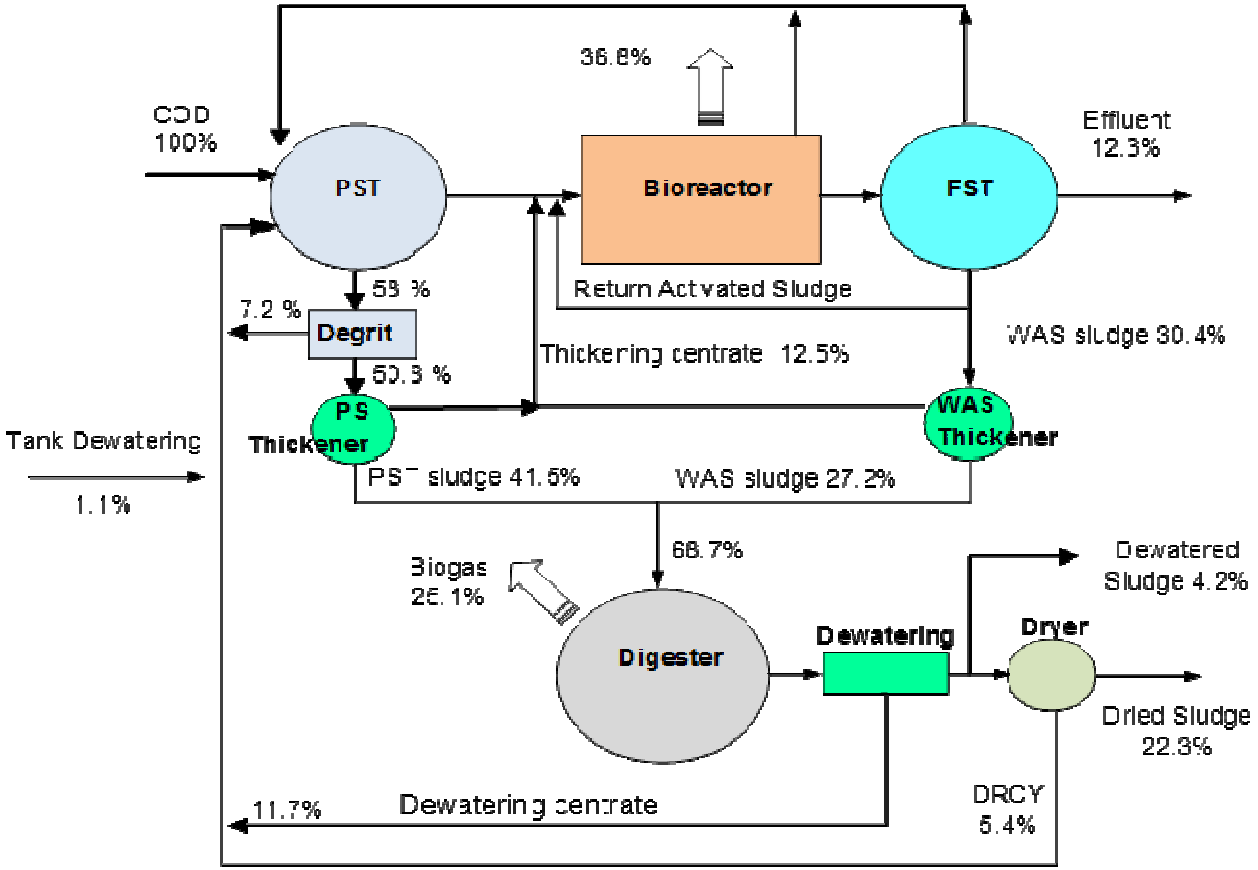
A-B stage activated sludge process



Wett B., Buchauer K. and Fimml C. (2007) Energy self-sufficiency as a feasible concept for wastewater treatment systems. IWA Leading-Edge Conference. 4 - 6 June, 2007, Singapore.

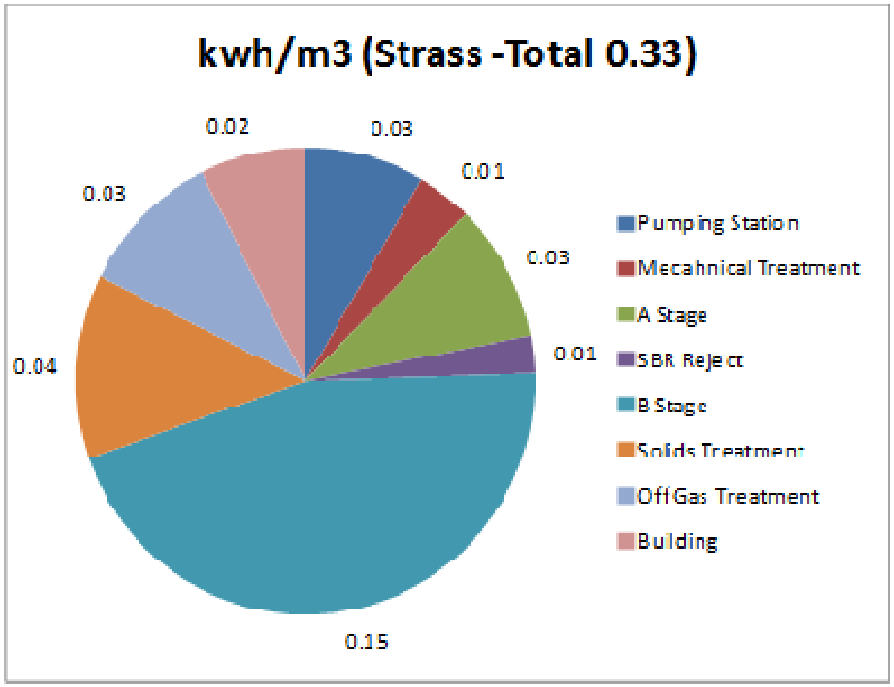
Carbonaceous flow and mass balance
樟宜再生水厂碳流向和平衡

COD return:
About 25% of the influent

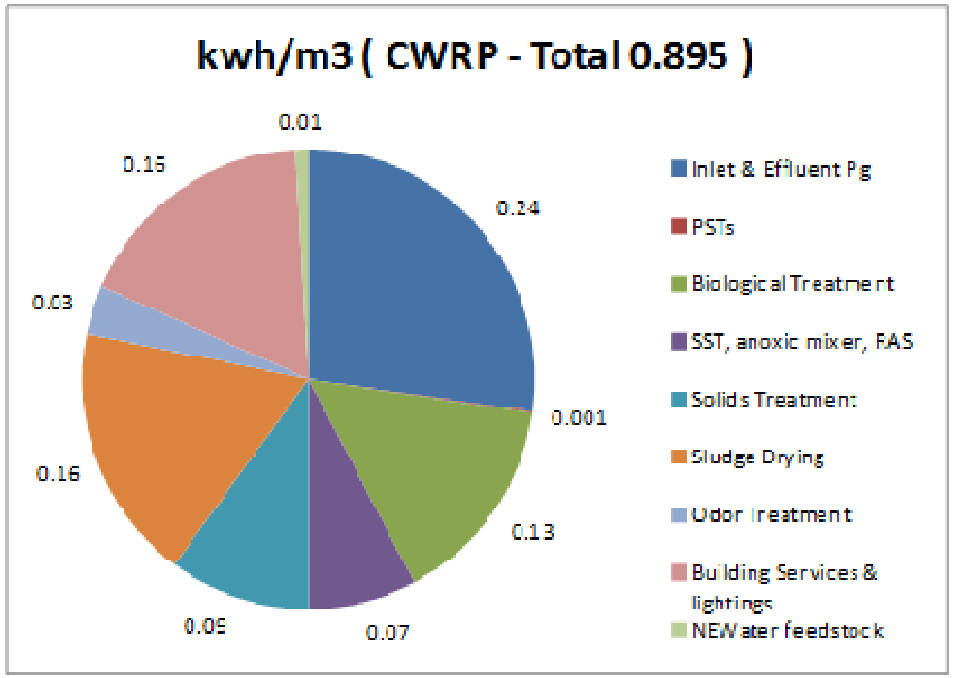


Cao et al. 2015

Benchmarking with Strass WWTP: Energy efficiency
与Strass废水厂能源效率的对比



Process energy consumption: **0.33 KWh/m3**



Process energy consumption: **0.4 KWh/m3**

Cao et al. 2015

Nowadays mass balance is applied in daily management in four WRPs in Singapore.

Road map: energy self-sufficient and positive
能源自足和盈余的路线图

Version 1: 0.13 KWh/m3,
Version 2: ~0.3 KWh/m3,
Version 3: energy self-sufficient of whole plant including NEWater

Solutions and Actions

- Increase biogas production by sludge pre-treatment
  污泥前处理
- Application of high converting efficiency generator
  使用高效率发电机
- Enhance pre-harvesting carbon (from 40 % to 60%)
  碳的前捕获
- Mainstream partial nitritation and Anammox.
  应用主流部分亚硝化和厌氧氨氧化
- Energy generation from non-conventional carbon sources
  使用非常规碳源生产能源

Actions for increase of energy recovery (version 2)
增加能量回收: 已经采取的行动 (第二版)

Ultra sound pre-treatment:
Ultrasonic sludge disintegrator installed at UPWRP.
10% of biogas increase

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High efficiency (38%) electricity generators in Changi WRP:
> 50% of electricity increase

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Thermal Hydrolysis Process (THP)
污泥热水解过程

- 20% of biogas increase
- Reduce land occupation (approx. 50%) of anaerobic digesters
- Reduce chemical cost of dewatering

- Benefits when pre-harvesting carbon and incineration are used
- Net-energy benefits
- Maintenance requirements

HTP under construction in Jurong WRP

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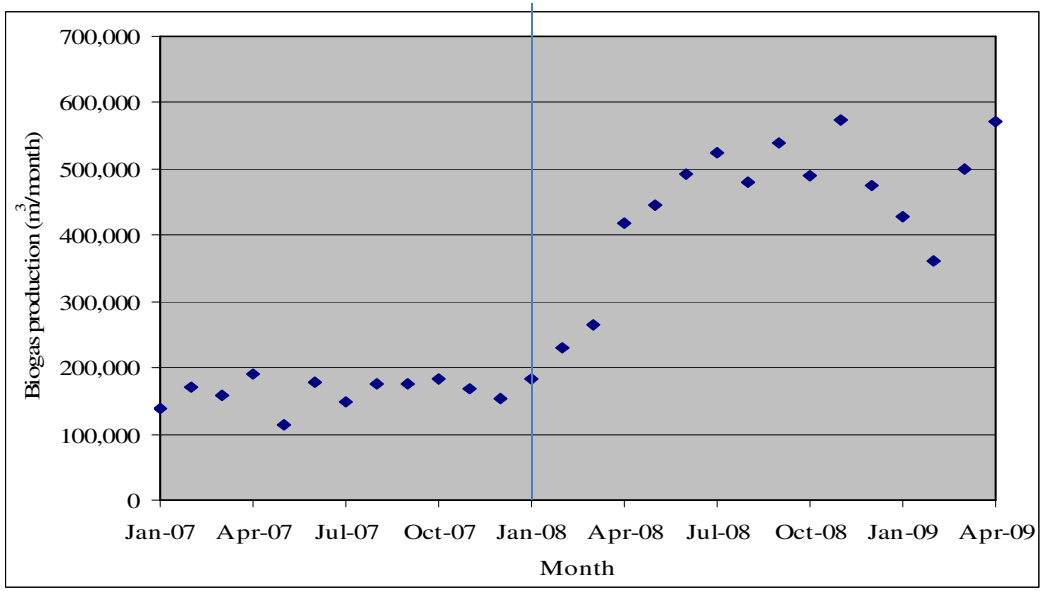
Co-digestion of O&G (food waste) and Sludge
污泥与食物垃圾(脂肪油)共厌氧消化



About 250 m^3/d of fats, oils and greases (FOG) was introduces into the anaerobic digesters in JWRP. The electricity generated from the biogas of FOG digestion meets about 15% of the total energy consumption.

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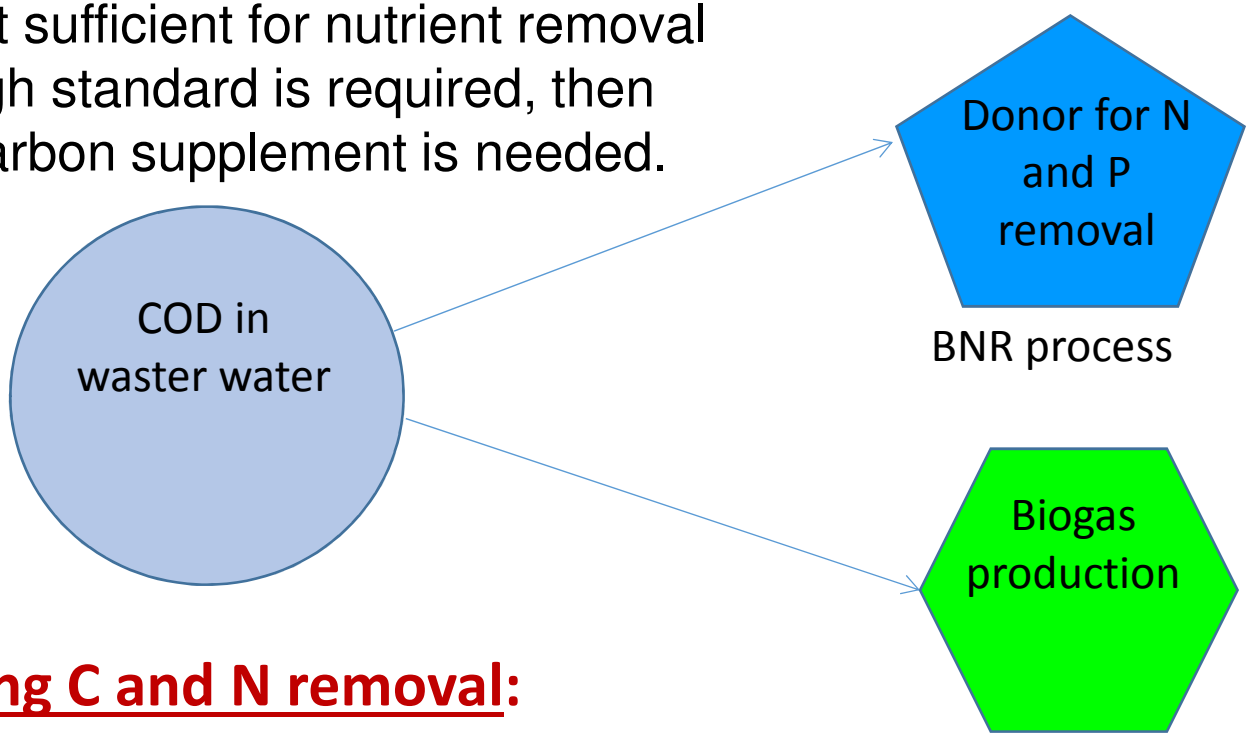
DTSS Ⅱ 2025: Energy neutral/positive (Version 3)

第二阶段深隧道系统 2025: 能源自足,盈余(第三版)

A fundamental dilemma in WWT: Carbon Management

污水处理一个最基本的困境: 碳管理

For conventional BNR COD in wastewater is often not sufficient for nutrient removal when a high standard is required, then external carbon supplement is needed.



<u>Decoupling C and N removal</u>: Innovative BNR where COD is not needed, then all or major portion COD goes for energy recovery ?!!!

Cao, 2016

Future Plant: mainstream PNA

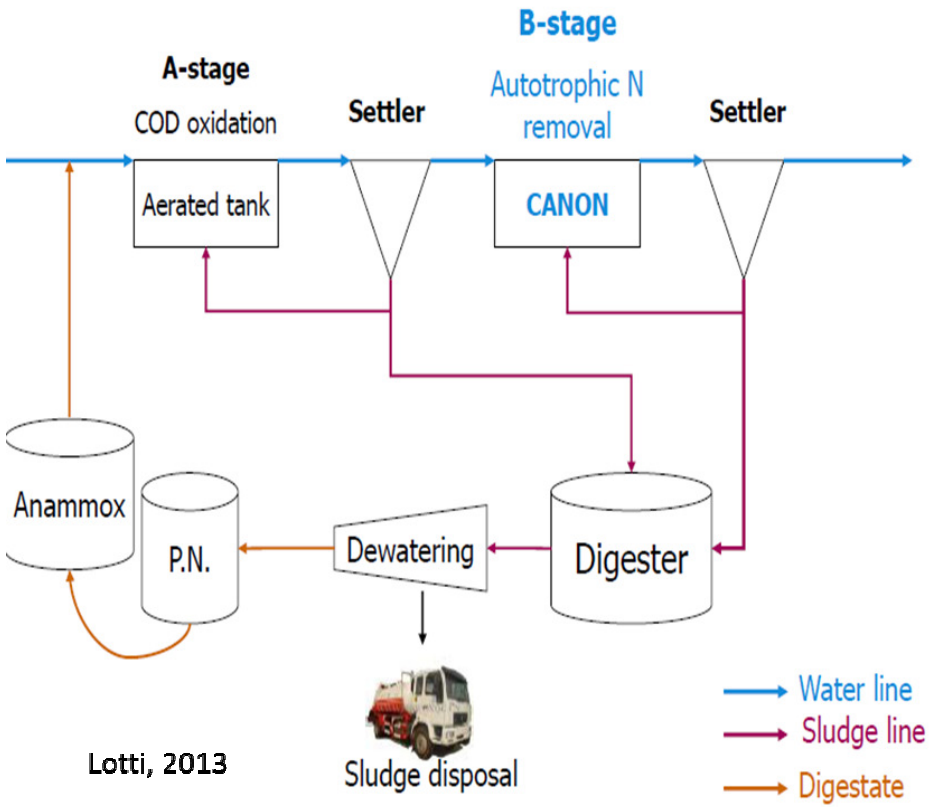
能量回收和主流部分亚硝化和厌氧氨氧化

- COD pre-harvesting: from 40% to 60%

碳前捕获从40%增加到60%

- 50% increase of electricity generation

发电量增加50%



A unique change for WWTPs to be energy neutral and positive !

污水处理厂的独特的机会取得能源平衡和盈余!

Won IWA Grand Applied Innovation Award 2014 together with DC Water, HRSD and Strass WWTP

Mainstream Partial Nitritation and Anammox (deammonification) in Changi Water Reclamation Plant, Singapore

新加坡樟宜再生水厂200 000m³/d 污水短程硝化厌氧氨氧化脱氮工艺

The first and largest scale mainstream partial nitritation and Anammox in the world

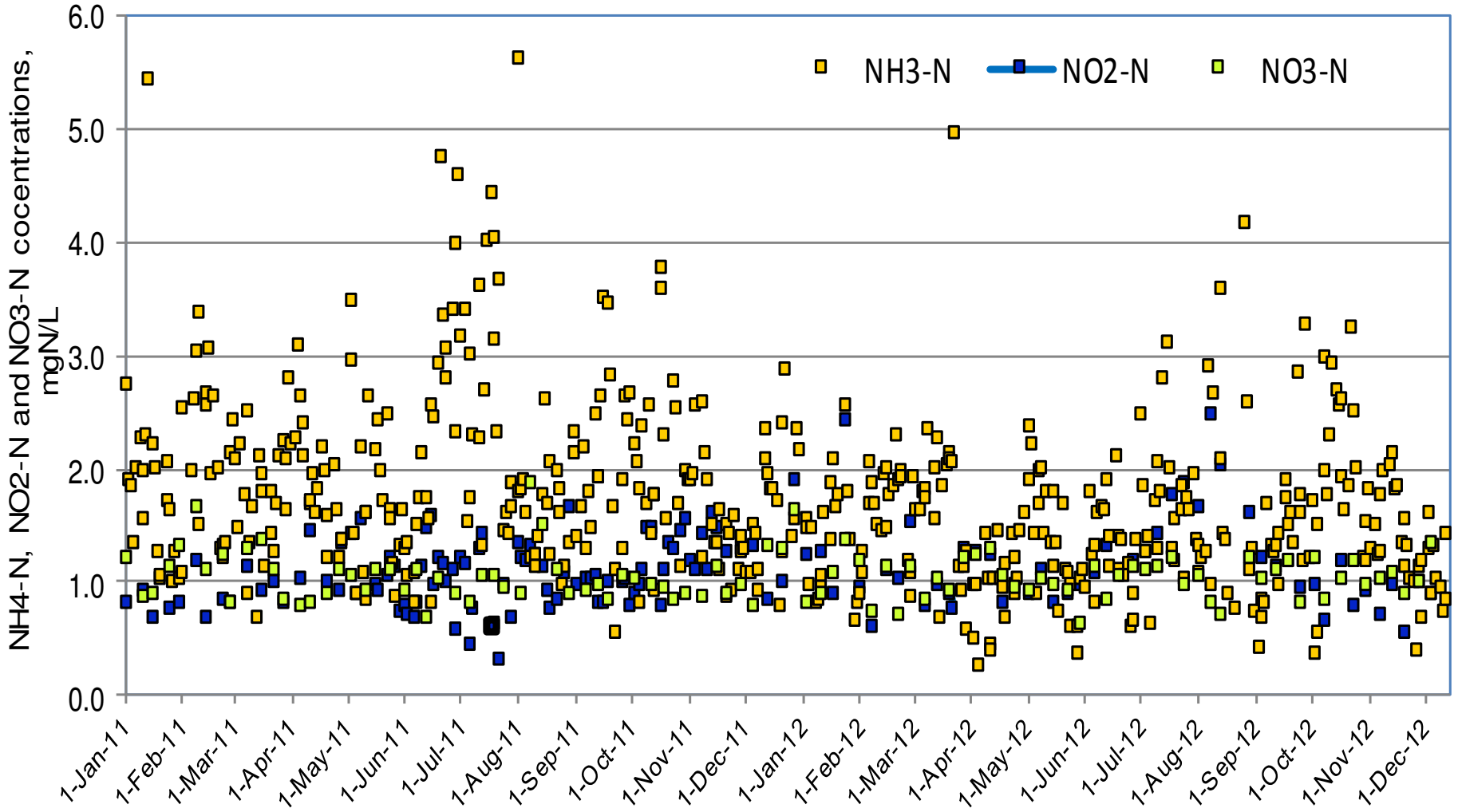
世界规模最大污水短程硝化厌氧氨氧化脱氮工艺

Cao et al. 2013, 2014, 2015, 2016, 2017

Final effluent data 2012:

	NH4-N	NO2-N	NO3-N
Avg	1.7	1.1	1.0

TN < 5 mg N/L



Cao et al., 2013

Three challenges to apply mainstream PN/A in DTSS II
第二阶段深隧道系统应用主流短程硝化厌氧氨氧化脱氮工艺三大挑战

- Reproduce PNA based on thought understanding PNA in existing process

  透彻理解现有的短程硝化厌氧氨氧化脱氮工艺

- Application of MBR in DTSS II instead

  膜生物反应器的应用及其影响

- Application high efficiency pre-harvesting carbon process instead of conventional primary settling tanks (PST)

  开发高效碳的前捕获工艺和应用及其影响

Pre-harvesting carbon and mainstream PN/A
碳的前捕获和主流部分亚硝化和厌氧氨氧化

- Energy+ (25 m^3/d) (2011-2017)

High rate carbon pre-harvesting process (A-stage) and short-cut AS

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- Integrated Validation Plant (IVP) (1 000 m^3/d) (2013-2016)

High rate pre carbon-harvesting process (A stage) and MBR+RO

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- Pilot study to simulate PN/A in Changi WRP (25 m3/d) (2013-2017)

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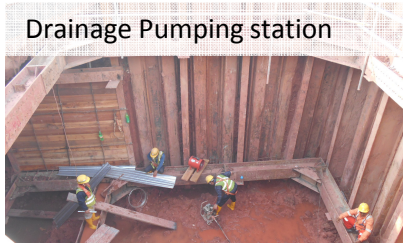
Pre-harvesting carbon and mainstream PN/A (cont.)

碳前捕获和主流部分亚硝化和厌氧氨氧化

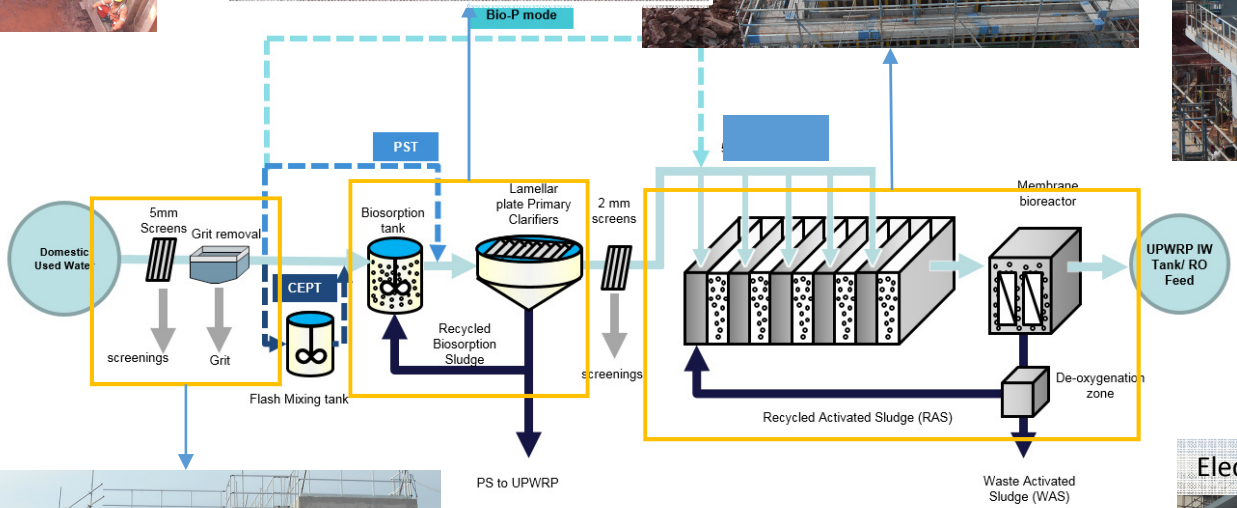
Drainage Pumping station



Primary treatment

Bioreactor and membrane tank

Control Building



Preliminary treatment

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Electrical Building

Demonstrating scale carbon pre-harvesting and PN/A MBR: 12,500 m^3/day, 2 trains with 6250 m^3/day each.

Pre-harvesting carbon and mainstream PN/A (cont.)

碳前捕获和主流部分亚硝化和厌氧氨氧化

旨在应用于主流的侧流部分亚硝化和厌氧氨氧化

- Pilot scale side-stream demon plant in CWRP (2012-2016).

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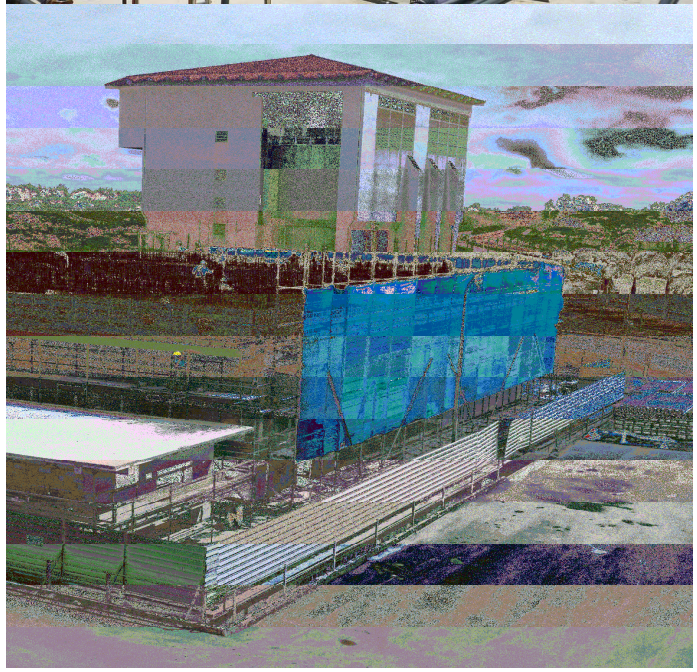
- Full scale side-stream demon in CWRP under construction (2017).



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Synergies of food waste and sludge co-digestion
食物垃圾和污泥共厌氧消化

- Digester I (320 m^3): Co-digestion of thickened surplus activated sludge and food waste.

- Digester II (320 m^3): Digestion of food waste only.

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Synergies of co-incineration of dewatering sludge and municipal solids
脱水污泥和城市固体废弃物的联合焚烧

- Co- incineration of dewatering sludge and municipal solids in nearby integrated energy management plant (IEMP)
- Electricity generated from incinerator send to used water plant
- Heat recovery and reuse

Waste to Fuel Power Plant (WFPP), Amsterdam

Energy recovery of WRPs in Singapore in 2025
2025年时的新加坡再生水厂能量回收

- Electricity generation without external carbon addition in 2025 will be 0.3 kwh/m3.

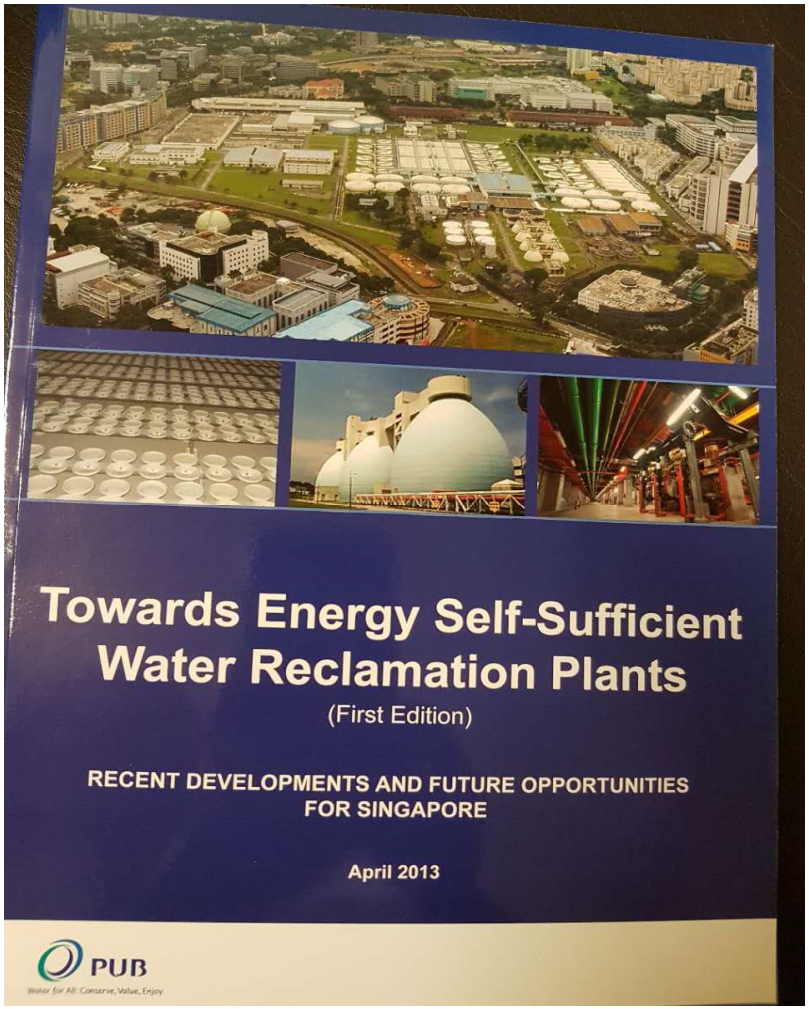
在没有外碳源投加, 新加坡再生水厂2025年回收电可达0.3 KWh/m^3.

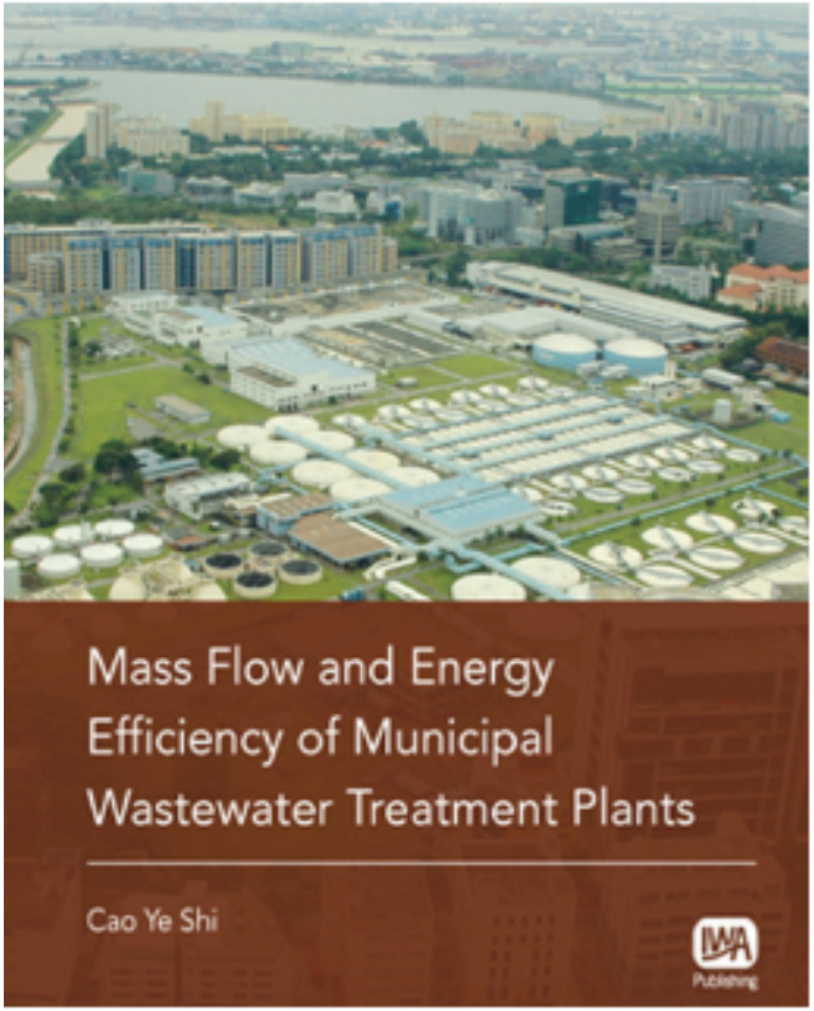
- With food waste co-digestion and urban solid co-incineration water reclamation plants in Singapore in 2025 can be energy positive.

应用食物残渣联合消化和城市固体联合焚烧, 新加坡再生水厂于2025年可达能量自足.

Singapore Approaches
途径

- Early and planning
  提早规划
- Formulate clear and high targets according to the Singapore conditions
  根据新加坡条件制订高目标
- Adopt first class international technology and best practices
  采用国际一流技术和最佳实践
- Invest on research and development to verify applicability step by step
  投资在研究和开发, 一步一步验证技术适用性


Towards Energy Self-Sufficient
Water Reclamation Plants
(First Edition)
RECENT DEVELOPMENTS AND FUTURE OPPORTUNITIES
FOR SINGAPORE
April 2013
PUB
Water for All: Conserve, Value, Enjoy


Mass Flow and Energy
Efficiency of Municipal
Wastewater Treatment Plants
Cao Ye Shi
IWA
Publishing

Mainstream PN/A in Changi WRP

Cao Yeshi, Mark van Loosdrecht, Glen T. Daigger (2017) Mainstream Partial Nitritation-Anammox in Municipal Wastewater Treatment: Status, Bottlenecks and Further Studies (Review paper). Appl. Microbial. Biotech . 101(4): 1365-1383 (DOI:10.1007/s00253-016-8058-7).

Cao, Y.S., Kwok, B. H., Yong, W. H., Chua, S. C., Wah, Y.L. and Yahya ABD GHANI (2013) The Main Stream Autotrophic Nitrogen Removal in the Largest Full Scale Activated Sludge Process in Singapore: Process Analysis. WEF/IWA Nutrient Removal and Recovery 2013: Trends in Resource Recovery and Use, July 28-31, 2013, Vancouver.

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Cao Yeshi, Kwok Bee Hong, van Loosdrecht, M.C.M, Daigger G. T., Winson Lay, Chua Seng Chye, Wah Yuen Long and Yahya Ghani (2017) The overview of PN/A performance and microbial community in Changi activated sludge process from 2011 to 2016: The potential effects of the dissolved oxygen. IWA NRR/LWWTP Conference, 10-13 Nov. 2017, Chongqing, China (submitted).

Acknowledgment

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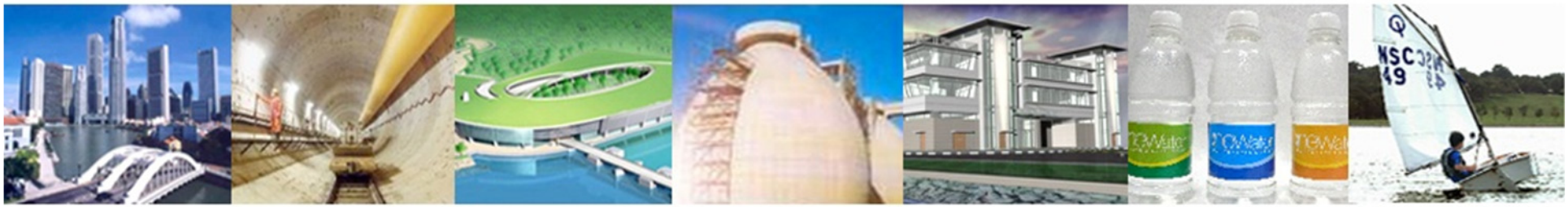

Thank you for your attentions

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Q & A

问 和 答

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