

Innovative ethanol production in a minimum of space

Turning waste into energy

Non-food biomass and advanced waste-to-energy concepts show great potential as providers of renewable fuel for transportation but at the same time pose new challenges for biorefinery processes. Sulzer is very active in this promising new field and offers complete process solutions and process plants, both skid-mounted and built-on-site. Recently, Sulzer delivered a modular bioethanol distillation unit to the Finnish company St1 Biofuels Oy. This project is a prime example of an innovative application of Sulzer's process technologies to bioethanol production, in combination with its skid-mounted assembly concept.

“Overall, the sustainable longevity and the energy efficiency of the entire bioethanol production plant are our main priorities,” says Mika Jokinen, Director of Operations of St1. By working closely with their customer, the experts from the Process Technology busi-

ness unit of Sulzer Chemtech were well aware of these requirements. They put their extensive know-how and full understanding of inherent system limitations as well as all information on relevant feed streams into the game. Different process simulation tools were applied to

adapt various plant concepts, resulting in an optimized process solution which could be offered to St1 with a guaranteed process performance based on the specific raw materials to be applied in the process.

The Finnish energy company St1 Biofuels Oy produces bioethanol trans-

Waste products that do not compete with the food chain offer great potential for sustainable biofuel production.



portation fuels from waste and industrial process residues, thus introducing new methods of efficient waste management. In this way, the company uses organic raw materials that do not compete with the food chain. St1 recently acquired an existing fermentation plant in Finland and, as a first step, planned the upgrade to new processes to produce bioethanol from grain-processing residue. The bioethanol product is subsequently blended into the existing gasoline network of St1.

What St1 needed for this upgrade was a technology for the recovery of the bioethanol from the fermentation broth, and they found a strong and experienced partner in Sulzer Process Technology. Sulzer is a leading supplier of distilla-

tion column internals for bioethanol, biobutanol, and biodiesel plants and is market leader in this field in the USA. Sulzer has an outstanding position, particularly in bioethanol distillation, due to its extensive experience in fouling applications (mash columns). For advanced biofuels production, Sulzer Process Technology has delivered complete process plant solutions including liquid-liquid extraction, distillation (including reactive distillation), and membrane separation units to many countries around the world.

Unique heat integration

Based on its accumulated expertise in providing solutions for demanding industrial separations and its wide range of thermal-separation technologies, Sulzer has developed heat-integrated process solutions for advanced biofuel distillation and dehydration. Sulzer's heat integration concept for these applications is unique in optimally combining distillation and vapor permeation technologies. This hybrid combination substantially reduces overall energy consumption, as both technologies are utilized at their highest efficiency.

Sulzer analyzed the requirements of St1 and proposed a skid-based solution which is most suitable based on the

Types of biofuels

Biofuels are derived from biomass based on plant or animal material. Commonly used biofuels today are bioethanol, biodiesel, and biogas. Biofuels offer an alternative to scarce non-renewable resources like crude oil.

First generation biofuels are most commonly derived from sugar or starch crops (bioethanol) or vegetable oil seeds (biodiesel).

Second generation biofuels are derived from cellulosic non-food sources such as wood and switch grass, waste products from forestry, agriculture, households or paper production. The use of waste feedstock results in a high sustainability potential and greenhouse gas savings, i.e., a small ecological footprint.

For more information on Sulzer solutions for biofuels, please visit: www.sulzer.com/biofuels

plant's capacity. In addition, Sulzer's process design for the heat-integrated bioethanol distillation process addressed all customer requirements, including energy efficiency, delivery time, skid size,

Sulzer has an outstanding position in bioethanol distillation.

and cost. The decentralized waste-to-energy concept of St1 requires a highly economical production. Low capital investment in combination with low operational cost are essential parameters. The complete, preassembled skid as ordered by St1 comprised a mash column connected directly downstream to a heat-integrated rectification column, as core equipment.

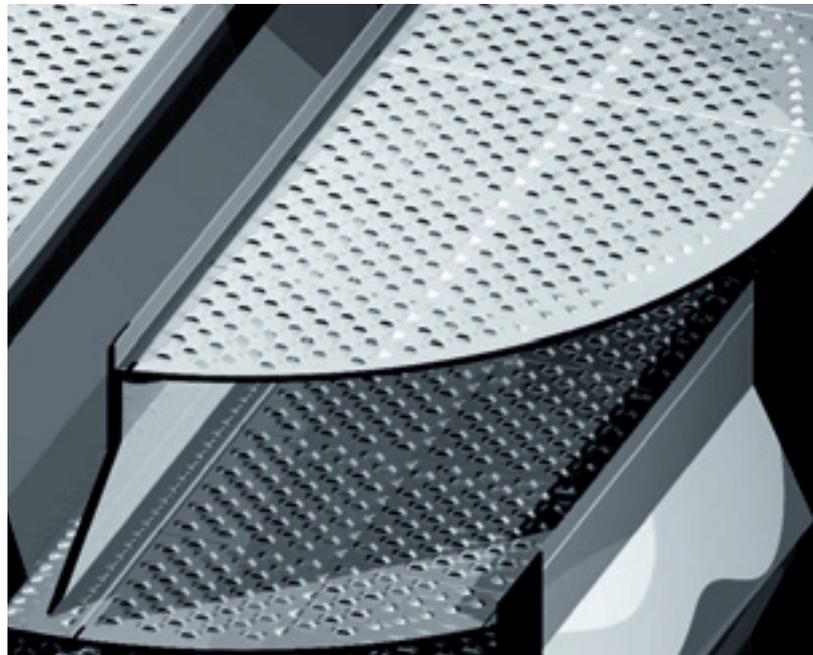
Efficient distillation process

Sulzer's distillation process is based on proven experience for first and second generation bioethanol plants and process designs for numerous other applications. The comprehensive application know-how for its thermal-separation technologies enabled Sulzer to provide St1 a plant with a guaranteed process performance.

In Sulzer's process concept, the bioethanol is concentrated up to only 90 wt% in the distillation section, which substantially reduces the energy demand in the rectification by 30–50% from that of conventional rectification design concepts.

In the mash/beer column, Sulzer VG AF™ trays are used ¹. These trays from the VGPlus tray family are especially designed for fouling services.

¹ The Sulzer VG AF™ tray from the VGPlus tray family is especially designed for fouling services.



In combination with the optimized process design parameters (adapted operating temperature, high turbulence in the evaporators), plant availability is considerably extended before cleaning becomes necessary. In the rectification tower, Kühni slit trays are applied. In similar applications, Sulzer's structured packing like the MellapakPlus family has also proven to be an excellent technology for process intensification in these towers.

Pumping challenging biorefinery fluids

Biorefinery processes need to handle challenging process streams with substantial solids content. Sulzer Pumps has extensive experience in biofuel applications and offers pumps that operate efficiently and reliably in advanced biorefinery processes. Sulzer Pumps is nowadays the trusted market leader in pumps for ethanol plants across North America. The company also delivered the process pumps for the St1 project.

Skid-mounted distillation plant

Sulzer has supplied more than 250 skid-mounted process plants over the last 25 years and has built up specific expertise in this field. One big advantage of modular units is that they minimize work and disruption on site. They require only



3 The installation of the plant's lower and upper skid sections at the customer's site in Finland required only minimal on-site activity due to the modular fabrication concept.

tie-in connections for the pipe work and wiring of the field instruments from junc-

Sulzer has supplied more than 250 skid-mounted process plants over the last 25 years.

tion boxes to the PLC (programmable logic controller).

Also in the St1 project, the overall costs, the high quality of the manufacturing, the very short delivery time of less than eight months, followed by very short on-site installation and commissioning time were essential in securing this order. The new distillation plant

needed to be ready to process waste grain at a mutually agreed short-term date.

Sulzer was responsible for the following project steps:

- Process design
- Basic engineering
- Functional description for plant operation and control including a cleaning procedure
- Manufacturing and procurement of the required materials, including process equipment, instrumentation, valves, and piping
- Assembly of the skid in Sulzer's purpose-built, state-of-the-art workshop
- In-house acceptance testing work
- Transport of the skid to site 2
- Supervision of the installation
- Commissioning assistance, site acceptance activities, and operator training

The final size of the complete skid was 4 × 4.5 × 22 meters. It was shipped by truck in two sections. The setup and installation work on-site, including commissioning, was finished in less than three weeks 3. This time also included the time for the customer to completely clad the steelwork structure. As soon as all mechanical and electrical tie-ins to the plant were completed, Sulzer's process engineers undertook the plant commissioning. This included water testing followed by the first processing of

2 The bioethanol distillation plant was delivered from the Sulzer workshop in Allschwil, Switzerland, to the company St1 in Finland.



mash feed. The guaranteed plant specifications were met to the satisfaction of St1. This unit has now been in operation since spring 2011. During the initial operation phase, Sulzer supported St1's plant personnel in optimizing the operating conditions of the plant.

Advantages of modular process plants

The main advantage of a modular or skid-mounted plant delivery is that the complete plant production and project responsibility is in one hand. This supports many customers who no longer have the capacity to engineer and manage larger projects fully in-house. It also reduces costs and shortens delivery times compared to conventional con-

The space requirements are reduced due to the compact plant design.

struction. In addition, efficient project realization and an optimal and integrated design are ensured by Sulzer's team of highly skilled and experienced engineers, who internally work closely together and are also in regular contact with the customer.

Further advantages of Sulzer's modular process plants are:

- Reduced space requirement due to compact design
- High-quality fabrication and installation under workshop conditions applying standard state-of-the-art fabrication and testing procedures
- Cost-competitive assembly of skids performed in Sulzer's own dedicated workshops or at sites close to customers under the full control of Sulzer
- Testing activities (FAT) performed in the workshop, prior to skid installation
- Reduced on-site installation activities, production downtime of existing facilities, and required on-site safety measures
- Increased strategic flexibility of customer's production sites due to the possibility of an easy relocation and reuse of skid-mounted plants at other locations

Requirements of modularity

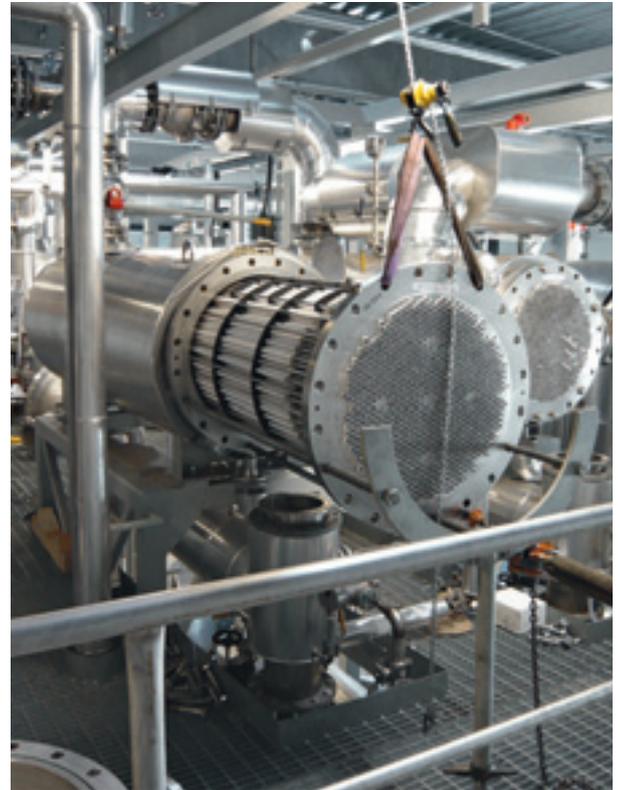
Customers benefit from modular plant concepts but also have to consider some requirements. In general, plants can be realized as a modular solution if:

- The equipment required fits in a skid
- The resulting layout is compact and allows for a skid size permitting road transport
- The project is clearly defined and changes to the process are avoided during execution (no designing on the go)
- Accessibility is assured in spite of the compact design
- Tie-in points on-site are accurate and agreed upon prior to the start of design
- Loading and off-loading requirements are carefully considered

Innovative dehydration of bioethanol

In the case of the St1 plant described, the wet ethanol produced is shipped to a centralized dehydration unit, where it is dehydrated to 99.8 wt%. The dehydration step is a fully heat-integrated vapor permeation unit using zeolite membranes [4] manufactured by Mitsui Zosen Machinery (MZM). Sulzer has a long-standing successful cooperation with MZM. The dehydration installation is the world's largest unit using zeolite membranes. Sulzer realized this plant in close cooperation with St1 and partner companies, and this unit has been in successful operation since 2008/2009. The final bioethanol product is blended into fossil gasoline and is available as E85 in selected filling stations in Finland.

In contrast to the classic bioethanol distillation and dehydration processes, which are based on a combination of distillation and dehydration with molecular sieves, this very innovative distillation/vapor permeation membrane process has an unrivalled energy efficiency. In cases where the distillation and dehydration units are operated at the same location, which is usually the case for industrial scale plants, Sulzer's fully heat-integrated hybrid solution for the downstream section can offer an incomparably reduced energy demand of approximately 1 kg steam per liter of ethanol produced.



[4] Sulzer's innovative vapor permeation unit uses zeolite membranes and allows energy-efficient dehydration of bioethanol.

New concept for revamping existing plants

Revamping existing plants by integrating an additional membrane drying section increases the overall plant profitability by reducing energy consumption and increasing throughput. This improvement is especially important in times when raw material and energy costs are increasing.

Currently, Sulzer is working with selected bioethanol plant operators to prove this concept. Complex heat integration and various recycle streams in existing bioethanol plants require close cooperation during the development phase. This way, Sulzer can assure its customers that all possibilities and limitations are taken into account.

Thomas Raiser
Sulzer Chemtech Ltd
Gewerbestrasse 28
4123 Allschwil
Switzerland
Phone +41 61 486 37 33
thomas.raiser@sulzer.com