The heart of the SEK 27.5 million (≈ EUR 2.6 million) total project delivery from Cellwood, which included construction, equipment upgrades and other ancillaries, is the HC pulper (left) and the reject separator (cylinder with the yellow guard).

# Unlocking the potential

**A key challenge for anaerobic digestion (AD) plants using food waste as feedstock is getting the substrate contaminant free. For the Swedish municipality-owned Skellefteå Biogas, it was a serious headache – until it revamped the pre-treatment line with pulp friction.**

**LOCATED IN NORTH-EASTERN SWEDEN** on the Baltic Sea coast, Skellefteå is described as the "southern entry into Swedish Lapland". Covering almost 7 175 sq km in area of which 374 sq km is water, it is the 12th largest municipality by area. It has a population of around 73 000 of which the city of Skellefteå is the largest urban centre with over 35 000 inhabitants.

In 2007, the municipality commissioned a SEK 140 million (≈ EUR 13.6 million) dedicated biogas plant to treat food waste and produce compressed biomethane, bio-CNG, for Skelleftebuss AB, a public transportation company also wholly-owned by the municipality that had begun switching its city bus fleet from diesel to bio-CNG. Currently operating a fleet of 130 busses of which 40 run on bio-CNG, the company aims to be running fossil free by 2021.

## Progressive WWTP

The biogas plant was built adjacent to the existing municipal wastewater treatment plant (WWTP) "Tuvan" about 7 km from Skellefteå city centre.

– Actually the Swedish term "samrötning" used for the entire Tuvan facility is misleading as it means co-digestion which the plant isn't. The food waste biogas plant is co-located but is entirely separate from the wastewater treatment plant, Peter Edlund, Head of the Water and Wastewater Department at the municipality pointed out.

Semantics aside, it is an important point since it has possible implications on the use of the digestate and residual sludge respectively. The former is used as a soil-improvement medium whereas the latter was until recently dried, pelletised and used in trials as forest fertiliser. This has been discontinued in part on account of unclear forest regulations.

– The dryer and pelletiser will be removed and another project will utilise the sewage sludge, said Edlund referring to the "SludgeIsBiofuel" project in which Skellefteå is a partner.

A European Union (EU) co-funded demonstrator project under the LIFE+ programme with amongst others Outotec (Sweden) AB and KIC Innoenergy, the overall aim is to achieve phosphorous and energy recovery by drying and high temperature oxidation of sewage sludge using a steam dryer, which is being installed.

Originally built in 1972, Tuvan is the main wastewater treatment facility for Skellefteå, receiving wastewater from several urban areas in the municipality. It is currently a conventional three stage treatment facility with a capacity to treat up to approximately 120 000 pe.

– The safety flare along with the biogas storage, cleaning, upgrading to biomethane and the compression units are the only technologies shared by the two facilities, said Edlund.

Prior to 2007, the raw sewage gas from the biological stage of the WTTP was used directly in two gas boilers, 1 MW and 500 kW respectively, to supply heat to the WWTP or flared when the heat demand was low.

## Bio-CNG and pellet heat

With the biogas and upgrading plant operational in 2007, all the gas produced from both facilities is upgraded to bio-CNG. Instead, to manage the heat demand for the buildings, digesters, the hygienisation tanks, and the digestate/sludge drying, a heat off-take deal was reached with the local municipality-owned energy utility Skelleftekraft that built a wood pellet fired heat plant on site. The wood pellets are produced at Skelleftekraft's integrated combined heat and power (CHP) and pellet plant in Skellefteå.

– With the municipality as owners of all three parties – Tuvan, Skelleftebuss and Skelleftekraft – it made more sense from the municipality's overall carbon reduction goal for us to use a locally produced forest biomass fuel and supply as much bio-CNG to the bus company as possible, explained Peter Edlund.

## Pre-treatment woes

The biogas plant had an original >>

*"We ended up putting in a 100 m³ LNG tank to ensure gas fuel supply, just in case. The irony is obvious and although we're prepared to pay extra for LBG we haven't been able to source any"*

**PETER EDLUND**
Head of the Water and Wastewater Department at Skellefteå municipality

>> design capacity to treat up to 15 000 tonnes per annum of source separated organic household waste as well as solid and liquid slaughterhouse waste. Some 2.1 million Nm³ biomethane per annum was the combined total output target of the sewage gas and biogas facilities at Tuvan. However, the biogas plant never got off the ground properly in terms of functionality or capacity.

– The problem does not lie with Skellefteå kitchens and households that have been exempleary since the start when it comes to source segregating food waste. We carry out random content checks from time to time to assess the accept level and find it is consistently 96 to 98 percent, Edlund said.

The municipality operates a two-bin refuse collection system – one for food waste and organics that is collected in bio-based plastic bags and the other is for combustable non-recyclables that is used for energy recovery.

–We want as little food waste in the energy recovery fraction as, apart from the nutrient recycling aspect, it costs the municipality money whereas biogas saves money by replacing fossil fuel, said Peter Edlund.

### Consultive tender

In mid-2015, Skellefteå issued a collaborative tender to address the entire food waste pre-treatment stage, deemed as the root source of the biogas plant's operational woes.

– By that stage we were quite frustrated with the old food waste pre-treatment line. It never reached its stated capacity, and it required a lot of maintenance. The working environment was not ideal for the staff and the machines needed manual cleaning, often, said Edlund adding that at the same time, there was the bio-CNG supply agreement with Skelleftebuss to fulfil.

This was getting increasingly difficult as new gas busses were being added to the fleet.

– We ended up putting in a 100 m³ LNG tank to ensure gas fuel supply, just in case. The irony is obvious and although we're prepared to pay extra for LBG we haven't been able to source any, said Edlund.

### Collaborative project

The tender was awarded to Cellwood Machinery AB, a Swedish company that develops, manufactures and supplies machinery and systems for the pulp and paper industry. The core solution deployed was a system consisting of a high concentration (HC) pulper and a reject separator. Both are technologies widely used in the paper industry for dissolving pulp and removing contaminants.

In addition, the order also included ancillaries such as a rotary shredder, pumps, conveyors as well as stirrers and buffer tanks for the digester. However, the chosen technology delivery was not a given when the initial tender contract was awarded.

– Being a rebuild and retrofit project all we really knew was what didn't work in the existing pre-treatment process, not what could work so we couldn't place a tender for a specific type of solution but form it as a joint project instead, said Peter Edlund.

Consisting of three phases, the first part of the contract was a joint consultancy to thoroughly evaluate the existing system, identify all the shortcomings, bottlenecks, process- and site constraints along with specific requirements including substrate quality, reject handling and overall plant capacity.

The phase also included examining different technology options and ultimately deciding on a technology pathway forward based the evaluation. The second phase entailed a detailed planning and costing of the chosen pathway and phase three was the building and commissioning of it.

A receiving bin (left) under the reject separator takes the entire volume of purged reject. A PST screw conveyor feeds the reject in a metered fashion to the dewatering step for the rejected materials.

– The entire project was carried out in a spirit of partnership and collaboration. Neither of us knew exactly what would be needed until the evaluation had been carried out. Even then there were other options on the table so it was by no means a done deal for us, said Peter Ek, Business Development Manager at Cellwood.

One key criterion was that the pre-treatment technology had to have a minimum capacity of 14 tonnes per hour.

– A wet hammer mill solution was an option studied but would have meant a setup of two parallel eight tonne per hour units. While redundancy might be considered an advantage, Cellwood tailored the pulper dimensions so that we could reach the capacity with a single line which meant a lower overall investment cost. And we had already seen the pulper concept in other biogas plants, so we knew that it was a robust and reliable process with low operating and maintenance costs, said Edlund.

### Design, build and commission

The new pre-treatment plant is built inside the existing premises. The receiving units, substrate buffer- and hygienisation tanks and digester along with the existing dedicated receiving and pre-treatment lines for solid and liquid slaughterhouse waste have been kept from the original setup.

In the available space, Cellwood's engineers drew up a customised layout to accommodate the shredder, HC pulper, reject separator, and a reject dewatering and handling system. Two pieces of equipment from the original pre-treatment setup, both of which were supplied by Cellwood in 2007 and 2013 were reused after upgrades. The cyclone for removal of solids such as grit, glass and egg-shells was upgraded to improve efficiency. A Disperser - a type of disc refiner – that creates a substrate of the solid slaughterhouse waste pre-treatment line and pumps to the buffer tanks.

Cont on p.8

Peter Ek, Business Developer for Cellwood Machinery AB.

Cont from p.7

## Transfer station

The pre-treatment process includes several steps. Incoming material is delivered in closed containers and these are emptied into one of the two original receiving bins each with a live screw floor that feeds the material into a single screw-conveyor in-feed located centrally underneath between both hoppers.

– We have a transfer station at a recyling centre located off-site. Here the organic fraction is reloaded into closed containers that are delivered to us instead of having refuse trucks coming in and unloading at the biogas plant, Peter Edlund explained.

The main reason is that the refuse trucks are of multi-compartment type collecting both combustable and organics on the same round. In addition, there is no dedicated storage other than the receiving bins at the biogas plant.

– This way the truck drivers save on an extra trip and we avoid the risk of getting an accidental truck load of combustable contaminants in the receiving bin. We also get much better control of the feedstock logistics and can time deliveries according to the process, not when a refuse truck needs emptying, Edlund said.

## First step, a shredder

From the receiving bin, the material is transported to the first processing step, a one pass Eric Schomberg rotary shredder supplied through Cellwood. The material is dropped onto the shredder and passes through it once.

– The rotary shredder rips open bags and packaging without grinding anything. It breaks rounded material like raw potatoes or oranges that otherwise tend to roll around in the pulper and it breaks frozen material into manageable sizes, Peter Ek explained.

The latter is an important factor, not just for frozen TV dinners but given the climate. A container with food waste that has spent the weekend out in -35$^{0}$C is more like a load of rocks. In addition, the shredder also functions as first removal of large foreign objects such as rocks and metal contaminants such as disc-brakes and scrap-iron, which have been known to occur.

– It has an inertia break so if something gets jammed, it stops so that the contaminant can be removed, Ek said.

## Dissolved with pulp friction

The next stage in the process is the HC pulper itself. From the shredder the material is transported to the top of the pulper via a vertical shaftless screw-conveyor from Plåt & Spiralteknik i Torsås AB (PST).

– Somewhat counterintuitive perhaps but a vertical screw-conveyor can be more reliable than an inclined one. And it saves space compared to other solutions, he explained.

A batch process, HC pulpers are used for dissolving material in concentrations of between 20 and 22 percent dry solids (DS). In essence it is reminiscent of a giant kitchen blender – an enormous four-legged stainless steel mixing bowl with a specially designed tapered screw rotor centred at the bottom. Each leg stands a weight sensor.

Water is added to the pre-determined batch of "ingredients" which has a DS content of 25 to 32 percent and once the screw begins to rotate, a fluid vortex is created forcing the material in a three-dimensional downward and up the sides of the vessel dynamic.

However, unlike a kitchen blender that uses knifes, no shredding or cutting takes place in the pulper. Instead frictional defibration and dissolving of the organic matter takes place to a concentration of 18 - 22 percent DS whereas the inorganics such as plastic, grit, bottle caps and glass are largely unaffected. This is a key attribute for the next phase in the process, the separation of susbtrate from contaminants.

## Reject separation

Once the pulper has completed its pulping programme, the contents are emptied via the bottom of the >>

>> pulper vessel into the reject separator. Here, the substrate is "washed" with recirculated reject water and screened through 6-millimeter holes. The screen has a slow rotating scrapper that prevents blocking of the screen. Plastics, metals, citrus peels and other non-solubles are efficiently separated and dumped into a reject handling system, where the reject is dewatered and transported to a container. The container is sent for energy recovery.

The accept susbtrate is pumped to a buffer tank before a new batch cycle begins. From the buffer tank, the substrate is pumped in one of the two hygienisation tanks, where the substrate is heated from around 10ºC to above 70ºC and held at 70ºC for one-hour before being cooled to 50ºC.

Using heat exchangers, cold incoming substrate is heated by cooling the outgoing hygienised substrate, which is sent through a cyclone to remove sand, grit and egg-shells. The clean hygenised substrate is then ready for the thermophyllic digester.

## A cleaner substrate

For Skellefteå, the pre-treatment retrofit project had three main goals – produce a cleaner substrate, increase gas exchange, and less maintenance.

– With the pulper we get an industrialised batch process which is easy to operate and consistently provides a consitent contaminant free high-quality substrate, said Peter Edlund.

The results from independent laboratory analysis, taken as part of the commissioning trials, confirm that the substrate is indeed very clean. The Swedish standards specify limit values for visible contaminants >2 mm. The measured value is 0.03 percent, which corresponds to 6,6 cmÇ/kg.

– That is an incredibly low value. With a clean substrate we get a better bacterial culture in the digester, and that means more gas from the same material, said Edlund.

Compared with the older Swedish regulatory requirements of 0.5 percent maximum – the HC-pulper process is almost twenty times better and is a future assurance of the new standards. The values are well in line with results achieved at other biogas facilities in Sweden and Norway that Cellwood have installed its pre-treatment solution.

– Our operators are very satisfied. They have run the new plant for quite a number of months now, and they are relieved to be working with a well-functioning process. The working environment has improved dramatically, said Edlund.

## Unlocked potential

Since the "first waste" input in April 2017, the process has been optimised to fine-tune the pulper "recipies" and corresponding batch run times. The equipment has also been trimmed for increased energy efficiency.

– We've run well over 800 batches, corresponding to approximately 9 000 tonnes through the plant, so we are getting to know the process intimately and the facility is operating very well, said Edlund.

With the new pre-treatment line the annual capacity has been confidently raised to 17 000 tonnes.

– This is over double of what we had reached with the old plant. Now we can expand our feedstock sourcing to supermarkets and neighbouring municipalities, said Peter Edlund.

## New upgrading plant

Clear is that Cellwood's pre-treatment solution has unlocked a whole chain of other investments at Tuvan, some of which are already underway. This includes a new and significantly larger, 4 000 $m^3$, biogas storage capacity as well as a new upgrading unit as the existing was already operating at full capacity. The upgrading unit is being supplied by Malmbergs, that also supplied the original unit which will be decommissioned.

– With the new biogas storage and upgrading unit we will have the capacity to upgrade all the gas and manage any temporary fluctuations or disruptions in production without having to resort to flaring, said Edlund.

A new gas filling station being built close to the bus depot and fire station. Instead of trucking bio-CNG to the filling station a a 7 km dedicated gas pipeline is being laid directly to the biogas plant.

*Text & photos: Alan Sherrard*
*BI99/6037/AS*

Separated contaminats consisting mainly of plastic- and carton packaging along with citrus peels coming coming out of the reject seperator before going into the dewatering process. Notable is the intact "unmacerated" condition.

More gas means more upgrading capacity is needed. A new Malmberg Compact GR 6 upgrading unit along with high-pressure compressors and decompressors is being installed. The total investment is around SEK 100 million (≈ EUR 10.1 million) of which SEK 16 million (≈ EUR 1.62 million) is an investment grant from the Climate Step (Klimatklivet) programme administered by the Swedish Environmental Protection Agency (Naturvårdsverket). The new upgrading plant will be able to produce about 2.1 million Nm3 of biomethane annually.


Contrary to the Swedish "co-digestion" terminology used, Tuvan's food waste biogas plant is a co-located facility and separate from the WWTP. Shared facilities, biogas storage, upgrading, compression and flare are all post-digestion.

In continous operation, the cyclone effectively removes undisolved particles such as sand, grit, glass and egg-shell from the substrate mitigating the risk of future issues with digester sedimentation and pump wear.