Steamdrying of Beet Pulp,
Larger Units, No Air Pollution, and Large Reduction of CO₂ Emission.

Abstract
The latest years steamdrying of beet pulp has mainly developed in USA, where now 6 large dryer are in operation. The purpose has been energy saving and reduction of pollution. The technology has been developed to larger units and also a dryer with stepwise heating by 2 internal heat exchangers, whereby the power production in the factory is maximized. The world largest steamdryer is in operation at Amalgamated sugar in Idaho, where 83t/h water evaporation has been proved possible in this one dryer. The total project was 16 million US $ including building, conveyors, power supply, piping, etc. In some of the USA states drying in coal fired drum driers is not allowed for pollution reasons.
Steamdrying of the beet pulp does not give any air pollution at all, neither with dust or emission of VOC, and as all the fuel to the alternative drum drying is saved, there is a large reduction of CO₂ emission. So has the steamdryer in Idaho reduced the CO₂ emission by 600 t per day. Compared to most other investments steamdrying of beet pulp gives a much higher reduction of CO₂ per invested million € than most other large investments as for example an ethanol plant.
The beet sugar industry is today closely related to drying of most of the beet pulp though in many European countries this is not considered as a part of the sugar factory itself, as the pulp belongs to the farmers. But the sugar industry has to consider this as a part for the industry that has to be taken care of. If the pulp is not taken care of there will not be produced sugar. The sugar industry in western Europe has reduced the energy consumption over the last decades so in the factory itself there can not be done much more, but by steamdrying of the pulp the fuel consumption, and thereby the CO₂ emission can be reduced by ½ of what a modern effective sugar factory itself consume.
How it works.

The drying takes place in a fluidized bed driven by superheated steam blown up through the pulp. It all takes place under pressure in a pressure vessel also containing a dust separation, a heat exchanger, and a fan.

The pulp is fed through the rotary valve (1) to the screw (2), which brings the pulp into the pressure vessel (3) filled with superheated steam. The only moving part in the dryer is the impeller (4) circulating this steam up through the perforated curved bottom (5) into a low ring shaped fluid bed (6) where the pulp is kept “fluid” swirling around as the arrows show. Guiding plates (not shown) make the pulp move forward in the ring. The lighter particles are blown up between the plates (7) radiating from the heat exchanger 12 outwards towards the conical vessel wall without reaching this. Due to the reduced velocity the particles fall onto the forward inclined plates, slide down on those and pass the gab between the plates and the conical vessel wall. In this way also the lighter particles passes forward around in the dryer and arrives to the discharge screw (8) and will pass the rotary valve (9).

The circulating steam arrives into the upper part of the dryer, where dust is separated in the main cyclone (10). The dust pass by means of an ejector out through the pipe (11) end goes out with the dried product.

The dust free steam goes down inside tubes in the heat exchanger (12) where it is reheated, as steam is supplied through the pipe (13). The supply steam is condensed and leaves the dryer through the pipe 14. By a higher supply steam pressure, a higher temperature of the circulating steam is achieved, and that will again increase the drying potential of the steam, when it again is blown up in the ring shaped fluid bed (6) by the fan (4). Therefore the capacity of the dryer will increase with increased supply pressure.
How does the steamdryer fit into the sugarfactory

Figure 2. The steamdryer is a kind of evaporator placed in front of the juice evaporators. The steam leaving the dryer, which is the water evaporated out of the pulp, goes to the first step of the juice evaporator. Here the steam is used in a separate body as the condensate can not go back to the boilers, but it is good for e.g. freshwater for juice extraction. The clean condensate from the heat exchanger in the dryer shall go back to the boiler house.

As illustrated on figure 2 the drying will take place without air pollution, as the drying takes place in a closed vessel. And the drying does not consume energy, as all supplied energy is reused. There is therefore no increase of consumption of fuel in the boiler house due to the pulp drying. But the power production can go down. The energy in the lost power is not lost; the energy is still there. Only the possibility to convert it from heat in steam into power is lost.

Integration in existing factories.
The figure 2 illustrates how the integration in the sugar factory could be made in a new factory. In existing factories there might not be a steam outtake from the turbine. About the integration in existing factories there are briefly and in general the following to take care of:

- In the boiler house there will not be any changes.
- Power production will be affected more or less. If there is some steam that is reduced in pressure through valves to supply the evaporation, this amount of steam can pass through the drier, and thereby do some drying without causing reduction of power production. Otherwise it will be necessary to take some steam away from the turbine, and thereby reduce the power production. If there the boilers have a high steam pressure (>60 bar) it will probable pay to set up a small new turbine to reduce the steam pressure down to the pressure needed for the drier. (10 – 28 bar). If the power production goes down by 1 MWe, the fuel consumption the boiler house will go down by 1.2 to 1.4 MW.
- The first step of juice evaporators must consist of 2 bodies. If that not already is the case it will be necessary to install a new evaporator for the steam from the dryer.
More than 100% saving of the energy needed for drum drying.

A general rule is that steam drying will give a saving of 95 % of that fuel, which is needed for the same drying in a drum drier. In fact it is theoretically possible to get more saving. Please have a look on the figures 3A and 3B – an example taken from USA.

Figure 3A. Energy flow in a sugar factory with drum drying of pulp.

Figure 3B. Energy flow in a sugar factory with steam drying of pulp.
Figure 3A is an example of energy flow through a sugar factory with power production and drum drying. The numbers show the flow in MW. The energy consumption is high as common in an American sugar factory. In America there is a large need for energy because of frozen beets and many factories have desugarization of molasses which also demand energy. The factory produces 9 MW power in this case fig. 3A and consume 8 MW, so 1 MW is sold. American factories have often a low steam pressure (15 to 28 bar).

Figure 3B shows how it will be with steam drying in stead of drum drying. The evaporation stations receive the same flow of energy as before. The amount of steam directly from the boilers is reduced to a minimum. The steam flow through the turbine is also reduced, so power production has gone down by 3 MW. But the savings are not only the 45 MW that the drum drier use, but even the amount of energy to the boiler house has gone down by 7.2 MW as well.

This 7.2 MW comes from 3 sources:
- Less power production requires less fuel to the boiler house.
- The power supplied to the fan in the drier is recovered in the steam leaving the steam dryer in opposition to drum drying, where all energy supplied is lost.
- The energy in the 50°C hot pulp supplied to the dryer is in the dryer lifted to a higher level, so it can be used in first step of the evaporation.

**Environment.**

The steamdrying of beet pulp takes place in a closed vessel. There is therefore no emission of dust and no direct primary emission of the vapour from the drying. But there can be a secondary emission of VOC and thereby smell, if this is not taken care of. This was one of the subjects at the yearly steamdrier seminar in Copenhagen in 2005 hold by EnerDry for their clients.

The steam leaving the dryer has very little amount of dust, which can be found as suspended solids in the condensate formed by condensing the steam in the evaporator, where the energy is used. This is usually 2 ppm by weight, and never above 10 ppm. The non condensable that leaves the evaporator is dust free, as the mentioned small amount of solids will go into the liquid face and out with the condensate. There is therefore no dust emission at all.

There are 2 ways, where the vapour with VOC can get out. 1) Emission of non condensible gasses. 2) Waste steam from the rotary valves and conveyors.

Most steamdrier installations have/had - especially earlier - the non condensible gasses from the steamdriyer steam going directly out from the evaporator, where the steam is condensed. This should never take place both in order to recover the energy, but also in order to avoid the emission of VOC evaporated from the pulp. The main component in the VOC is acetic acid, there are also other organic acids and some CO. The acetic acids and the other VOC’s are easily dissolvable in water and have a vapour pressure that decreases drastically, when the temperature is brought down. And the vapour pressure is at all temperatures lower then for water. The solution to avoid emission of the VOC is therefore to use the vent from the evaporator at a low temperature, whereby those organic components will end up in the condensate and not in the atmosphere. Alternatively the VOC emission can be removed in a simple small scrubber with cold water. The amount of VOC emission from 50 t/h evaporation in the dryer can thereby be brought down below 25 g C/h out of which the most is coming from CO. This is negligible compared to other emissions from a sugar factory.

The possible smell emission comes mainly from the organic acids, as just explained those will have gone into the water face, if the non condensible gasses are cooled. The amount of non condensable from 50 t/h evaporation -, when cooled to 20 °C - is 100 to 200 m³/h and mainly consisting of N₂. This amount can be sent to the boiler in a 50 mm pipe and burned is so wanted.

The waste steam from the rotary valves should be condensed on the pressed beet pulp in the heating screw for beet pulp going to the dryer. Thereby the emission comes down to the level coming from any other pressed pulp conveyor.
The condensate arising from the dryer vapour can be used for juice extraction. But that does not change the fact, that the factory will have more water going out, which could be condensate from the evaporators. If the steamdryer condensate goes directly out it will increase the BOD load on the water purification plant by the magnitude of 2%.

**Increased production of pellets.**

Drum drying causes a loss of product, as a part of the pulp is burned away or partly burned whereby product is lost. This loss can be very considerable as illustrated on figure 4. The loss is among other things also depending on the inlet temperature in the drum.

![Figure 4.](image)

**The development in USA**

The latest development of the steamdrying has mainly taken place in USA, where now 6 large dryers are installed or under construction. The increasing energy prices and also the demand for non air polluting technology has been the reason for investment in steamdryers in USA.

Since 2003 a steam turbine has been used to drive the large fan in the dryer. The world largest dryer with a capacity of 83 metric tons water evaporated per hour is installed. It has 2 internal super heaters, whereby the reduction of power production is minimised.

**6 Steamdryers in USA**

The first 2 steam driers in USA were commissioned in 1999 in Minnesota at the SMBSC factory. The dryers were supplied by Niro A/S, but in 2004 internal parts were exchanges by EnerDry in order to bring the capacity up to wanted level. In 2003 the steam dryer at the Minn-Dak Farmers factory in Wahpeton, North Dakota was started. The factory has only 17 bar steam available and does not make its own electricity. All larger drives in the factory are turbines. The smaller drives are electrical motors. It was therefore obvious to have the dryer driven by a turbine placed on the ground underneath the dryer. The transmission was done through an angle gearbox to the vertical shaft on the fan.
<table>
<thead>
<tr>
<th>Company</th>
<th>State</th>
<th>Dryer</th>
<th>Supplier</th>
<th>Nominal capacity</th>
<th>Used capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMBCS</td>
<td>Minnesota</td>
<td>2 x size 10</td>
<td>Niro 1999, Rebuilt by EnerDry 2004</td>
<td>2 x 40 t/h</td>
<td>2 x 40 t/h</td>
</tr>
<tr>
<td>Minn-Dak Farmers</td>
<td>North Dakota</td>
<td>Size H</td>
<td>EnerDry 2003</td>
<td>50 t/h</td>
<td>40 t/h</td>
</tr>
<tr>
<td>Amalgamated Nampa</td>
<td>Idaho</td>
<td>Size J</td>
<td>EnerDry 2006</td>
<td>71 t/h</td>
<td>73 t/h</td>
</tr>
<tr>
<td>Michigan Bay City</td>
<td>Michigan</td>
<td>Size H</td>
<td>EnerDry 2006</td>
<td>50 t/h</td>
<td>38 t/h</td>
</tr>
<tr>
<td>American Crystal</td>
<td>Minnesota</td>
<td>Size H</td>
<td>EnerDry 2007</td>
<td>50 t/h</td>
<td>45 t/h</td>
</tr>
</tbody>
</table>

The Amalgamated drying project in Nampa.

The Nampa sugar factory in Idaho slices 11000 t/day (metric) in approx 120 days. There is made 900 ton sugar per day the remaining sugar is stored as thick juice. The factory has also a molasses desugarization plant producing sugar and crystalline betaine from molasses. That gives also a need for concentration of raffinate. The factory has both 28 and 14 bar boilers. As many other American factories the factory has still a wide use of steam turbines in stead of the larger motors. The pulp pressing is only to 24% DS, so the need for drying is more that 70 t/h evaporation. It was decided to install a dryer size J with a guaranteed capacity of 71 t/h evaporation.

![Figure 5 The steam system in Nampa Sugar Factory.](image)

The main part of the power produced in the factory is produced by the 28 bar steam. In order to keep maximum power production it was decided to make the dryer with 2 super heaters. An upper one for the 14 bar steam and a lower one for the 28 bar steam. The steam system can be seen on
The flash steam from the 28 bar system goes to the 14 bar system, and this condensate does not yet go back to the boiler without flashing, but will do so in the future. In this way it was possible to keep a good power production. The production was reduced by 4 MW the first year, but the reduction will only be 2.5 MW, when the last changes in the steam system will be made. This reduction of power production shall be seen on the background of a saving of 62 MW as fuel out of which a modern power plant could make 30 MW electrical power. On the diagram it should also be noted that the steam from the dryer is used one time more than in most steamdrying projects. The steam goes from the dryer to an evaporator for concentration of raffinate and the vapour from that evaporator goes to the first step of the juice concentration plant.

The Nampa dryer has a top diameter of 12.4 m. With this size it has been possible to make the drier with the world largest drying capacity within this relatively small diameter. As mentioned before the drying capacity was guaranteed to be 71 t/h with only 400 psi (28 bar), but on the first week of operation the dryer went right up to 73 t/h evaporation using more than half of the steam from the 200 psi (14 bar) steam system, and the remaining steam supply came from 400 psi (28 bar) system. There was neither pulp enough nor steam available to go higher. From the temperatures measured in the dryer it is possible to calculate the max. capacity to be 83 t/h evaporation (metric). This high capacity is only possible by a high circulation of steam in the dryer, and that is only possible with the fluid bed design and dust separation patented by EnerDry.
<table>
<thead>
<tr>
<th></th>
<th>Steam supply</th>
<th>Pulp in</th>
<th>Pulp out</th>
<th>Evap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guarantee</td>
<td>200/400 psi</td>
<td></td>
<td></td>
<td>67 t/h</td>
</tr>
<tr>
<td>Guarantee</td>
<td>400/400 psi</td>
<td></td>
<td></td>
<td>71 t/h</td>
</tr>
<tr>
<td>Average 24h</td>
<td>195/360 psi</td>
<td>99 t/h</td>
<td>26 t/h</td>
<td>73 t/h</td>
</tr>
<tr>
<td>14 Febr. 2007</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated max Capacity</td>
<td>200/400 psi</td>
<td>111 t/h</td>
<td>28 t/h</td>
<td>83 t/h</td>
</tr>
</tbody>
</table>

Table for size J evaporation capacities in Nampa.

In USA it is common to operate on frozen or partly frozen beets. That gives a very big variation in particle size having a lot of large pieces, which can not be dried properly in the dryers of the earlier design. The large pieces will in the earlier design come out with 40 to 60 % DS. Therefore the remaining pulp has to be dried to a higher DS in order to make the average on 90% DS. Thereby the dryer looses a lot of its capacity, and in worst case it is not able to get 90% DS in average. The EnerDry drier handle this by holding the coarse particles back by a method protected by another patent.

Another important thing by designing a steam dryer is have the finer particles (not the dust) dried properly. This takes places in the conical part of the drier, where about 40 % of the pulp is dried. If this fraction is not taken care of, it will go out not properly dried or go into the dusts separation and create problems there. Therefore the conical part is necessary.

The steam dryer in Nampa replaces 3 old coal fired drum driers from the 1950’s. Major maintenance and a reduction of the environment impact were necessary. To fulfil the demands from the environment authorities it was decided have the steam dryer installed, which at the same time could give a daily saving on 200 t coal and an increased production of pellets as there would no more be burned product away. That would give a yearly saving of 2 mill $. The coal in USA is cheap compared to Europe. The project was an investment of 16,5 million $ (10,6 million € with the $/€ rate March 2008). That covers all costs for the total project inclusive building, conveyors, piping, electrical installations etc. The project was very well received by the public expressed as positive publicity in television and newspapers.

Figure 7. The dryer in Nampa under erection.
Steamdrying of beet pulp in Europe.

There are 10 steamdryers for beet pulp in operation in Europe. Most of them were installed in the mid 1990’es. Two of the oldest and smallest are installed in France. Many are installed in the former DDR in Germany, where all dried pulp is dried in Steamdryers. The interest for steamdrying in Europe is going up again for different reasons. 1) The heavy increase in energy prises. 2) Increasing demand for reduction of CO\(_2\) emission. 3) Demand for reduction of emission of dust. 4) Coming demand for reduction of smell and VOC. 5) After the change of the regulation of the European Sugar Market there is beginning investments in the remaining factories.

The sugar industry in most countries has the obligation to reduce the CO\(_2\) emission by so far 20%. In some countries the pulp drying is considered as a part of the factory, in other countries not. If the pulp drying is considered as a part of the factory it is easy to reduce the CO\(_2\) emission simply by introducing steamdrying. But the sugar factories must realise that even if the factory itself is not directly responsible for the drying, this drying is a result of the sugar production and the drying is a necessity what concerns the main part of the pulp, which can not be used wet.

Energy consumption in the factory itself (without energy for pulp drying) has improved a lot over the last 30 years by intelligent development done in this industry in West Europe. Over the years the fuel consumption has been reduced from 250 kWh/ton beet to now around 170 kWh/ton. It is now difficult to improve further, but if all pulp is dried in drum driers this drying consumes around 90 kWh/ton beet, whereby the total comes up on 260 kWh. The potential for energy saving, and correspondent reduction of CO\(_2\) emission, is to find by steamdrying of the pulp. There exists already a factory that in average for a week has proved a consumption of only 157 kWh/ton beet drying 75% of the pulp (25% of the pulp was sold as wet pressed pulp) producing all the electrical power the factory needs.
Steamdrying of other products.

There are 2 steamdryers in Sweden. One for drying woodchips in a utility for district heating and power production, where the woodchips are steam dried before they go to the boilers. Another one dries bark to be pressed to pellets and sold for fuel.

A steamdryer has I USA been tested for drying of DDGS from ethanol production of corn. The DDGS has another structure, and a very short drying time, so the parameters for operation are different. Drying time for beet pulp is 3 – 5 minutes. The DDGS is dry in far less that one minute. But to design a dryer for low retention time is much easier than to design a dryer for high retention time. By steamdrying the DDGS the total fuel energy consumption in the DDGS plant can be reduced from 33000 BTU per gallon ethanol to 19000 BTU per Gallon. This corresponds to a reduction from 9156 to 5271 kJ/litre ethanol.

Economy.

The steam drier size H installation at Minn-Dak Farmers in North Dakota in 2003 was 9,3 mill US $ (Less then 6 mill € with the today €/$ rate). That covered a complete installation including building, piping, conveyors, juice evaporator, extension of the existing pelletising installation, engineering etc. As already mentioned the complete project for the size J (71 t/h evaporation) drier in 2006 was 16,5 million $ (10,6 mill €).

A budget for a size H (50 t/h evap.) in Europe could typically be so:

- Dryer ex works: 4,3 mill €
- Transport and erection 1,2 mill €
- Evaporator 1 mill €
- Building 1,2 mill €
- Piping and conveyors 1,8 mill €
- Various 1 mill €
- Total 10,5 mill €

Gain by steamdrying (example)

Size H has a capacity of 50 t/h evaporation. It is assumed that the factory with a slice of 10 000 t/day in average will need an evaporation of 45 t/h in 100 days. If the steamdryer replaces a gas fired drum drier with a gas price of 29 €/MWh. It is assumed that the power production is reduced by 3 MW and the power to be bought costs 70 €/MWh. This less power production will save approx. 3,6 MW gas. As no pulp is burned away the production of pellets will go up by 1,5 t/h. (Assumed 6% loss in the alternative drum drying). The pellet price is set to 180 € per ton.

Saving on gas. 45000x3000/3600/1000 =37,50 MW
Per year: 37,5x29x24x100 = 2,61 mill €
No pulp burning 1,5x100x24x180 = 0,65 mill €
Saving on labour and maintenance 0,20 mill €
Total 3,46 mill €
Lost power production. (70x3 – 3,6x29)x24x100 = -0,25 mill €
Net gain per 100 day campaign 3,21 mill €
Pulp pressing.

<table>
<thead>
<tr>
<th>Number of presses</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed [rpm]</td>
<td>2.95</td>
<td>2.05</td>
<td>1.47</td>
<td>1.13</td>
<td>0.8</td>
</tr>
<tr>
<td>DS [%] (5% on beet)</td>
<td>26.3</td>
<td>28.7</td>
<td>30.3</td>
<td>31.6</td>
<td>32.3</td>
</tr>
<tr>
<td>DS kg/hr (marc + dissolved)</td>
<td>20833</td>
<td>20833</td>
<td>20833</td>
<td>20833</td>
<td>20833</td>
</tr>
<tr>
<td>Pressed pulp [kg/h]</td>
<td>79213</td>
<td>72589</td>
<td>68758</td>
<td>68137</td>
<td>64498</td>
</tr>
<tr>
<td>Pallets [kg/h] (90% DS)</td>
<td>23148</td>
<td>23148</td>
<td>23148</td>
<td>23148</td>
<td>23148</td>
</tr>
<tr>
<td>To evaporate [kg/h]</td>
<td>56005</td>
<td>49441</td>
<td>45808</td>
<td>42669</td>
<td>41350</td>
</tr>
<tr>
<td>Water removed for 1 press [kg/h]</td>
<td>6024</td>
<td>3833</td>
<td>2619</td>
<td>1630</td>
<td></td>
</tr>
<tr>
<td>Price install Stord 2500</td>
<td>1300 k€</td>
<td>1300 k€</td>
<td>1300 k€</td>
<td>1300 k€</td>
<td>1300 k€</td>
</tr>
<tr>
<td>Investment per 1 t/h more water out</td>
<td>195 k€</td>
<td>319 k€</td>
<td>495 k€</td>
<td>793 k€</td>
<td></td>
</tr>
</tbody>
</table>

Dewatering of the pulp starts by pressing the pulp in the twin screw presses followed by the drying. It is well known that lower rpm of the spindles in the presses gives higher dry substance but lower capacity of the press. That means that installation of more presses will reduce the needed dryer capacity. Where is the optimum?

Table showing pulp pressing to different dry substance.

By using the data sheet for Stord press 2500 a table is up set for the gain by installing different number of presses. The numbers refer to a sugar factory slicing 10 000 t/day beets. A reasonable pressing can be achieved with 4 presses (26.3%DS). One by one the number of presses can be increased, and the pressing improved. The first steps gives much more water pressed out then the later steps.

A press costs 600 000 €. To that comes the drive, and all the installation costs, so the total could be 1,3 mill € for an installed press. If the number of presses is increased from 4 to 5 there will be pressed 6,624 t/h more water pressed out for the investment of 1,3 mill €. The investment is 196000 € for 1 t/h more water presses out. If the number of presses is increased from 7 to 8 there shall be invested 793000 € for having 1 additional ton water pressed out. This can be compared to the investment in a complete steamdryer installation size H for 10 mill. € having an evaporation of 50 t/h. That is a cost of 200 000 € per ton evaporated. The conclusion is that the pulp should be pressed to about 28% DS. It will be cheaper to do steamdrying then to press the pulp above 28%.

There can also be made an optimisation based on use of electrical power and maintenance costs. The optimum DS will be lower then 28%DS

Pulp as Fuel.

Steamdrying of the beet pulp could be the first step towards a sugar factory operates on its own beet pulp. Thereby the sugar factory operation will be CO₂ neutral like the cane sugar factories.

The dried beet pulp has the lower heat value of 17000 kJ per kg. The pulp has less sand than lignite and less sulphur. The amount of K and Na salts is low as it has just been “washed” by the extraction, which gives much less risk for scaling in the boiler.

Figure 10. Sugar factory steam drying and combustion of all beet pulp.

The power production is based on:
10 000 t beets per day.
All pulp is burned in the boiler.
Boilers produce 85 bar steam at 525°C.
Boiler efficiency 88%
Isentropic efficiency of turbine 85%
Efficiency of gear and generator 95%
The condenser temp is as high as 60°C.
Lower condenser temperature could increase the power production.
Beet pulp to 180 €/t corresponds to a fuel oil price of 425 € per ton of oil, or a gas price of 38,2 €/MWh. For the time being it is therefore not interesting to burn the pulp, as it was one or two years ago. Other bio fuels such as straw or woodchips may be cheaper, but the beet pulp is in the factory. It needs no transportation or a large store, and costs for granulation and marketing is saved. On the other hand there will be capital costs to pay for such a project.

**Energy saving and reduction of CO₂ emission.**

The steamdryer in Nampa reduces the combustion of coal by 200 ton per day. Thereby the emission of CO₂ is reduced by approx. 600 ton per day. This can be compared to other investment for reducing the CO₂ emission like an ethanol factory or windmill park.

By using ethanol in the cars in stead of gasoline the net CO₂ emission is reduced as the growing of the corn or the wheat will absorb CO₂. But there is spend fuel for the tractors in the fields and for transportation as well as fuel for the steam boilers in the ethanol plant.

There can also be invested in windmills. For 10 mill € there can be installed 4 large windmills with the installed capacity of 4 x 2,0 MW. They will in average over a year produce 20% of the installed capacity. Those 4 windmills will cost 12 mill € installed.

Those three possibilities to reduce CO₂ emission is compared in the table below, where the CO₂ reduction also is related to the investment.

<table>
<thead>
<tr>
<th>Nampa Steam dryer</th>
<th>An ethanol factory on wheat</th>
<th>4 x 2 MW windmills</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 t/day coal not fired</td>
<td>Production: 8000 hl/day = 21000 gallon/day</td>
<td>Average production 23 % = 1,8 MW.</td>
</tr>
<tr>
<td>600 t/day CO₂ emission avoided in 120 days per year.</td>
<td>Avoided CO₂ emission: 1200 t/day</td>
<td>A coal fired power plant will need 3,8 MW as fuel. Which corresponds to: 500 kg coal per hour, (27250 kJ/kg)</td>
</tr>
<tr>
<td></td>
<td>CO₂ emission from cultivation -250 t/day</td>
<td>Avoided CO₂ emission: 1500 kg/h = 36 t/day</td>
</tr>
<tr>
<td></td>
<td>CO₂ Steam boilers (487-789): -600 t/day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Net CO₂ reduction 350 t/day</td>
<td>In 340 days a year</td>
</tr>
<tr>
<td></td>
<td>In 340 days a year</td>
<td>Average production 23 % = 1,8 MW.</td>
</tr>
<tr>
<td>72 000 t CO₂ reduction per year.</td>
<td>119 000 t CO₂ reduction per year.</td>
<td>13 000 t CO₂ reduction per year.</td>
</tr>
<tr>
<td>No in-going product</td>
<td>2200 tons / day corn or wheat is used. 700 tons / day DDGS is produced.</td>
<td>No in-going product</td>
</tr>
<tr>
<td>Investment: 10,6 million €</td>
<td>Investment: 200 million €</td>
<td>Investment: 12 million €</td>
</tr>
<tr>
<td>6792 t yearly CO₂ reduction per million € invested</td>
<td>595 t yearly CO₂ reduction per million € invested</td>
<td>1083 t yearly CO₂ reduction per million € invested</td>
</tr>
</tbody>
</table>

The table shows the CO₂ reduction for the Nampa steamdryer, an ethanol factory, and windmills related to the investment.

**Conclusion:**
- Up to 83 ton water evaporation in one drier.
- 6 large steam dryers in operation in USA.
- 100% saving of fuel for drum drying is theoretical possible.
- 2 super heaters make more power production possible.
- Zero emission of dust, VOC and smell.
- Steamdrying takes less investment per ton water removed than pressing pulp over 28% DS.
- More reduction of CO₂ emission then by most other investments.