Howdon & Bran Sands STWs

using advanced anaerobic digestion to improve operational efficiency and environmental sustainability in Northumbrian Water

by Donna Rawlinson, Steve Coverdale, Barry Oliver and John Ord

Following the implementation of the Urban Waste Water Treatment Directive and the subsequent ban on the disposal of sludge to the North Sea, Northumbrian Water (NW) embarked on the construction of what was then the UK's largest thermal sludge drying facility. For approximately ten years NW's sludge treatment focussed on sludge drying (at Bran Sands, Middleborough) and dewatering with lime stabilisation (at Howdon, Newcastle); both achieving an enhanced treated product status.

Advanced Digestion plant under construction including twin stream Cambi THP - Photo by Steve Mayes - Courtesy of Northumbrian Water Ltd

Feasibility study

Following a high level review of potential sludge treatment options, MWH carried out a feasibility study in early 2006 to determine the potential costs, operating cost saving and integration issues associated with the installation of thermal hydrolysis advanced digestion (AD) at both of these sites. Whilst the thermal hydrolysis (TH) part of the process was relatively new, the digestion and CHP aspects were seen as well proven technology. Design calculations indicated that the new process would generate multi-million pound savings in annual operating costs and significant environmental benefits including:

- 2,000,000m^3 of liquid sludge reduced down to 150,000m^3 of sludge cake.
- Sludge cake being a Class A biosolid.
- 50% reduction in solids requiring disposal.
- 10MW of renewable power from biogas production.
- 20% of NW's total electricity demand being met by renewable sources.
- All of NW sewage sludge being used to produce renewable electricity.
- The facilities include cake imports to reduce the impact of sludge transportation.
- 20% reduction in carbon footprint.
- Provides NW with a more sustainable strategic sludge management solution.
- Existing assets used where possible.
- Bran Sands driers remain as a strategic contingency.

On this basis two design and construct contracts (totalling over £60m) with performance guarantees, were awarded to Aker Solutions (now Jacobs E&C) to install AD at Bran Sands in 2007, and GTM (a joint venture between Galliford Try and Imtech Process) to install AD at Howdon STW in 2010.

Bran Sands Advanced Digestion Facility

The Bran Sands Advanced Digestion Facility, commissioned in 2009, was designed to treat up to 40,000tds/y of sewage sludge comprising:

- 14,500tds/y of indigenous sludge from the adjacent effluent treatment works.
- 1,500tds/y of liquid imports.
- 24,000tds/y of cake imports from satellite works.

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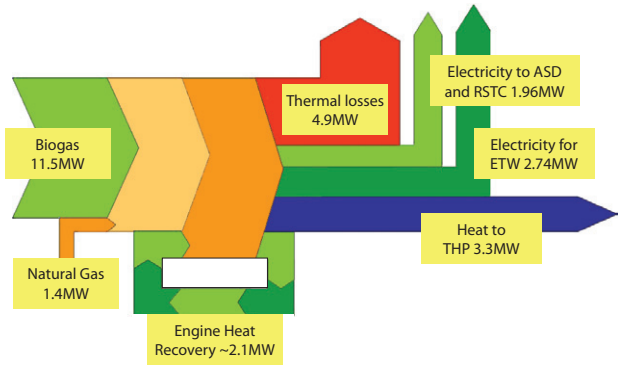


Figure 1: Sankey diagram to show energy balance for TH Advanced Digestion (40,000tds/annum) - Courtesy of Northumbrian Water Ltd

Construction of the sludge cake reception building to allow fully contained import of raw sludge cake from other sites
Photo by Steve Mayes - Courtesy of Northumbrian Water Ltd

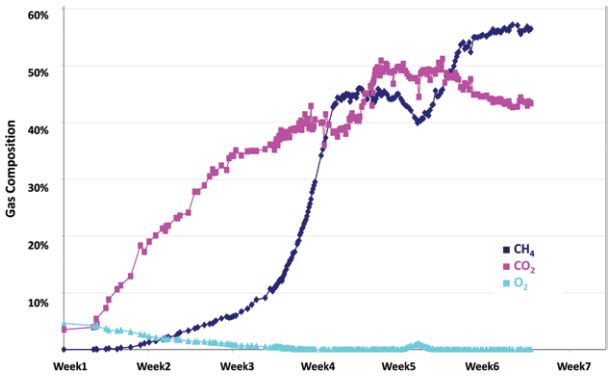


Figure 2: Graph to show rate of production of CH_4 during Bran Sands commissioning programme - Courtesy of Northumbrian Water Ltd

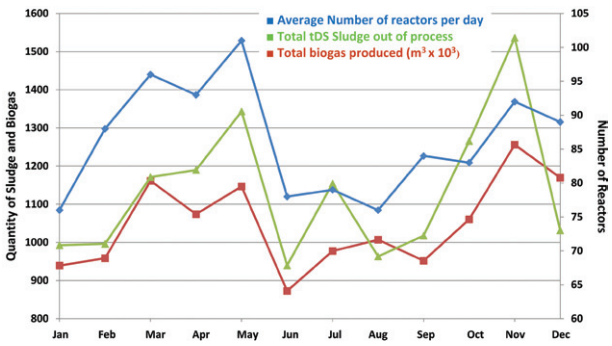


Figure 3: Graph to show how the amount of biogas related to the amount of raw sludge being treated and digested sludge to be recycled (during 2011) Courtesy of Northumbrian Water Ltd

Plant description

Liquid imports and indigenous sludges are pumped into an existing storage facility before being screened and transferred to a new pre-dewatering plant. Cake transfer pumps transfer the dewatered cake to reception silos before being pumped to the TH buffer tanks and two parallel TH streams (provided by Cambi). Each stream consists of a pulper, 4 (No.) reactors and a flash tank. The header is supplied with steam from a combination of waste heat recovery modules, which recover high grade energy from the gas engine exhaust streams and triple fuelled boiler plant (as per energy balance in Figure 1).

The output from the 2 (No.) THP streams is combined before being split into 3 (No.) separate digesters. The 3 (No.) digesters provide 18 days retention time; based on 90% Effective Digester Volume (EDV) at design throughput. The temperature within each digester is controlled by air blast sludge coolers installed on each feed line.

Digested sludge is dewatered using centrifuges and transferred to cake storage. This cake store has been provided with separate bays to enable loading and unloading of cake by front loaders whilst also allowing cake to be stored for longer periods before transfer off-site (to increase dewaterability).

Odourous air which is generated within the facility is ducted to the existing odour control plants, utilising biofilter technology.

Liquors generated by the pre and post-digestion plant operation are transferred to the main effluent treatment works for processing.

Plant performance

Performance to date has been promising. Using 2011 data, NW had a total throughput of 37,000tds/annum.

Pre and post-dewatering: During the commissioning period NW dewatered raw and digested cake with both belt presses and centrifuges. Based upon robust data and operational experience NW has recently upgraded its dewatering and now use only centrifuges. NW has noted that:

- Raw cake dewatered to 27%ds (with a capture rate of 96%).
- Digested cake dewatered to 28%ds (with a capture rate of 93%).

Note: At the time of writing (July 2012) new centrifuges are still being commissioned at Bran Sands and there is scope for further optimisation (power demand, polymer use, capture rate and dry solids).

Biogas production: During the commissioning period, NW observed excellent results, whereby biogas quality reached an acceptable methane concentration within 6 weeks (see figure 2).

One of the key issues to overcome was the contamination of the biogas with water vapour. NW is currently in the process of installing additional dehumidification to significantly improve the biogas quality and provide the appropriate protection to the gas engines and boilers (all of which have suffered with availability issues over the past 3 years of operation).

Volumetrically, the process has generally behaved as expected. The temperature of the digesters has constantly been controlled to 40.5°C (+/- 0.3). Figure 3 shows the annual biogas production during 2011. This aligns to both the incoming sludge patterns, the number of THP reactors being processed (averaging 90/per day) and most importantly the amount of renewable electricity being generated (equivalent to 4MW).

Howdon Advanced Digestion Plant

GTM has delivered NW's latest TH Advanced Digestion Plant at the Howdon Sewage Treatment Works. This plant has built on the lessons learned from Bran Sands and similar plants built for other

Water Companies in recent years, including Welsh Water's Cardiff and Afan plants.

Plant description

The new TH plant at Howdon has a design capacity of over 40,000tds/annum and can process all the indigenous sludge arising at Howdon and any imported sludge cake from satellite sites. The plant includes a new strain press installation to screen all liquid sludges. Elsewhere, screening has been found to significantly improve plant availability, reduce downstream maintenance, and improve renewable power generation. Liquid sludge is conditioned with polymer and dewatered using Alfa Laval's latest generation of high speed dewatering centrifuges. The sludge cake is conveyed directly into one of 2 (No.) sludge cake storage silos.

The plant also includes sludge cake reception facilities comprising a fully enclosed building with vehicle access, 2 (No.) cake reception hoppers, and automatic transport of sludge cake into the sludge cake silos. This plant was delivered by Agrivert using a well proven design developed by Hunning. All raw sludge reception facilities are fully enclosed with dedicated odour control facilities to ensure no odour nuisance arises from the new plant. The odour control plant is based on lessons learnt at Anglian Water and includes a first stage biological scrubber and second stage chlorine dioxide impregnated carbon which can reliably treat high levels of mercaptans.

Sludge cake is conveyed from the storage silos and diluted to approximately 17%ds before being pump transferred to the TH plant. Hot water recovered from the high efficiency CHP units is used for cake dilution in order to optimise the heat balance and minimise the use of support fuel. The TH plant is a two-stream installation with each stream comprising of a pulper, 4 (No.) reactors and a flash tank. This technology is well proven, with heat recovery and mixing in the pulper. The reactor conditions (165°C for 30 minutes) are achieved using direct steam injection. Balancing of the thermally hydrolysed sludge in the flash tank allows continuous feed to each digester. Condensed vapours and inert gas is transferred forward to the digesters to ensure effective odour control.

TH sludge is diluted using UV disinfected final effluent (to avoid re-contamination), mixed with recirculating digested sludge, cooled by final effluent using specialised heat exchangers and fed to each digester via the pump mixing system to ensure effective dispersion. Three post-tensioned concrete digesters have been installed, each of approximately 7,000m^3 capacity and including specialist pump mixing and integrated sludge coolers to allow the optimum digester temperature of approximately 40°C to be maintained. The anaerobic digesters provide optimum conditions to anaerobic digestion of the hydrolysed sludge and included lessons learned from other plants including increased free-board and facilities for foam management.

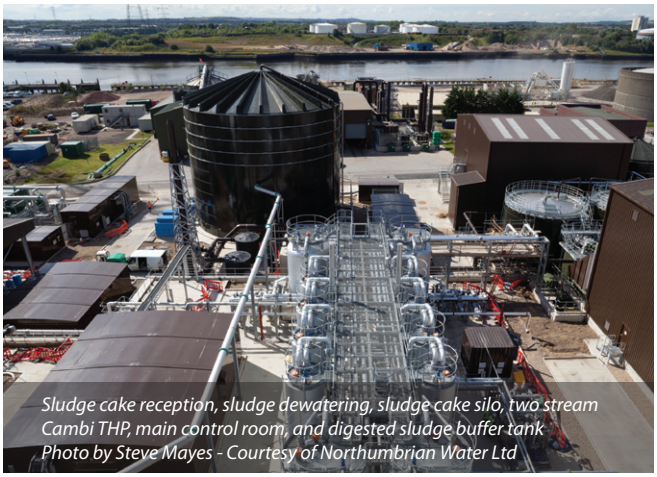
Biogas flows from the digesters through large diameter pipework, specially inclined to a number of large condensate traps to allow cooling and automatic removal of condensate. The biogas is used primarily by the 3 (No.) 2MW high efficiency CHP units, allowing more than 40% of the available energy to be converted to renewable power. In addition, the exhaust gas is transferred from each CHP unit to one of 3 (No.) composite steam boilers. These boilers can use biogas and natural gas or fuel oil as support fuel to reliably and efficiently produce the steam required for TH.

The digested liquid sludge is displaced from the digesters before centrifuge dewatering. Similar to Bran Sands, liquors are returned to the main treatment works for further clean-up.

Lessons learnt from Bran Sands

Lessons learnt from Bran Sands and other recent installations have been widely used in the design, construction and commissioning of the Howdon plant. These include:

View of the biogas holders, high efficiency CHP and composite steam boiler plant - Photo by Steve Mayes - Courtesy of Northumbrian Water



Sludge cake reception, sludge dewatering, sludge cake silo, two stream Cambi THP, main control room, and digested sludge buffer tank Photo by Steve Mayes - Courtesy of Northumbrian Water Ltd

Digester roofs including pump mixing and biogas pipework under construction - Photo by Steve Mayes - Courtesy of NWL

View of the three anaerobic digesters and membrane type gas holders for collection of biogas before use in the high efficiency CHP units Photo by Steve Mayes - Courtesy of Northumbrian Water Ltd

- Use of strain presses to fine screen all liquid sludges, reducing downstream maintenance and improving overall availability.
- The design includes multi-stream processes with sufficient standby provisions to ensure no single point of failure.
- Well proven equipment has been selected wherever possible.
- Plant flexibility including liquid and imported sludge cake facilities improves NW's overall resilience for sludge treatment, renewable power generation and recycling to agriculture.
- Full containment of raw sludge operations with extraction to proven two stage odour control system using biological first stage and chlorine dioxide impregnated carbon in second stage for improve removal of mercaptans.
- Use of well proven twin stream TH with standardised modular design and factory pre-assembly for improved quality control and safe and lean site installation.
- Optimised heat balance including; control of TH feed %ds, cake dilution with hot water, use of surplus hot water for office heating, use of CHP exhaust for producing steam, and triple fuel composite steam boilers for full flexibility.
- Optimised anaerobic digester design including jet mixing, increased free board and foam management.
- The use of increased diameter biogas pipework with large automatic condensate traps for improved gas cooling and condensate removal.
- Installation of a carbon filter for improved biogas cleaning and reduced CHP maintenance.
- Installation of large integrated high efficiency CHP units (3 (No.) x 2MWe) for optimum utilisation of biogas and economic benefit.
- Fast process start-up, use of process start-up which was successfully developed for Cardiff, allowing the full load conditions and optimum economic benefit to be achieved within 6 weeks of seeding with acclimatised sludge cake.
- Design flexibility to accommodate future expansion.

Next steps for Northumbrian Water's Sludge Strategy

NW is both innovating and leading the industry in utilising AAD:

- Employing AAD using novel TH, which produces 50% more biogas than is possible using conventional anaerobic digestion: 30,000,000m^3 of biogas produced from NW's sludge (per annum).
- 100% of its sewage sludge used to produce energy. No other UK water company uses all of its sludge production to generate power.
- Design includes the innovative reuse of waste heat from the AAD process to service adjacent facilities on site.

The innovation continues and Northumbrian Water is currently investigating:

- Further reuse of any remaining waste heat from the AAD process.
- Cleaning and directly injecting the biogas into the national gas grid.
- Continuous optimisation of the process so that operational performance is maximised.
- Considering alternative feedstocks (e.g. food waste) to increase operational performance even further.

When Howdon AD is fully commissioned (Autumn 2012), NW will be treating 2,000,000m^3 sludge per annum to produce around 80,000MWh of renewable electricity. This is equivalent to 40% of the energy needs for the entire cycle of its wastewater treatment. Furthermore the whole of the Howdon Sewage Treatment Works will be entirely energy self sufficient, with any excess renewable electricity exported to grid.

As a result it is expected that NW emissions per megalitre (the normalised basis of comparison between water companies) will become the lowest in the country. The company's long term goal for emissions reduction, 35% by 2020 from a 2008 base (50% including grid decarbonisation), exceeds that of both the UK government and the EU. Emissions have fallen by 20% in the last four years.

Wider environmental benefits include:

- Sharing benefits from lower energy use and government incentivisation schemes for renewable energy with customers - keeping customer bills low.
- Fewer process emissions released to the atmosphere.
- NW's sludge treatment follows UK Waste Hierarchy priorities (Reduce-Reuse-Recycle-Recover).
- Produces a Class A enhanced biosolid with a high nutrient value, which is more attractive for use in agriculture.
- Increased self-generation acts as a buffer against volatile world energy markets.
- Lower consumption of fossil fuels.
- A strategic sludge management solution to NW.
- Negligible odour impact.
- Re-using existing assets where practicable.
- Significantly reducing sludge transportation across NW's region. 2,000,000m^3 of liquid sludge ultimately reduced down to 150,000m^3 digested sludge cake.

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Construction of the biogas take off pipework and pressure relief system on top of each digester - Photo by Steve Mayes - Courtesy of NWL