# Annex C1-2:
*Evaluation Report* 2 from the demonstration phase after 12 months

| Subject | Project acronym / Ref. No. | Date |
|---|---|---|
| *Deliverable under Action C.1* | Etanolix 2.0 for LIFE+ / LIFE12 ENV/SE/000529 | 30/07/2016 |

| Issued by | Company / Department |
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*Evaluation Report* 2 *from the demonstration phase after 12 months – Monitoring and evaluation of pilot plant*

Evaluation Report 2 concludes the period from Jan 1 – Jun 30 2016. This report will cover progress, issues and solutions with and within the unit, with a main focus on the receiving station of the Etanolix 2.0-unit and the integration to the refinery.

**Progress**

Deliveries of feedstock to the Etanolix-unit have slowly increased during the period from 150 tons to 230 tons/month, see *Figure 1*.
The main reason to the slow gain is that the work with finding suppliers, agreeing about contracts and arranging with logistics takes time and involves a lot of people.
Suppliers also often have a contract already in place with other parties, e.g. farmers that have to end before deliveries to Etanolix can start. Contracts have been signed for 80 % of the estimated volume for maximum production, see forecast presented in *Figure 8.*

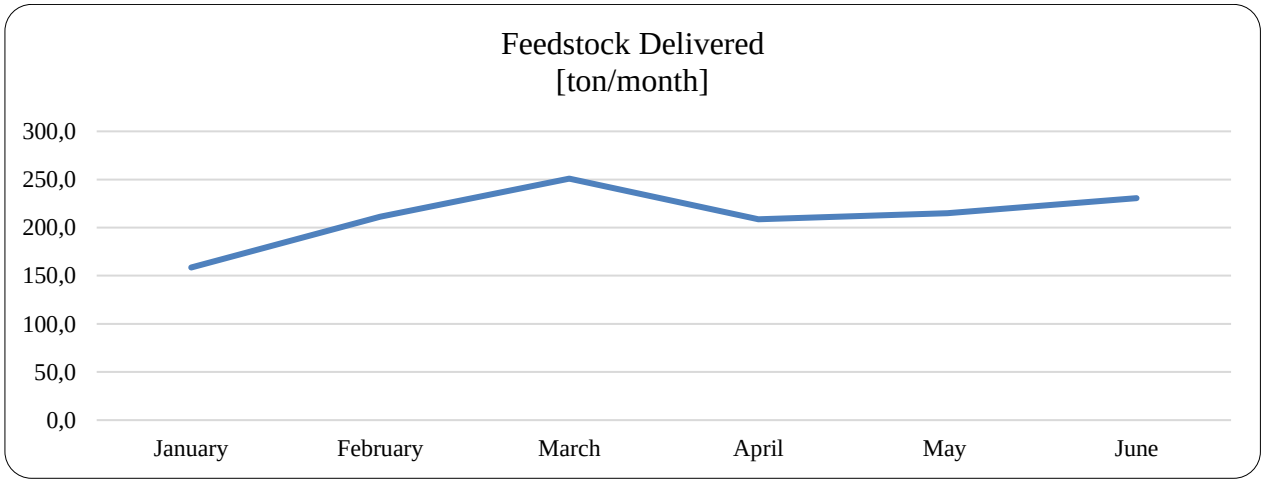


**Figure 1.** Delivered feedstock to the receiving station during January 1 –June 30 2016.

The quality of the feedstock and its packaging is crucial for the unit to reach a good processing pace. There have been continuously discussions with the feedstock suppliers about how to decrease

the amount of big plastic bags or change them to a more suitable type of material as paper. This has improved somehow over time and the processing rate in average is increasing.

Perpetual training and information to supplier and their staff about what and how to deliver the feedstock into the refinery makes the processing of feed easier and faster. The amount of feedstock delivered to the receiving station, presented in *Figure 1*, can be compared with the maximum plant throughput equal to approx. 1650 ton/month.

Testing during the period has stated which capacity the receiving container is able to handle. Equipment has been optimized and several different operation modes have been tested to ensure best possible treat rate for different sourcing material. The volume of the container is fit for purpose to handle a full load of different sorts of feed stocks, but speed of throughput is limited by the weight of incoming raw material (further described in *Issues and Solutions*). If the receiving container capacity is exceeded, the processing rate is decreased or could even cause a stop to the production.

A hydraulic arm called Roll-PAC was installed in the receiving bin in January that manually helps to spread the feedstock even in the bin. The installation made it possible to maintain an even processing rate of the feedstock and thereby speed up the intake.

The production rate was limited from February to June due to a broken mixer in the hydrolysis tank. This forced the hydrolysis to slow down, but this could be sorted due to modified supply pattern and deliveries of feed stocks in and another pace and therefore did not affect the overall production rate.

From start we had problems with dissolved CO2 in the mash causing high acidity in the produced ethanol. High acidity can cause problems with corrosion in engines and must be monitored during production and has to be within specification. The design with nitrogen purge introduced in the middle of December 2015, also mentioned in the first evaluation report, solved this problem.

The production of ethanol (*Figure 2*) during the period is on specification regarding acidity.
The monthly production was approx. 50 m3/month and accumulative production was 267 m3 during the period

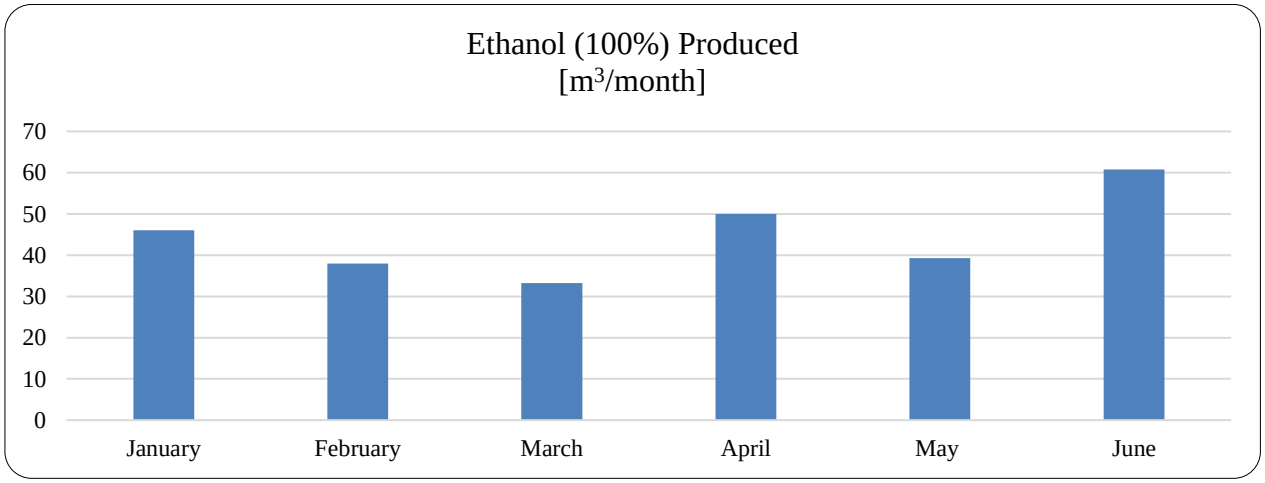


**Figure 2.** Produced ethanol from Etanolix 2.0 on a monthly basis.

The production of stillage follows the ramping of feedstock intake. The dry solid content in the production have been optimized. That means that the stillage contains more feedstock and less water. This results in a stillage-product with higher nutrient-content which is better for the customers, but shows as a smaller volume of delivered stillage. In total, 3 343 $m^3$ of stillage was produced during the period, compared to the maximum amount of 25 000 $m^3$. 1 352 $m^3$ was delivered as animal fodder and 1 991 $m^3$ as feed for biogas production, *see Figure 3.*

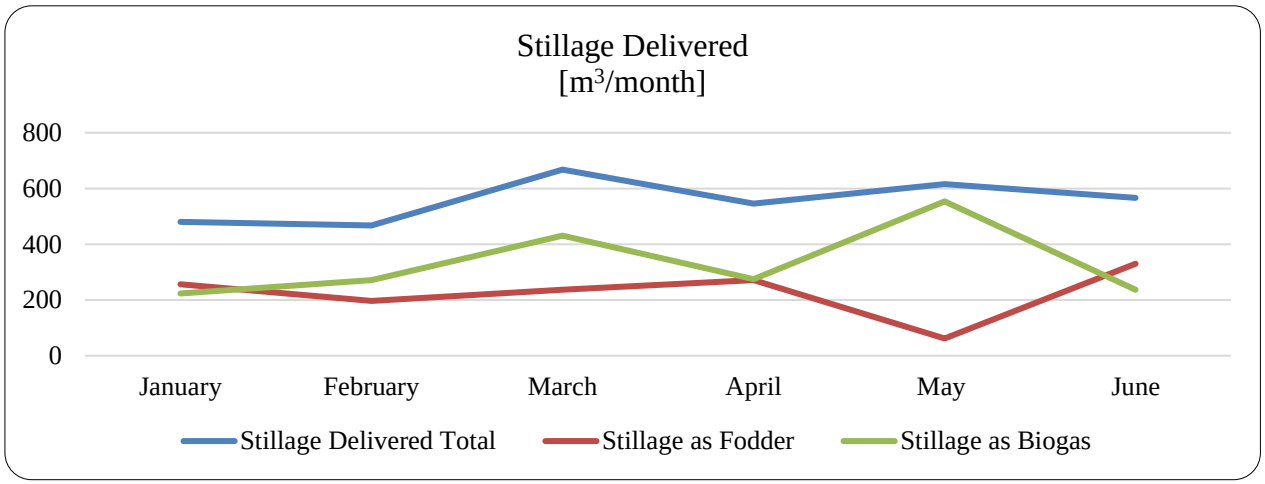


**Figure 3.** Stillage delivered from Etanolix 2.0 in January 1 –June 30 2016.

As the total throughput of raw-material to the unit was low compared to maximum design unit throughput, consequently produced ethanol and stillage was relatively low with 10.7% and 13.4% respectively.

Daily laboratory analyses and quality controls are made on production, stillage and ethanol. The schedule for quality testing and reporting contains both analyses necessary for operating the processes and enable production improvements and compulsory analysis issued from customers and legislations. Before ethanol and stillage are transferred or delivered to refinery tank farm and customer, respectively, complete analyses are made to ensure the correct quality of the product.

In May 25th a visit from *Jordbruksverket*, which is the national Control Agency for production of animal fodder, was made. They audited the production units against hygienic control and inspected the Etanolix plant. The result was this was good, a report was sent as an evidence of fulfilling the legislative criteria's. This document can be seen on request to the refinery's environmental department.

The ethanol yield is affected by different components as carbohydrates, sugar content, starch and how easy they are to break down in suitable sugar components. Suppliers of feedstock are chosen, as far as possible, due to feedstock quality with high contents of above, volumes and suitable packaging. A good feedstock produces a high yield, examples is candy, cookies and white bread. A yield (ethanol produced/received feedstock) above 20% shows good quality feedstock for the production.

The yield (*Figure 4*) was lower from February to end May due to the above mentioned broken mixer in the hydrolysis, which made it necessary to add more water to that process step than necessary. When the mixer was replaced the yield stabilized on 20-25%.

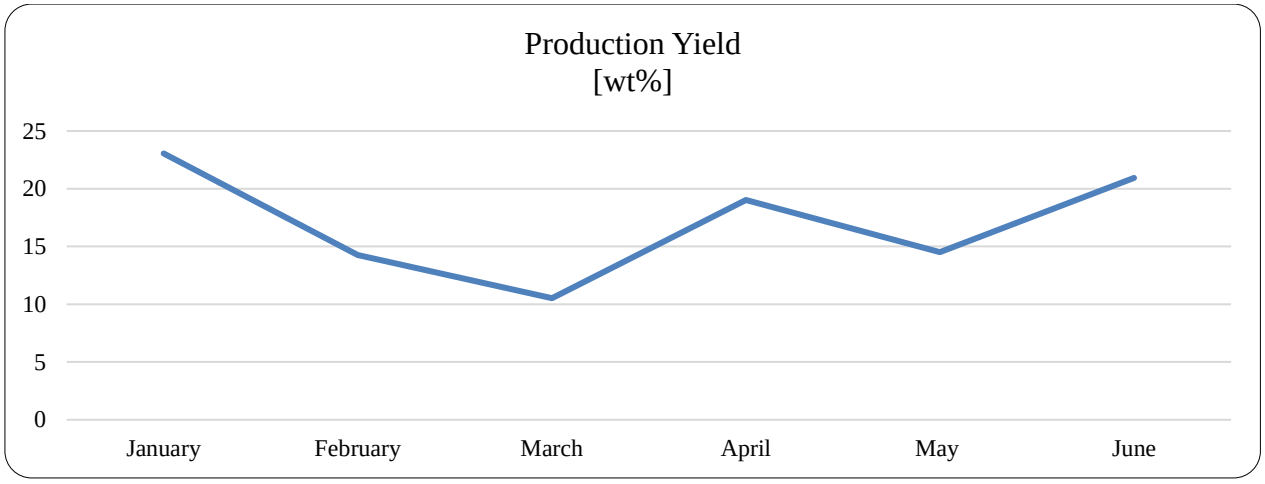


**Figure 4.** Ethanol yield

The integration with utilities supplied from the refinery has, during the whole period, worked according to plan.

## Energy Consumption and Environment

Due to low throughput, the energy consumption was relatively low compared to design, that would expect 712.6 MWh/month, see *Figure 5*.

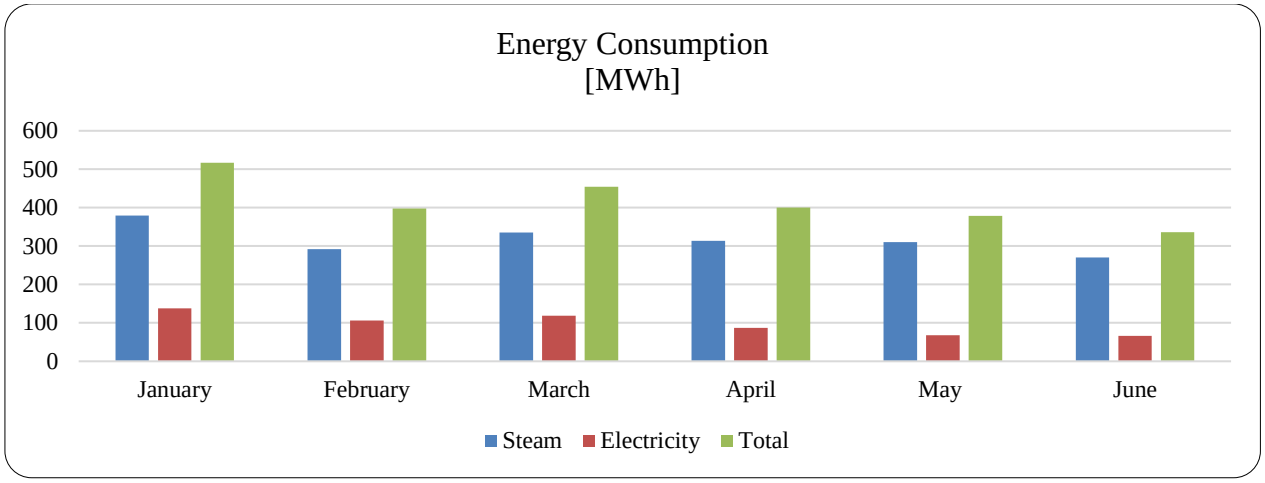


**Figure 5.** Energy consumption in the Etanolix 2.0 unit. The energy consumption is divided in the energy provided by excess steam from the refinery and electricity.

The use of energy is only partially comparable with the amount of feedstock and production. Equipment such as instrument, cooling pumps etc. is always active using energy even if the unit does not run at full rate. During the winter period a lot of energy is used for heating the equipment. That means that the energy-efficiency/produced $m^3$ of product will be better with an increase amount of feedstock. This is presented in *Figure 5* where the energy consumption is roughly the same during the period even when the production is increasing. At maximum production rate, it is estimated that 712.6 MWh/month will be supplied.

There have been no negative effects on the refinery's water treatment plant during the period.

Air emission measures, from both the fermenter's CO2-scrubber and the distillation's scrubber, have been performed and after optimization revisited and controlled; thereafter showing efficiency, of each scrubber, above 95%.

Green House Gas (GHG) calculations for $CO_2$ reduction have been made accordingly to Renewable Energy Directive. The reduction will just as energy efficiency increase along with higher throughput, see *Figure 6.*

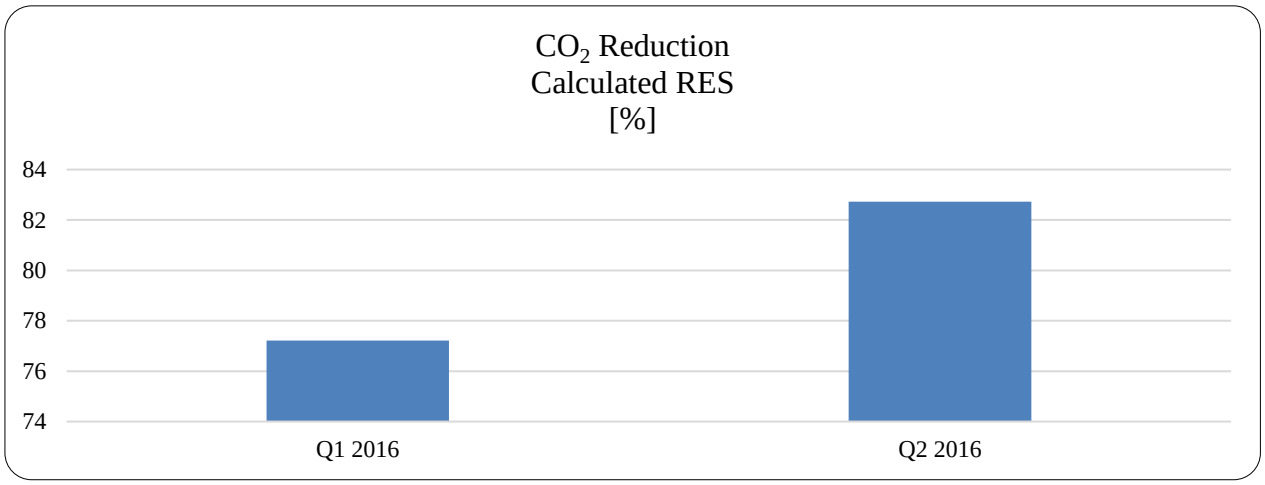


**Figure 6.** CO2 reduction calculation RES.

There have been several optimizations on the distillation process during May and June that significantly increased the stability in the process and reduced downtime.

Waste from the unit consists of plastic from the packaging and sludge from the CIP (Clean in Place) unit, see *Figure 7*. The plastic goes to a local facility for energy production and the sludge is delivered to a customer that is producing fertilizers. Other is feedstock that has been rejected due to impurities, mold or foreign objects. In total there was 255 tons of waste during the period.

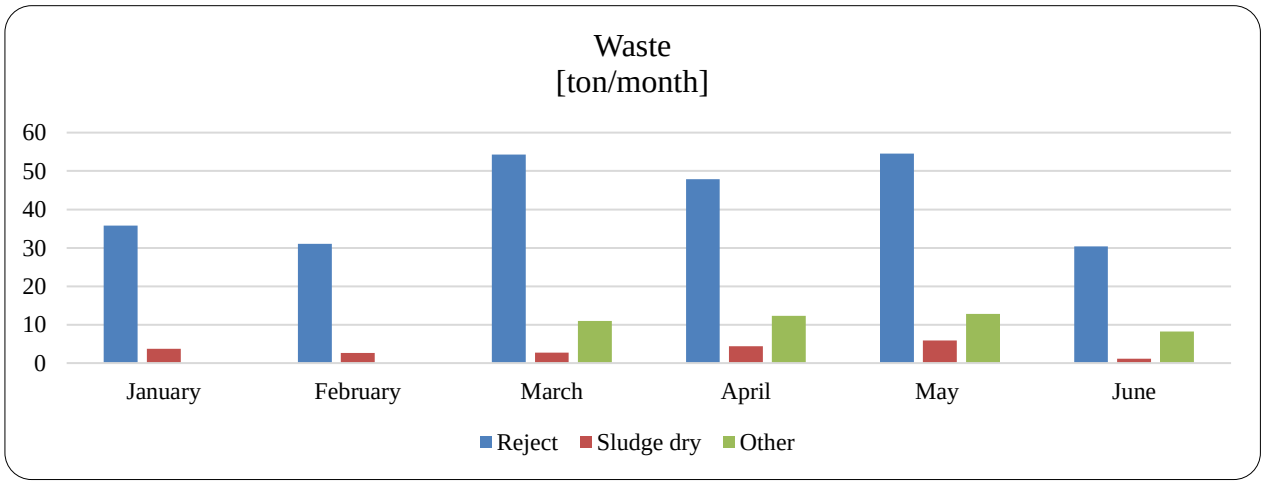


**Figure 7.** Waste from Etanolix 2.0.

**Issues and Solutions**

Receiving station / Prototype:

Extensive testing of the prototype - receiving station - with different types of feedstock has been made and it's clear that the weight of the feedstock into the receiving bin is limiting its functionality (both speed and the general potential to operate at all if too much is delivered at the same time). The rotating screws can just handle a maximum load of approx. 12 ton. If loaded with more, the processing rate is decreased or in worst case the screws are blocked.

An example to be given is tests performed for the receiving station when feed stock was delivered. During testing the screw motors were optimized to its maximum. One screw broke due to mechanical stress during this test. This resulted in that (in February) rotation guard and a blocking guard were installed. The rotation guard measures the speed of the screw rotates in at both ends. If one end of the screw rotates faster than another other, it indicates that something is wrong and the motor will be stopped. This reduces the risk for mechanical stress in the screws. The blocking guard controls if one conveyer shows indication of blockage and thereby stops the engine. Further tests to improve the prototype and enable a higher throughput will be done. A test program with variable speed of the screws will be performed during Q3 2016, in order to maintain an increased processing rate.

Even though the volume and the speed in the receiving station is almost up to specification, the limitation of just having a maximum of 12 ton in the receiving bin affects the logistic situation and can cause waiting time for the transporter of feedstock. For the moment there is no solution or plan jet on how to change this.

Feed-stock:

The quality of the feedstock is an important issue. This will most certainly always require a high focus and continuous effort to quality control being flexible with different suppliers and volumes available. Having issues with the feedstock can in worse case also lead to "jamming of the screws" or the un-packaging machine leading to downtime of the unit.

As learning from problems with specific feed-stocks information and repetitive training of raw material suppliers on how to sort, pack and quality assure the feedstock before delivered into Etanolix 2.0. The downtime has decreased significantly since the startup. There is also an ongoing work, as part of the project, to find new sources of feedstock where the packaging will be easy and fit for purpose for this specific prototype design to handle.

There is also a risk if "unwanted material" enters the collecting bins and reaches the receiving station. It is a part of normal routine that the Etanolix-operators check all deliveries before they

accept the truck to deliver material into the receiving station. This procedure is an important quality check which has made it possible to increase the throughput month by month as well as minimizing the risk of having impropriate material into the process.

In June it was discovered that three pipes below the fermenters were leaking. An investigation showed that there were damages caused by (corrosion) and erosion in the pipes due to wrongly received material within the feed stock (most probably sand). The pipes had to be changed.

## Future work

Upcoming work is concentrated in optimizing throughput of feedstock at the receiving station. A schedule on how to obtain a higher throughput is presented in *Figure 8.* Once the throughput of feedstock reaches approx. 45-50% of maximum, it will be possible to run the distillation continuously instead of batch mode as it is today.

Work will continue to engage suppliers with good quality of feedstock to ensure deliveries of at least 100% of the calculated maximum amount of feedstock.

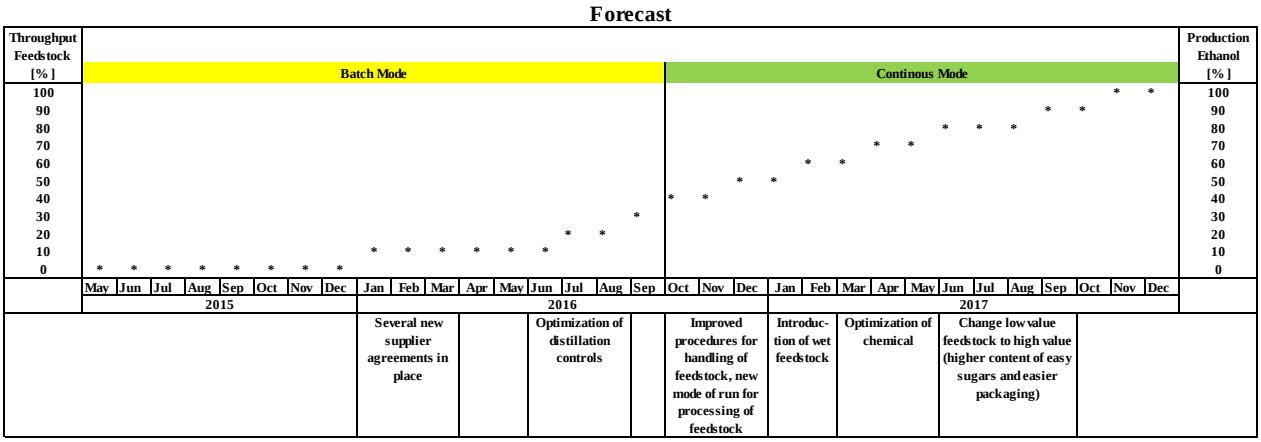


**Figure 8.** Forecast and plans for Etanolix 2.0 during the time period 2015-2017

**Results**

- 330 operational hours of feedstock accumulated to 1275 tons was delivered into the receiving station.
- 15 short distillation campaigns, production time 750 hours, meaning a cumulative ethanol production of 267 m3.
- 9 batches of produced ethanol quality tested according to laboratory analysis program.
- Total production of stillage is 3343 m3 (whereof 1352 m3 have been delivered as animal feed quality).
- The ethanol yield fluctuated during the period but stabilized on 21%.
- Integration into refinery such as water and cooling system, steam, electricity, infrastructure (piping and tank connections), waste water system etc. is functioning as planned.
- Chemical uses are measured by quantity. At this stage, how much has been purchased rather than how much is required in the plant.
- Accumulative waste for the period was 255 tons that have been sent for burning and heat recovery.
- The Etanolix waste water quality has been demonstrated for e.g. pH, suspended solids and this has been proven according to program to ensure adoption in the refinery's biological waste water treatment. Nevertheless, since we are in the early phases of the demonstration period and that the production until now has been irregular (not continuous as planned for) and that only small amounts of waste water were produced compared to the final goal, this area will be an important issue to keep close track of as the demonstration goes forward since it is also linked to the refinery’s environmental permit.
- Environmental parameters e.g. odor has been considered acceptable already at this stage of the demonstration phase. At present, not all environmental parameters such as $CO_2$ and other air emissions have been calculated and measured due to the aforementioned reason under the previous point (i.e. Etanolix waste water quality). The operation must be more frequent and loads higher in order to obtain representative results.