Cambi Thermal Hydrolysis
Theory, market and the future

WEF eShowcase – 19 October 2016

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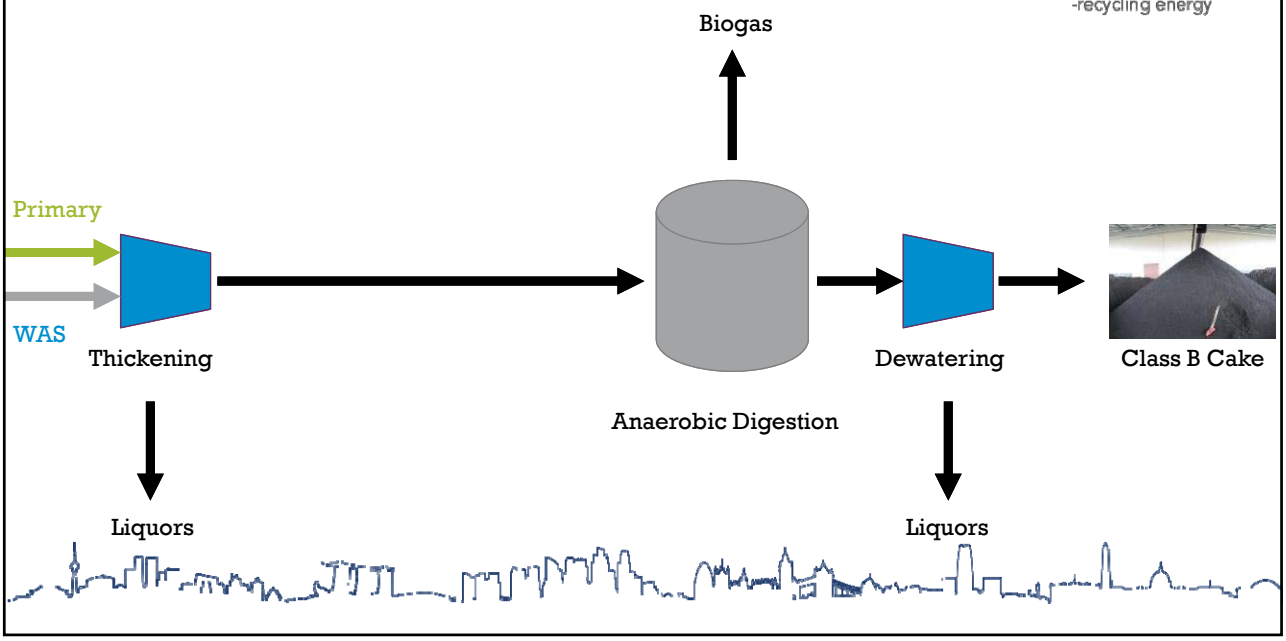
Background and theory of thermal hydrolysis

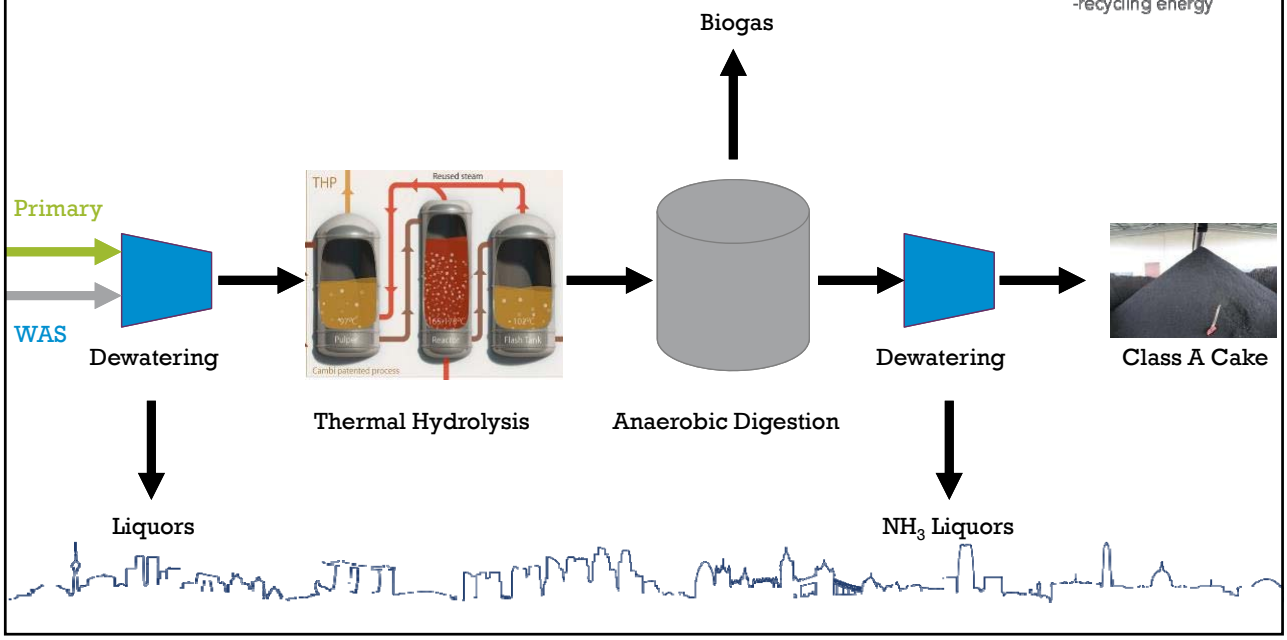
Pressure Cooking

- Approx 330 °F
- 94 psi
- 20 – 30 minutes

Pressure Cooking of Sludge

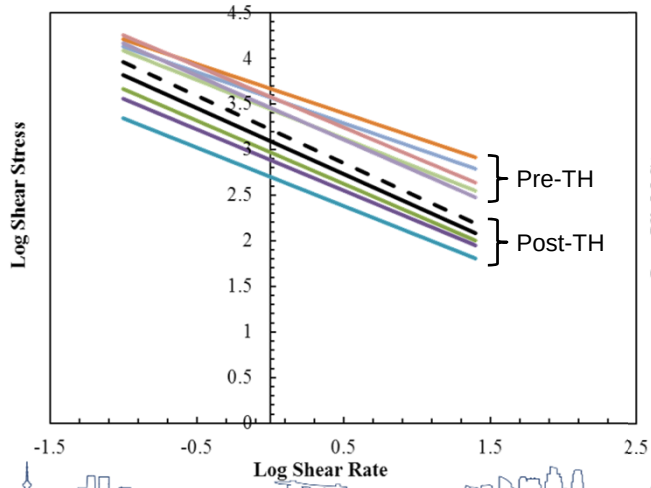


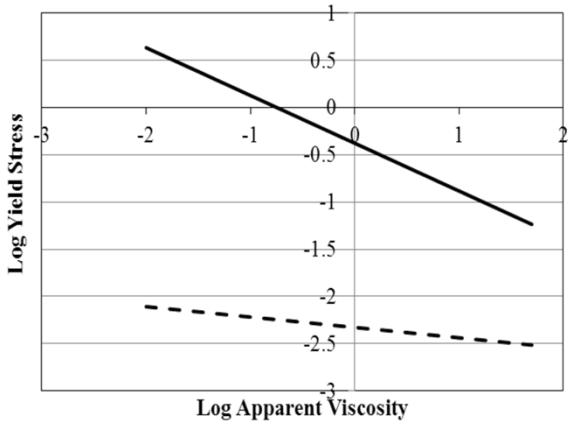
Standard thermal hydrolysis



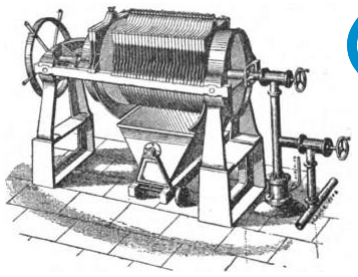
- Rheology is fundamentally changed by processing with heat

Rheology change is temperature dependent





The original use of thermal hydrolysis



Sludge plate press from 1860s

- 1951, 10 years full-scale experience
- Live steam injection at 290 to 370 °F for 30 minutes
- Cake dry solids of 48%

Heat Treatment as an Aid to Sludge Dewatering—Ten Years' Full-Scale Operation. By C. Lumb. *Jour. and Proc.*, Inst. Sew. Purif. (Brit.), Part 1, 5 (1951).

The potential advantages of some mechanical sludge dewatering process over atmospheric drying include non-dependence on uncontrollable climatic conditions, ability to maintain sludge disposal to regular schedule in all seasons of the year, and small land area requirements.

Conditioning of sludge, prior to filtration, has usually been used. This paper describes the operation of a plant at Halifax, England, which, over a 10-year period, has conditioned raw sludge by heating the sludge mixture with live steam, to temperatures from 290° to 370° F. for 0.5 hr. The process, known as the Porteous process, involves the heating of sludge by means of live steam in pressure vessels. Heat exchange apparatus is incorporated

Relative speeds of filtration of sludges conditioned in different ways are as follows:

Conditioning Agent	Primary Sludge	Sec. Sludge [1]
None	30	1
Sulfuric acid [2]	100	2
Aluminum sulfate [3]	200	10
Ferric sulfate [3]	300	15
Ferric chloride [3]	400	20
Lime [3]	1,000	80
Heat treatment [4]	6,000	1,000

[1] Mixed humus and activated sludge.
[2] At optimum H value.
[3] At optimum dosage.
[4] ½ hr. at 360°F.

The average moisture content of the raw sludge is 95.1 per cent, of the thickened sludge after heat treatment and decantation, 89.9 per cent, and of the cake from the filters, 48.0 per cent.

Average analysis of the [illegible] for cake

Heating sewage sludge

Increasing reaction temperature

- Initial solubilisation of material in bulk phase
- Release of polysaccharides from loosely bound extra-cellular polymers (ECP)
- Destruction of tightly bound ECP further releasing polysaccharides
- Degradation of cell walls causing a collapse of cell turgor pressure causing cell rupture releasing intracellular proteins and cell wall debris
- Polysaccharides interact with each other and also the newly released proteins to make higher molecular weight Maillard and Andoni products which are non-biodegradable

Improving dewaterability

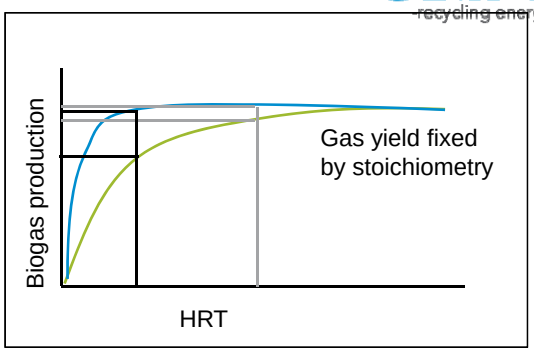
Improving biogs production

What it does

Decreases Viscosity	❑ Allows higher loading rates → reduces digestion size ❑ Improves dewatering
Destroys extracellular polymers	❑ Improves dewatering
Increases solubility	❑ Improves digestion
Decreases Particle size	❑ Improves digestion
Destroys Gordonia-like and similar organisms	❑ Destroys foam and minimizes foam potential
Sterilises sludge	❑ Meets advanced levels of treatment

Biogas Production Increase

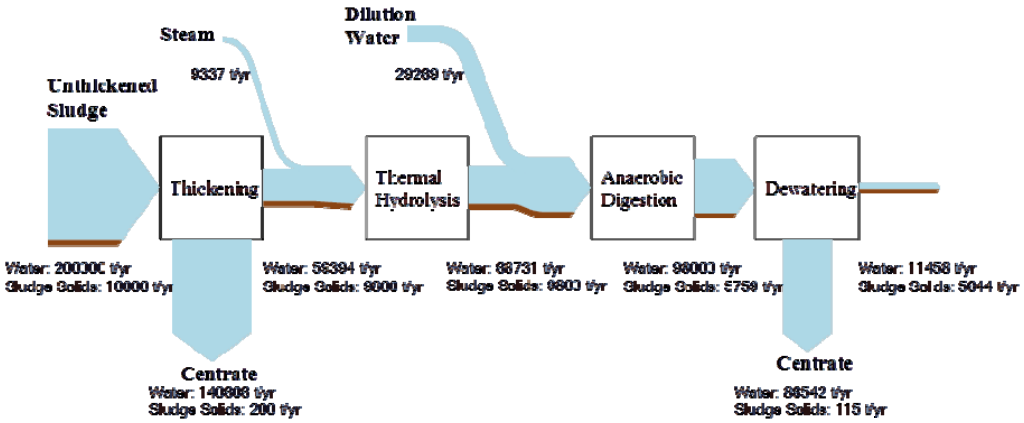
- Pre-treatment technology does not increase the biogas yield
  - This is fixed by stoichiometry
- However, thermal hydrolysis increases biogas *rate*
  - Better suited to lower retention times
    - 20 day HRT (approx. 25% increased biogas dependent on sludge type)
  - MAD after thermal hydrolysis is actually better suited at lower HRT
    - 90%+ of 20 day biogas yield within 10 days HRT
    - Is a further 10 days HRT worth the extra 5 – 10% biogas?
    - Text books do not account for TH



- Typical energy generation from sludge digestion*
  - MAD = 514 kWhr e/TDS digested
  - Acid phase = 670 kWhr e/TDS digested
  - Thermal hydrolysis = 980 kWhr e/TDS digested

* From DECC document

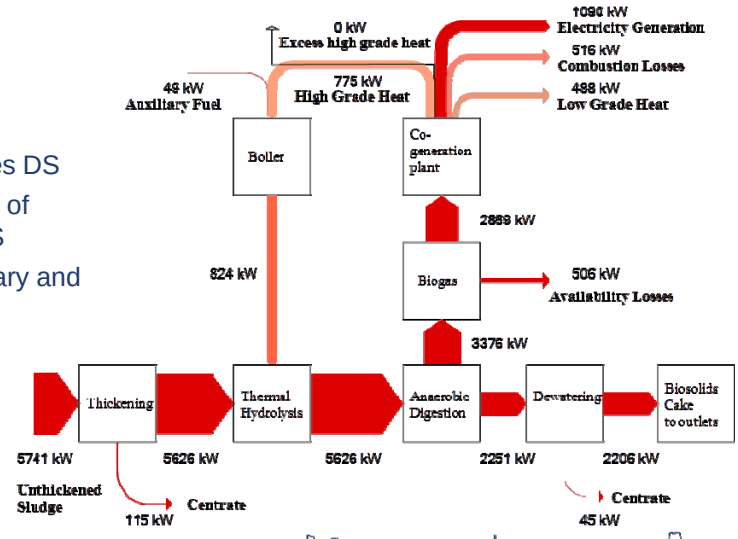
Typical Mass Balance



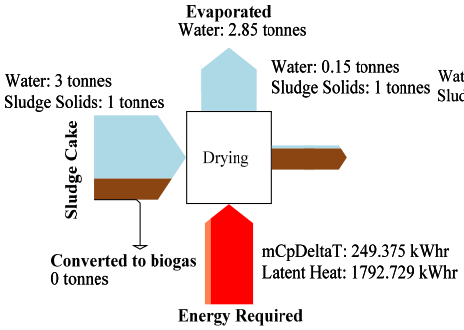
- Sludge composition of 60:40; primary:WAS; 10,000 metric tonne DS

Typical Energy Balance

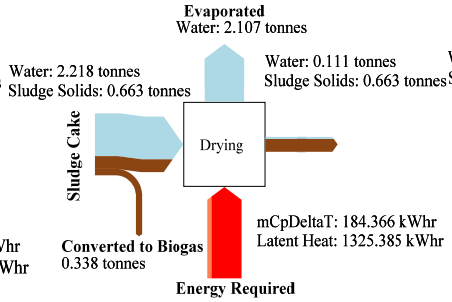
- 10,000 metric tonnes DS
- Sludge composition of 60:40; primary:WAS
- Processing all primary and WAS
- IC Engine



Influence on thermal systems

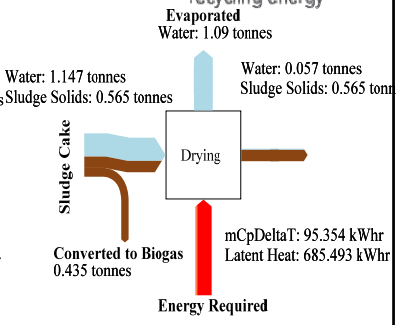


No digestion



MAD

- Less cake to dry
- 25% less energy required than raw

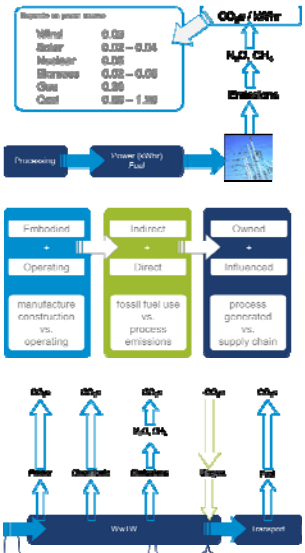


TH + MAD

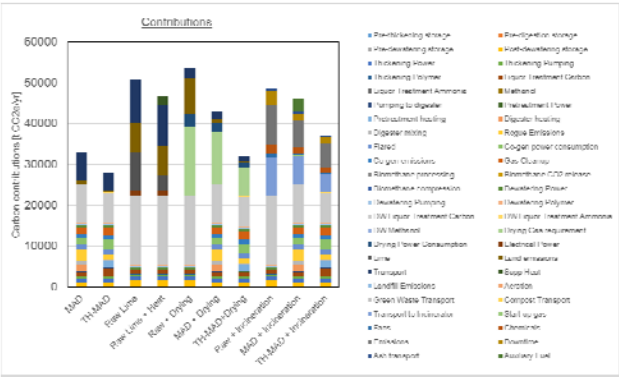
- Even less cake to dry
- Which also has less water in it per unit volume
- 60%+ less energy required than raw
- 50% less energy required than digested

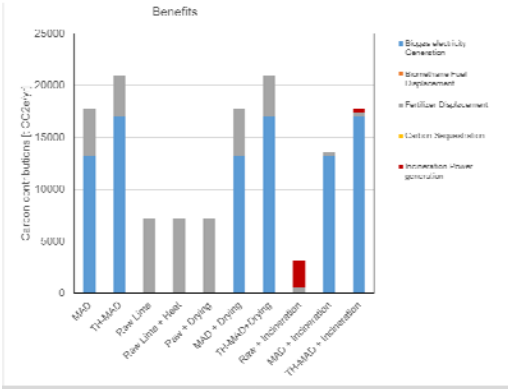
Cambi thermal hydrolysis and carbon footprint

- Thermal hydrolysis of sewage sludge has been found to provide greatest carbon footprint savings regardless of endpoint of sludge
  - Increased production of renewable energy
  - Better volatile solids destruction resulting in less biosolids downstream for transport and further processing
  - Better dewatering which further reduces biosolids for downstream processing. Also significant reduction in fossil fuel requirements for downstream drying
  - Higher dewaterability increases energy content in cake which provides greater energy recovery benefit in downstream incineration, whilst improved volatile solids destruction reduces the quantity of material which needs to be incinerated
  - Higher grade of biosolids means more landbank is opened up which reduces transport of biosolids
  - Higher loading rates in digestion so less material used in construction which reduces embodied carbon impact



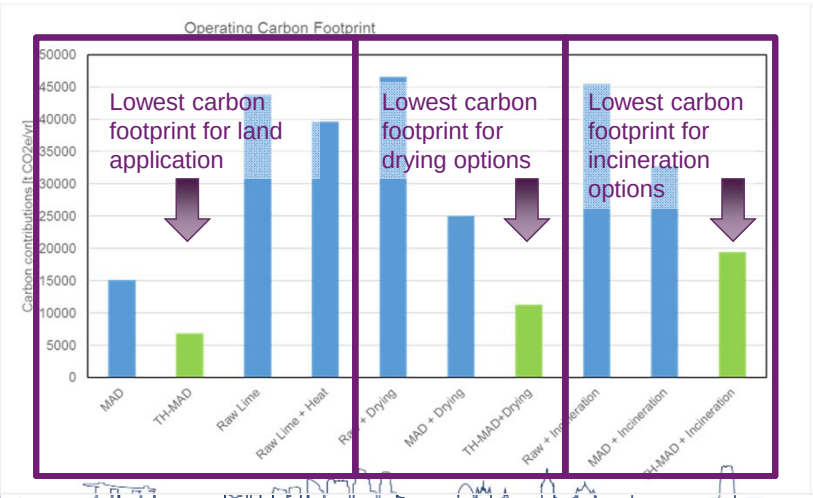
Cambi thermal hydrolysis and carbon footprint Example: 100 t DS/d





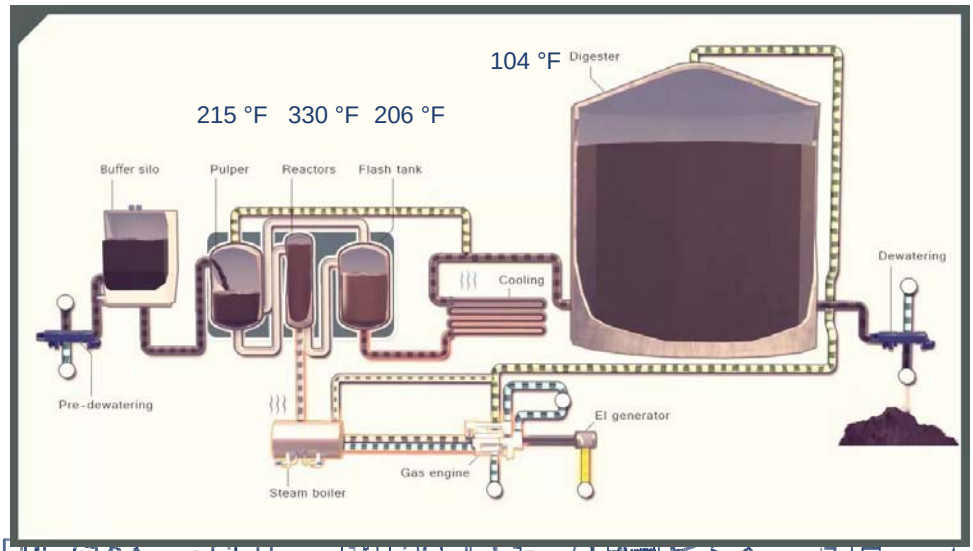
Smallest Contributions to carbon impact + Greatest benefits to carbon impact

Cambi thermal hydrolysis and carbon footprint Example: 100 t DS/d



CambiTHP™

THE ENERGY EFFICIENT AND RELIABLE STEAM EXPLOSION PROCESS SINCE 1996



Cambi Plant Sizes

B – 2 (2 m³ reactor)	B – 6 (6 m³ reactor)	B – 12 (12 m³ reactor)
		
Small size projects - Standardised package unit - pre-assembled & pre-tested - containerized unit	**Medium-large size projects** - Standardised package unit - Pre-assembled skids	**Extra large size projects** - custom-made - on-site construction
5 – 20 tDS/day	20 – 80 tDS/day	60 – 500 tDS/day

Thermal Hydrolysis Market

CAMBI experience

- Since 1995 Cambi have built 40 plants and have 16 plants under construction, in 21 countries
  - Total capacity to treat sludge and food waste from >53 mill. people, 1.55 million tons DS/year
- Multiple repeat customers
- 2 plants owned and operated by Veolia Water
  - Bruxelles Nord
  - Seafield Edinburgh
- European Biosolids Conference 15 – 16 November, 2016

Thursday, 26 June 2014 10:47

Veolia invests £14m+ in thermal hydrolysis at Edinburgh WwWT treatment facility

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Veolia has invested over £14 million on thermal hydrolysis technology at its Seafield Waste Water Treatment facility in Edinburgh.

The process will help produce over 100 tonnes per day of thermal hydrolysis cake, a new product to add key nutrients back into farming land.

The new cake is a balanced fertiliser that helps enrich the soil with key levels of nitrogen, phosphate and sulphur, a rich source of organic matter and a useful soil conditioner.

Bruce Moffat, Veolia's Organics General Manager said:

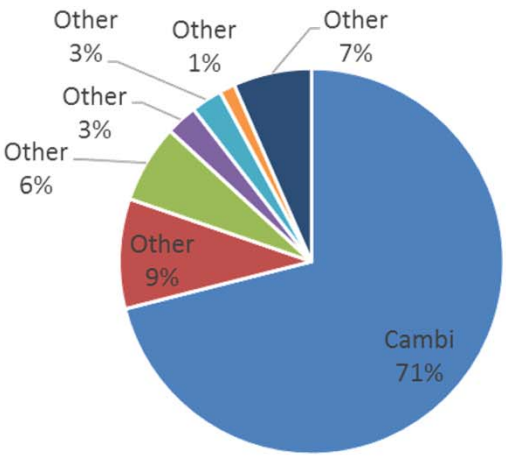
"We're delighted to launch this new product to the farming community. It will help save farmers' fertiliser costs with the added benefit that it's much less odorous than other bio-solids. Due to the way the cake is treated it can be used on a greater variety of crops including grassland."

Alongside the product, Veolia will also provide customers with:

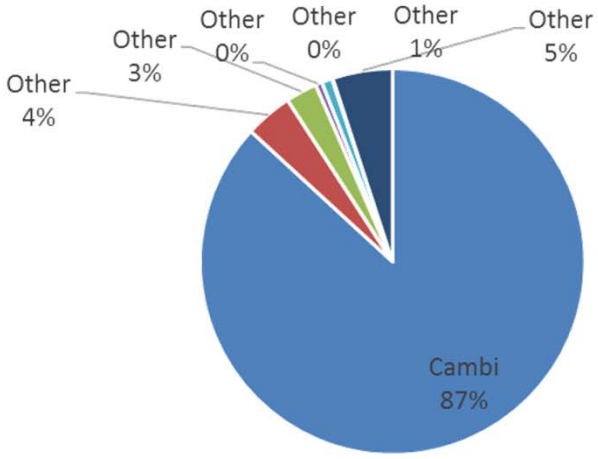
- Spreading to achieve consistency across the land
- All necessary soil sampling in accordance with sludge use in agricultural regulations
- Exemption registration with SEPA and other liaisons required
- Record keeping and field notifications to help manage information and cross

Thermal Hydrolysis Market

By plant number

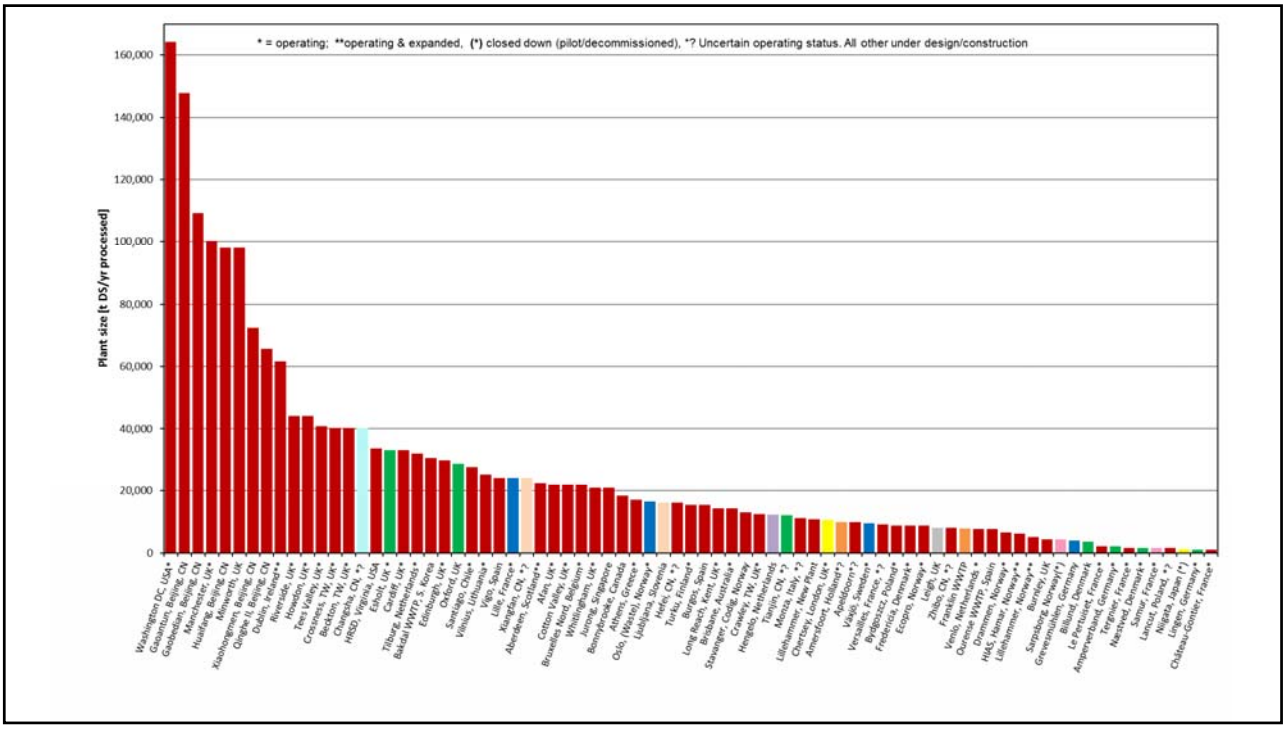


By capacity

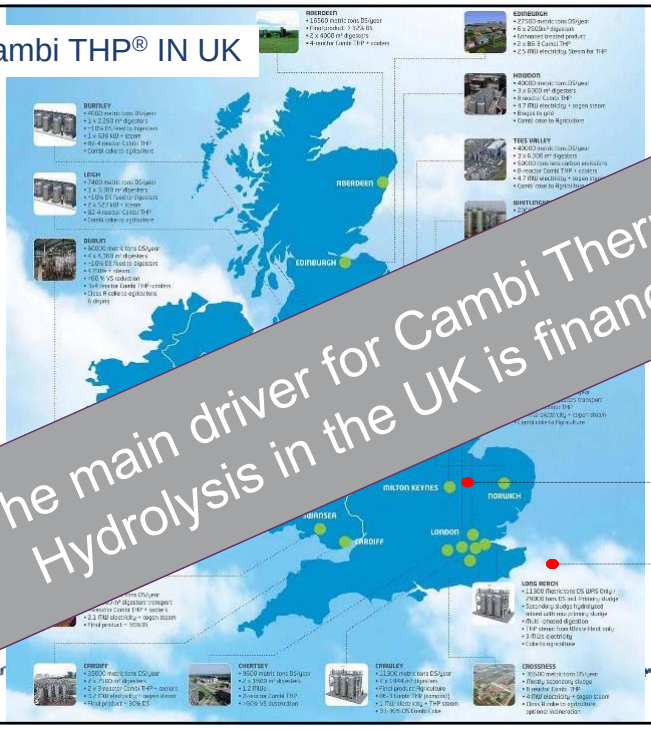


CAMBI SERVES A POPULATION OF MORE THAN 50 MILLION PEOPLE WORLD WIDE

SEOUL – DUBLIN – OSLO – BRUSSELS – ATHENS
SANTIAGO DE CHILE – EDINBURGH – CARDIFF – AND 20+ OTHER CITIES



Cambi THP® IN UK



The main driver for Cambi Thermal Hydrolysis in the UK is financial

- UK Water Industry has strict financial ulator - OFWAT
- ised companies on stock exchange
  - ited Utilities (last year $1000M spent in structure)
  - Revenue $2200M, of which $755M profit
- CambiTHP® treats >30% of UK's sewage sludge.
- Standard unit operation

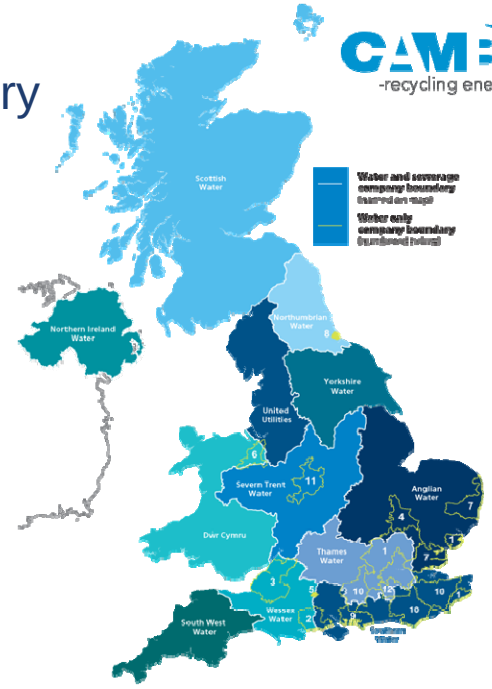
Minworth STW, Birmingham (2016),
Cambi 3 x B6-4, Severn Trent Water
- 2.5 million people
- Better dewatering >30% DS – 22% DS today
- cake quantity will be greatly reduced
- Class A product gives them more security
- shut down their incinerator
- Lee odorous cake product
- Improved biogas yields
- More import capacity including glycerol – so more biogas
- Integrated with Gas to Grid

Basingstoke (2016),
Cambi 1 x B6-4, Thames Water

Highest renewable energy producers in UK Water Industry

	Site	Pre-treatment
1	Davyhulme	Thermal Hydrolysis
2	Minworth	Thermal Hydrolysis*
3	Great Billing	EH
4	Mogden	None
5	Avonmouth	EH
6	Bran Sands	Thermal Hydrolysis
7	Cardiff East	Thermal Hydrolysis
8	Howdon	Thermal Hydrolysis
9	Longreach	Thermal Hydrolysis
10	Stoke Bardolph	Co-digestion

* Cambi recently awarded contract to upgrade from MAD to thermal hydrolysis



Blue Plains

BLOOM GOOD SOIL, BETTER EARTH.

DCWATER.COM

CAMBI -recycling energy

- Ageing
- Curing
- Screening
- Composting

→ Further processing

- 280 – 300 tDS/d processed
  - VS destruction 62 – 65%
  - 9 MWe generation
  - Cake dewatering on belt press 32% DS
  - Poly consumption approx. 14 lbs/TDS
  - Energy for thermal hydrolysis met by co-gen plant
  - Ongoing work to make biosolids products

- Biosolids exceeds composting requirements for all parameters except dry solids
- Better product qualitites when compared with composted biosolids

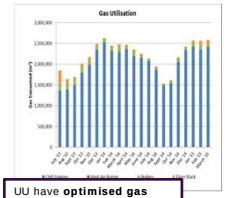
Davyhulme – United Utilities

United Utilities helping life flow smoothly

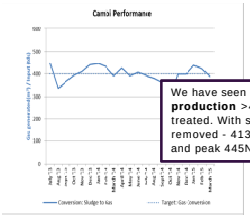
CAMBI -recycling energy

Key performance parameters from a years operation

Parameter	Units	Target	Measured value
Thickening Polymer usage	kg/tds	<10.0	5.96
Dewatering polymer usage	kg/tds	<10.0	8.07
Throughput	tds/day	275	225
Specific power consumption	kWh/tds	197	152
Renewable energy performance	kWh/tds	800	Up to 920
Cake dry solids	% DS	>28.5	31.3
Specific methane production	Nm^3/tds	>257	259
Specific biogas production	Nm^3/tds	400	400
Sludge Product status	Pass/Fail	Enhanced	Enhanced
Biogas utilisation to boilers	%	8	4.1
Volatile solids destruction rate	%	60	58 – 64
CHP Biogas use	%	91.2	94.3

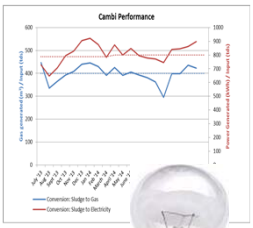


UU have **optimised gas** utilisation reducing the gas used as fuel in the boilers below 4% (target 8%) initially 12%



We have seen **good gas production** >400Nm^3/tds sludge treated. With septic sludge periods removed - 413Nm3/tds average and peak 445Nm3

Energy generation per tds treated sludge has **outperformed** expectations peaking at 920KWh/tds



Highest producer of renewable energy from sludge in UK

9 – 10 MWe generated

Energy neutral – UU are approximately 96% energy self sufficient at times neutral. **We also power UU's data centre and site vehicles**

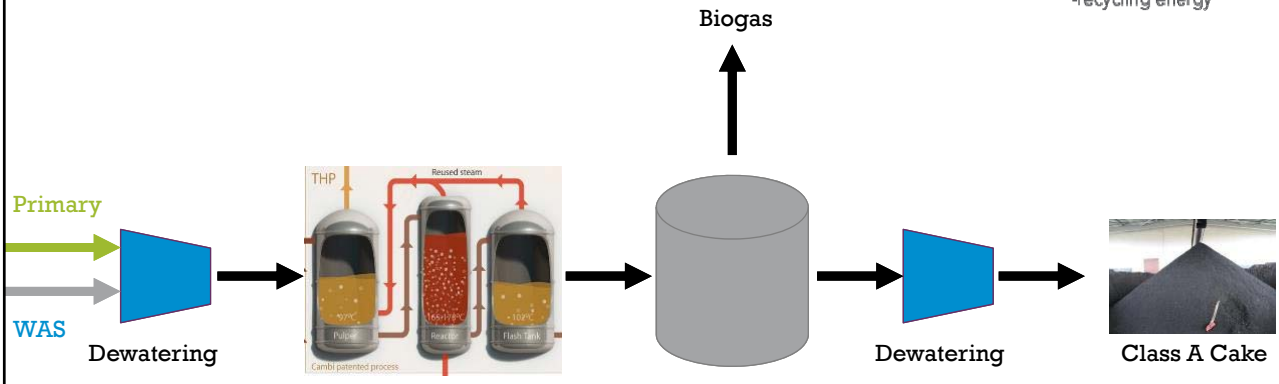
Slide: Richard Lancaster, UU

CAMBI -recycling energy

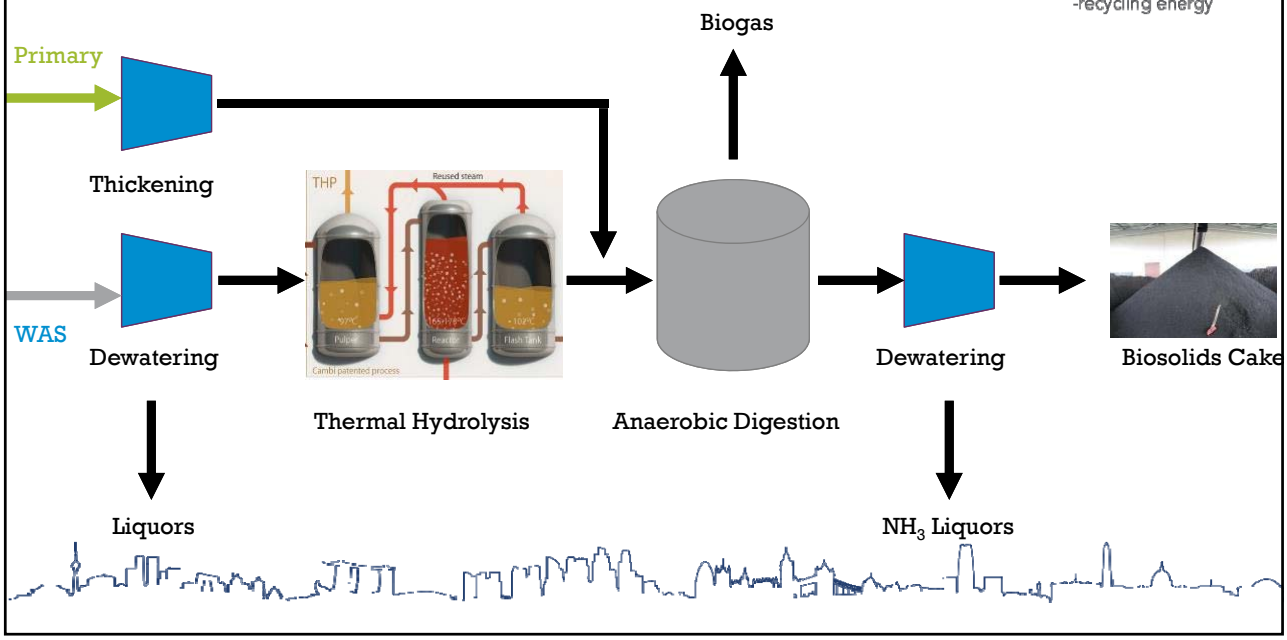
Future Developments

Standard thermal hydrolysis

CAMBI -recycling energy



WAS only thermal hydrolysis

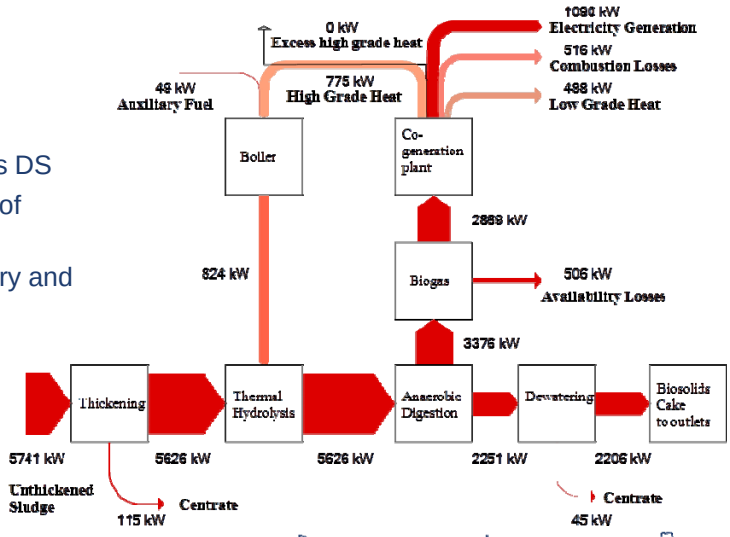


WAS only thermal hydrolysis

- Lower capex and steam consumption than full Cambi
- Contributes to digester heating/less cooling required
- Integrates will with CHP to make system run completely on waste heat
- Where there is no need for Class A biosolids:
  - Upgrade digester VS loading by about 30% and avoids digester construction
- 80% of the dewatering benefit for 50% capex

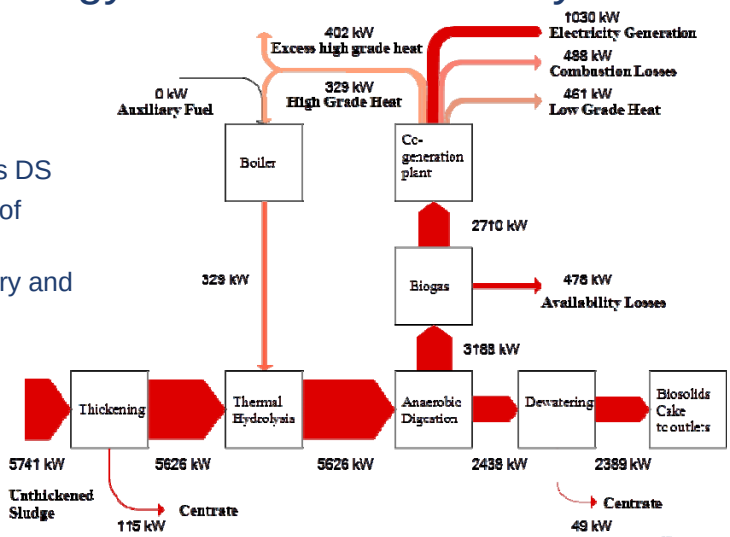
Typical Energy Balance – full THP

- 10,000 metric tonnes DS
- Sludge composition of 60:40; primary:WAS
- Processing all primary and WAS
- IC Engine

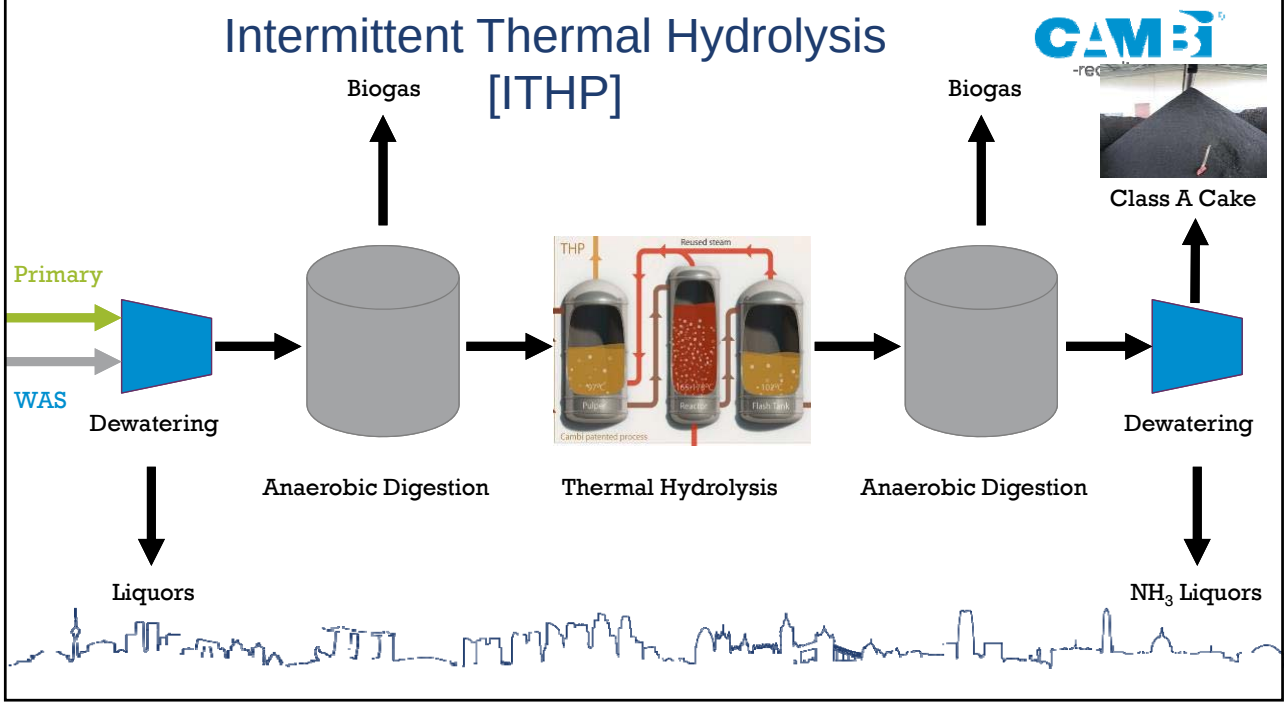


Typical Energy Balance – WAS only THP

- 10,000 metric tonnes DS
- Sludge composition of 60:40; primary:WAS
- Processing all primary and WAS
- IC Engine



Intermittent Thermal Hydrolysis [ITHP]



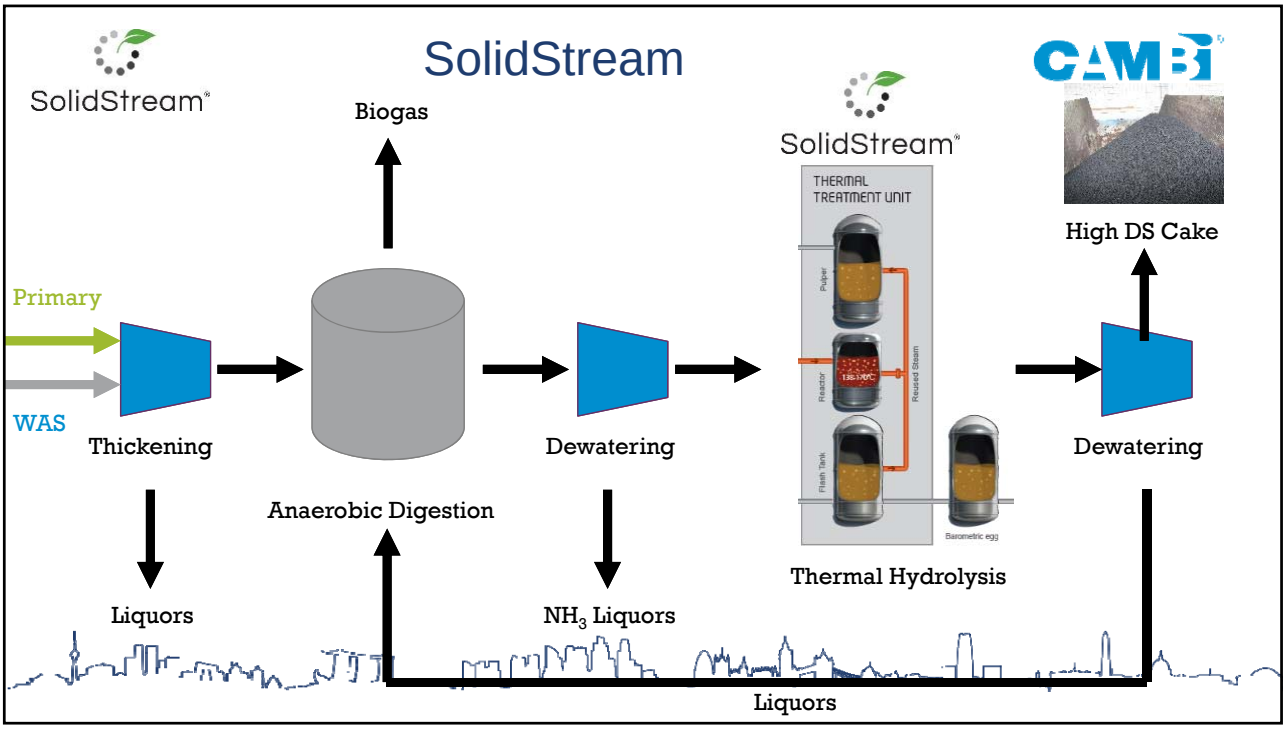
Second Generation THP - Summary of performance by Thames Water

Parameter	Units	Conv AD	THP	WAS only THP	I-THP
VSR	%	44%	59%	55%	65%
Gas Yield	scf/TDS	13183	17656	16372	19561
Gas yield	MMBTU/TDS	7.37	9.89	9.18	10.95
Elec Efficiency (gross)	%	15.30%	20.60%	19.10%	22.80%
Elec Efficiency (net)	%	12.30%	14.40%	12.90%	16.60%
Electrical Output	MWhr/TDS	0.72	0.97	0.90	1.07
Support Fuel	MWhr/TDS	-	0.28	-	-
Digester volume	gallons	12,236,400	3,775,200	6,930,000	7,656,000
THP Size	%	-	100%	40%	60%
Dewaterability (min/max)	%DS	21 \ 30	32 \ 45	28 \ 35	34 \ 48?

Basis:
100 tDS.d

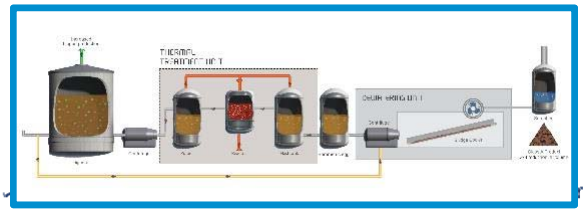
Primary 60%
WAS 40%

SolidStream



SolidStream – Process description

- Dewatered, digested sludge is fed to SolidStream process at 16% DS
- Sludge is treated at high Temp & Pressure **in pumpless process**
- Hydrolysed sludge is dewatered at elevated temperature (220 °F; drops to 185>°F with polymer)
- Dry sludge cake is cooled with air
- Cooling air is scrubbed to remove odor components
- Dewatering centrate & process gas are returned for biogas production
- **No cooler required**. Hot centrate heats up input sludge to digester temperature
- Can dewater to 35% DS **with no polymer**
- Plant is approximately **40% smaller compared to standard thermal hydrolysis**



SolidStream®

AmperVerband

CAMBI -recycling energy

SolidStream®

CAMBI -recycling energy

AmperVerband

- 5100 t US/DS; 83% VS
  - 14 tDS.d
- 62% primary, 38% WAS
- MAD 22 day HRT
- 50% VSR
- 20 – 23% DS cake
- 14,330 wet ton/year

SolidStream®

SolidStream™

CAMBI -recycling energy

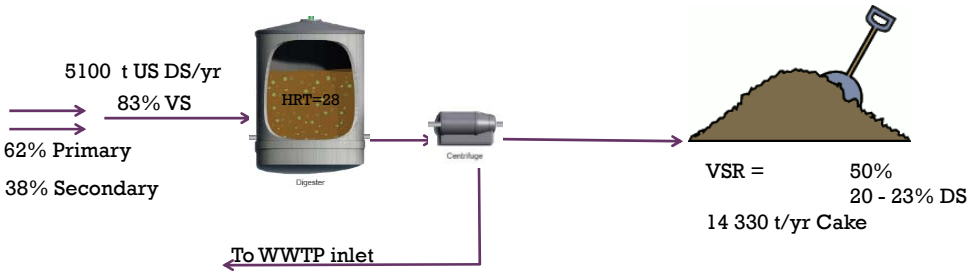
SolidStream®

Demonstration plant in AmperVerband

CAMBI -recycling energy

SolidStream®

Base Case, conventional



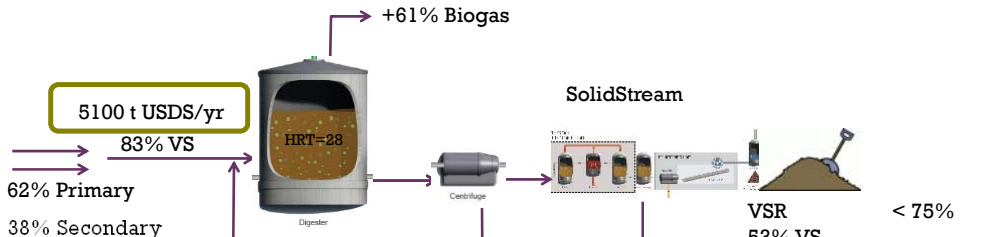
SolidStream

Demonstration plant in AmperVerband

CAMBI -recycling energy

SolidStream

SolidStream case, actual numbers 2016



Input Dry tons x 0.9
Output
= Wet tons

70% reduced wet ton cake
61% increased biogas
High quality cake

SolidStream

Biosolids cake

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Different to thermally hydrolyzed biosolids

No odor
Very crumbly – falls apart on squeezing
Further drying in storage

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Conclusions

Conclusions

- Thermal hydrolysis is a mature process
  - Standard technology – business as usual
  - Multiple suppliers
- Cambi processes over 30% of the UK sludge market – driver is financial
- Main market for TH is to process all sludge prior to digestion however other applications are gaining traction
  - Partial THP and intermittent to reduce steam demand
- SolidStream, 40+% DS cake, 75% VSR
  - Option for existing digestion plants which have sufficient digestion capacity rather than need to increase capacity or reduce digestion requirement
  - Ongoing research with different materials and configurations

Thank you: bill.barber@cambi.com

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Review

Thermal hydrolysis for sewage treatment: A critical review

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ABSTRACT

A review concerning the development and applicability of sewage sludge thermal hydrolysis especially prior to anaerobic digestion is presented. Thermal hydrolysis has proven to be a successful approach to making sewage sludge more amenable to anaerobic digestion. Currently there are 75 facilities either in operation or planning, spanning several continents with the first installation in 1995. The reported benefits of thermal hydrolysis relate to: increased digestion loading rate due to altered rheological