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German Notes on BAT for the production of

Large Volume Solid Inorganic Chemicals

Urea

Final report

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Summary

This document comprises the contribution of Germany to the exchange of information in the European Union on the use of Best Available Techniques (BAT) to control the environmental impact of industrial processes and describes the production of urea.

This German report provides information on technology for urea production to reduce environmental impact for the drafting of a European BAT – Reference document. It is based on a survey of the available literature and on information from the concerned industry, which include three producers in Germany for urea and the competent authorities.

The report describes the available techniques used in Germany in three existing plant for urea production. The reported standards of these existing plants are meant as information to be used in the process of information exchange and does not include conclusions of the German government with regard to techniques that are considered as BAT for new production plants.

As a summary of the available information about urea production a general consideration of best available techniques should include following basic facts:

- Dust (particulate urea) and ammonia are main components of emissions arising from urea production, which can be released with waste gases and waste water as well. Urea synthesis is also a source of process water. Solid waste is not a relevant release of this type of production unit.
- Main sources of gaseous and particulate matter emissions are prilling and granulation units.
- Available reduction measures for dust removal from different sources within the plant are dry dust collectors and electrostatic precipitators. But most effective measures for dust removal and ammonia as well is a wet scrubbing system, which is able to achieve emission values of 20 mg/m^3 for ammonia and 20 mg/m^3 for dust under acidic conditions.
- In the case of neutral wet scrubbing systems the scrubbing solution can be recycled to the urea production process, which can not be done in the case of acidic scrubbing solutions. A further use of ammonium nitrate containing scrubbing solutions is possible in fertilizer production units at the same site.
- Main sources of aqueous effluents are process water and solutions from waste gas treatment by washing units. There are different opportunities to handle these effluents. These can be recycled back to the urea production process but can

also be partially used in other production plants at the site, for instance in the liquid fertilizer production or in the glue production. In the case of discharges into the process water treatment unit, urea, NH_3 and CO_2 are to be separated for recycling of these off – gases into the urea synthesis and final biological waste water treatment.

This short presentation of focal points do not intend to be applied straightaway but may be a reference, what can be achieved in general in this sector referring the main release sources for urea production. As can be written in this report the existing plants in Germany does not reach the emission values for dust and ammonia in waste gas mentioned above currently. But these standards can be considered in the case of significant changes of existing plants and for newly built plants.

1 General Information

The use of urea as a fertilizer developed rather slowly at first. It has, however, become the most popular solid nitrogen fertilizer in the world, since it is known that it can preferably be used for flooded rice. The biggest demand for urea is now concentrated in Asia. The annual production on a worldwide basis has increased by about 30 mio. tons in the last 10 years and amounts to more than 100 mio. tons/year now.

Urea is also used as a cattle feed supplement, where it is a cheap source of protein. Moreover it is the feed material for melamine plastic and for various glues. The main German suppliers of urea are the following:

Table 1: Main German Suppliers of Urea, Production Capacities and Techniques

Supplier	Location	Capacity	Production Technology
BASF AG	Ludwigshafen	about 1.600 t/d	Total Recycle Technology
SKW Piesteritz GmbH	Lutherstadt Wittenberg	about 3.150 t/d	CO_2-Stripping
Hydro Agri GmbH	Brunsbüttel	about 1.000 t/d	NH_3-Stripping

2 Production Processes in Germany

2.1 Chemical Basis

The commercial synthesis of urea is based on liquid ammonia and carbon dioxide, which are formed at high pressure to ammonium carbamate (NH_2COONH_4) in a first step. In a second step ammonium carbamate is dehydrated by the application of heat to obtain urea and water.

$$(1) \quad \underset{\text{ammonium}}{2\,NH_3} + \underset{\text{carbon dioxide}}{CO_2} \longleftrightarrow \underset{\text{ammonium carbamate}}{NH_2COONH_4} \quad (\Delta H = -135\text{kJ/mol})$$

$$(2) \quad \underset{\text{ammonium carbamate}}{NH_2COONH_4} \longleftrightarrow \underset{\text{urea}}{H_2NCONH_2} + \underset{\text{water}}{H_2O} \quad (\Delta H = 16\text{ kJ/mol})$$

Boths reactions take place in the liquid phase in the same reactor and are equilibrium reactions. The yield depends on various operating conditions, which can be summarized as follows:

1. At a temperature of 170 °C and a pressure of 150 bar the conversion of ammonia and carbon dioxide to ammonia carbamate (1st reaction) is fast and complete, whereas the subsequent endothermic conversion to urea and water (2nd reaction) is slower and incomplete. An acceptable reaction velocity can only be achieved at a temperature of > 160 °C.
2. The formed intermediate product ammonia carbamate is in balance with urea and water (2nd reaction). In the beginning of the process a small amount of water supports the conversion from ammonia carbamate into urea and water, because it forms a liquid phase. In the following the presence of water decreases the conversion into urea and water. With an increasing amount of process water the conversion rate decreases according to reaction 2.
3. An important influence for the formation of urea is the mole ratio of NH_3 : $CO_{2.}$ An excess of NH_3 favors the conversion into ammonia carbamate, whereas an excess of CO_2 hardly provokes any further rate of reaction. Consequently either an important volume of NH_3 has to be recycled or the production of side products must be incorporated. By the help of a mole ratio of NH_3 : CO_2 of 2,5 to 4 a conversion rate of 60 – 70 % (in relation to the CO_2–input) can be realized.

The most typical production conditions can be summarized as follows:

Table 2: Typical Operating Conditions of the Urea Production

Parameter	Value
Pressure:	140 – 250 atm
Temperature:	180 – 210 °C
NH_3:CO_2-mole ratio:	2,8:1 - 4:1
Retention time:	20 – 30 minutes

Based on the reaction and kinetic conditions a mixture of NH_3, ammonia carbamate, water and urea is formed. Consequently the main problems in the production of urea are the following:

- Separation of urea,
- recycling of excess NH_3 ,
- decomposition of ammonia carbamate for the recovery of NH_3 and CO_2 .

As a side reaction urea is sometimes converted at high temperatures into biuret, which can be toxic for some kind of plants.

$$(3) \qquad \underset{\text{Urea}}{2\ H_2NCONH_2} \longrightarrow \underset{\text{Biuret}}{H_2NCONHCONH_2} + NH_3$$

Furtheron new developments in process technology related to the production of urea concentrate of the choice on improved materials, in order to minimize corrosion caused by ammonia carbamate solutions and to optimize the heat and energy balances.

2.2 General Basis of the Production Processes

The production of urea from ammonia and carbon dioxide can be divided into 4 principal procedures:

- Synthesis of urea (high-pressure synthesis section)
- Separation of unconverted NH_3 and CO_2 from urea (low-pressure synthesis section)
- Concentration of urea
- Conversion of the urea melt to the final product (prills or granular products)

Since the synthesis conditions as well as the processing of the urea melt are virtually uniform for the numerous technical procedure variations of the urea production, these differ above all in the type of separation and the recovery of unconverted ammonia and carbon dioxide. The separation of ammonium carbamate takes place after the following equation:

$$(4) \quad \underset{\text{Ammonium Carbamate}}{NH_2CO_2NH_4} \longrightarrow \underset{\text{Carbon Dioxide}}{CO_2} + \underset{\text{Ammonia}}{2\,NH_3}$$

The reaction is the reversal of the first step of the synthesis and strongly endothermic. The decomposition is reached by different combinations of heat, pressure reduction and stripping. The present procedures are distinguished in :

- Total Recycle Technology and
- Stripping Technology.

For the separation of urea from the other residual materials of the liquid phase, the Total Recycle Technology uses the reaction melt to reversibly transfer all components besides urea into the gas phase by pressure reduction. In case of Stripping Technology the partial pressure of the input materials is decreased in the liquid phase and consequently the balance moves in favour to the input materials. Therefore the outflow of the urea reactor is led under synthesis pressure in countercurrent to NH_3 (Snam-Progetti-Technology) or CO_2 (Stamicarbon-Technology). Because the unconverted materials are not decompressed and consequently do not have to be compressed again, the stripping technology causes reduced energy costs and investments.

2.3 Total Recycle Technology

2.3.1 Production Process

The Total Recycle Technology belongs to the conventional recycling processes with almost complete recovery of the materials. The molar ratio of NH_3 : CO_2 is 4:1 at the inflow of the reactor. About 65 – 67 % of the CO_2-input is converted to urea.

The block flow diagram of the urea production by means of the Toyo technology, as used at BASF Ludwigshafen, is shown in **figure 1**. At first ammonia and carbon dioxide are compressed to approximately 200 bar. Then they are led into the reactor, where they are converted into carbamate and urea. The obtained solution is now decompressed in 3 steps to 16 – 20 bar, 3 bar and 1 bar. This takes place in 3 decomposers, where the surplus ammonia and the residual carbamate are separated by heat destillation.

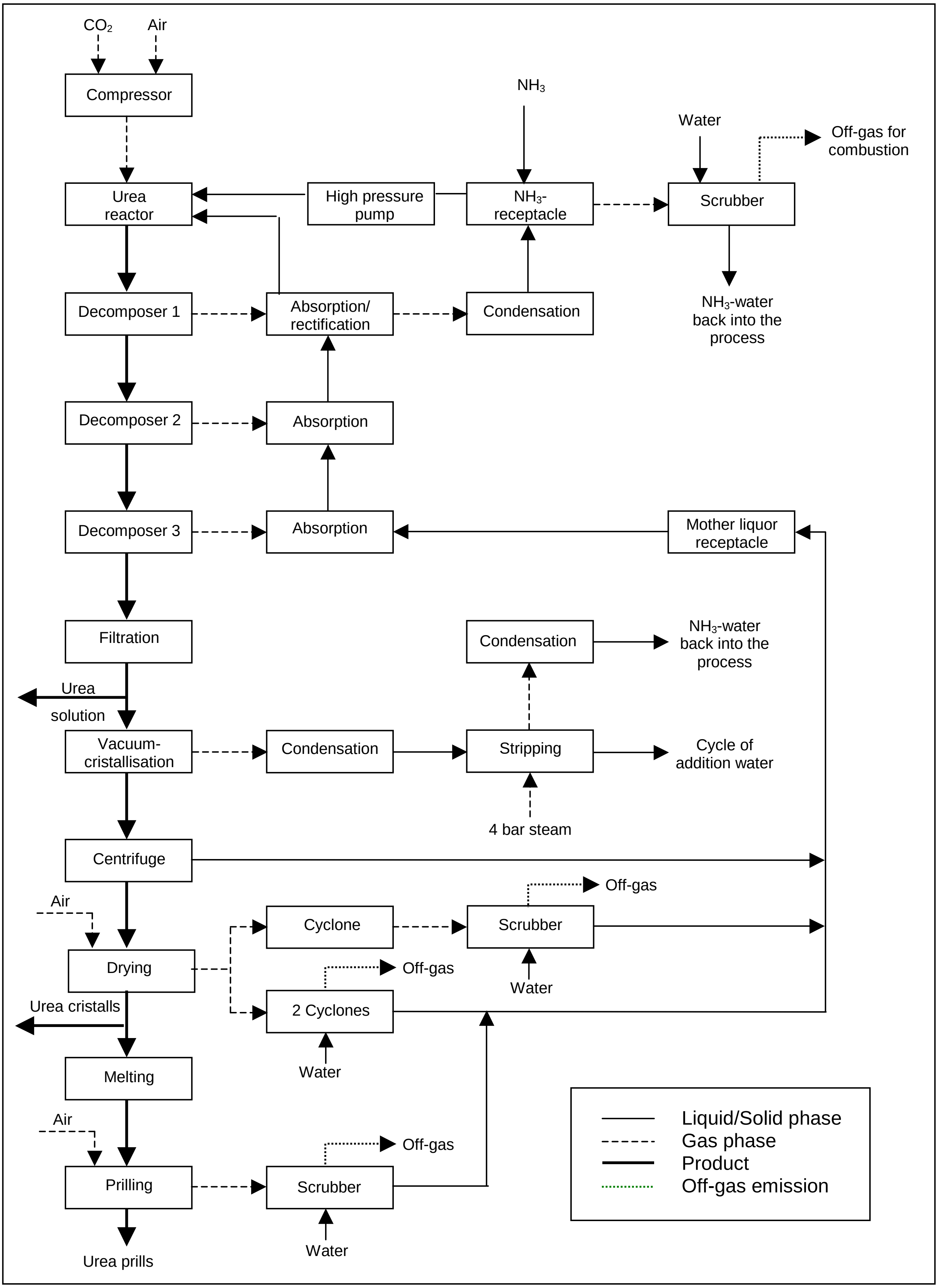

Figure 1: Total Recycle Technology

The mixture is absorbed in mother liquor by different pressure steps, in the last absorber step ammonia is separated from the carbamante solution by rectification. The carbamate solution is led back directly into the reactor, while the obtained pure ammonia is liquefied by condensation and is returned into the process. Inert gas, like CO, H_2, CH_4 or Ar, and other components of the air besides ammonia leave the receptacle and are transferred to a NH_3 washer and then to a combustion plant. The ammonia water is led back into the process.

The urea solution from the decomposer 3 is filtered and is either used directly in this form for the production of different products or is converted to solid urea. Therefore the solution is firstly evaporized and then crystallized. Afterwards the product is centrifuged and is dried with hot air. A part of the dried product leaves the process and can be used for different industrial applications. Due to the fact that the relatively small residual crystals - mostly in needle form - cannot be stored or transported, they are converted into so-called prills. These are liquid droplets which solidify and cool on free fall through the tower against a forced or natural up-draft of ambient air. They are removed from the tower base, led into a fluidized-bed-cooler, where they leave the process as final product.

The steam of the vacuum crystallization is condensed. The condensate is led to a steam stripping, in order to eliminate ammonia as far as possible. The treated slightly alcaline water is used as additional water for the cooling cycle, which operates at pH-values between 8 and 9. The resdiual ammonia is condensed as ammonia water and is led back into the process.

The water from the centrifuge is transferred to the mother liquor receptacle and then into the exhaust gas absorbers of the 3 decomposer steps. The exhaust air from the dryer is led over 3 cyclones. Water is added into 2 of the cyclones, in order to minimize dust emissions. An off-gas scrubber is installed behind the third cyclone. The exhaust air of the prill tower is also cleaned by means of scrubbing. The wash waters are returned across the mother liquor receptacle into the process again.

2.3.2 Emission Data and Energy Demands

2.3.2.1 Waste Water Emissions

In the frame of an internal program for reducing nitrogen emissions into the Rhine, BASF took all possible measures related to the synthesis of urea, in order to minimize the effluent volume as far as possible. Wash waters from the different off-gas scrubbers are therefore recycled and led back into the process.

A disadvantage of the wash water recycling, however, is a higher specific energy consumption, because due to the higher water share the conversion into urea decreases (see reaction equation no.2). In order to reach nevertheless high volumes of final products, the recovery of NH_3 and CO_2 is increased, which results in higher energy demands.

The reaction water from the synthesis leaves the production process as follows:

1. An urea solution is handed over for the glue production.
2. Water from the vacuum crystallization is pretreated by stripping, so that it can be used for the cooling tower.

No waste water is discharged into the sewage system.

2.3.2.2 Exhaust Air Emissions

The essential emission sources from the urea synthesis of the BASF are the following (see figure 1):

- Decomposition of carbamate,
- urea drying with air,
- prilling

Besides residual NH_3 from the input-gases the exhaust air from the carbamate conversion essentially contains inert-gases as well as oxygen from the input-air of the synthesis. It is not discharged into the atmosphere, but it is led to a combustion plant. The emission data of the urea drying and the prilling process are summarized in **table 3**. By the use of reaction water from the vacuum crystallization as addition water for the cooling tower, residual NH_3 can be stripped out. **Figure 2** shows the emissions of BASF classified with respect to the different process steps of the urea synthesis.

Table 3: Emission Data of the BASF Urea Manufacturing *

	NH_3		Dust	
	[g/t product]	[mg/m³]	[g/t product]	[mg/m³]
Urea drying				
Installation 1+2 (cyclone)	90 2)	60 1)	30 2)	20 1)
Installation 3 (cyclone+washers)	55 4)	35 3)	30 4)	20 3)
Prilling	600 – 700 5)	30 1)	1.000 – 1.300 5)	55 1)

* The stated values refer to the effective part streams in each case.

1) Measurement/Emission declaration (average half hour value)
2) Calculated on the basis of the concentration (mg/m^3) and the technical capacity
3) Admitted value (new part of the plant)
4) Calculated on the basis of the admitted concentration (mg/m^3) and the technical capacity
5) Calculated on the basis of the concentration (mg/m^3) and the production volume incl. typical oscillations in the measurement and the production

2.3.2.3 Energy Consumption

For the decomposition of carbamate, heat must be supplied in order to reach a sufficient yield. On the other hand, cooling is necessary for the NH_3 and CO_2-adsorption. The generated heat is used for the crystallization and preevaporation.

Altogether, a steam volume of 1,3 t per ton of urea is supplied to the process, a median value over all urea products. For the evaluation of the specific steam consumption it has to be considered, that BASF Ludwigshafen drives a gas and steam turbine power plant. Consequently electricity and steam can be generated with a relatively low demand of primary energy and can be used in all facilities of the chemical location.

The CO_2 is condensed electrically. The energy demand lies around 70 kWh_{el} per ton of urea without the CO_2-condensator.

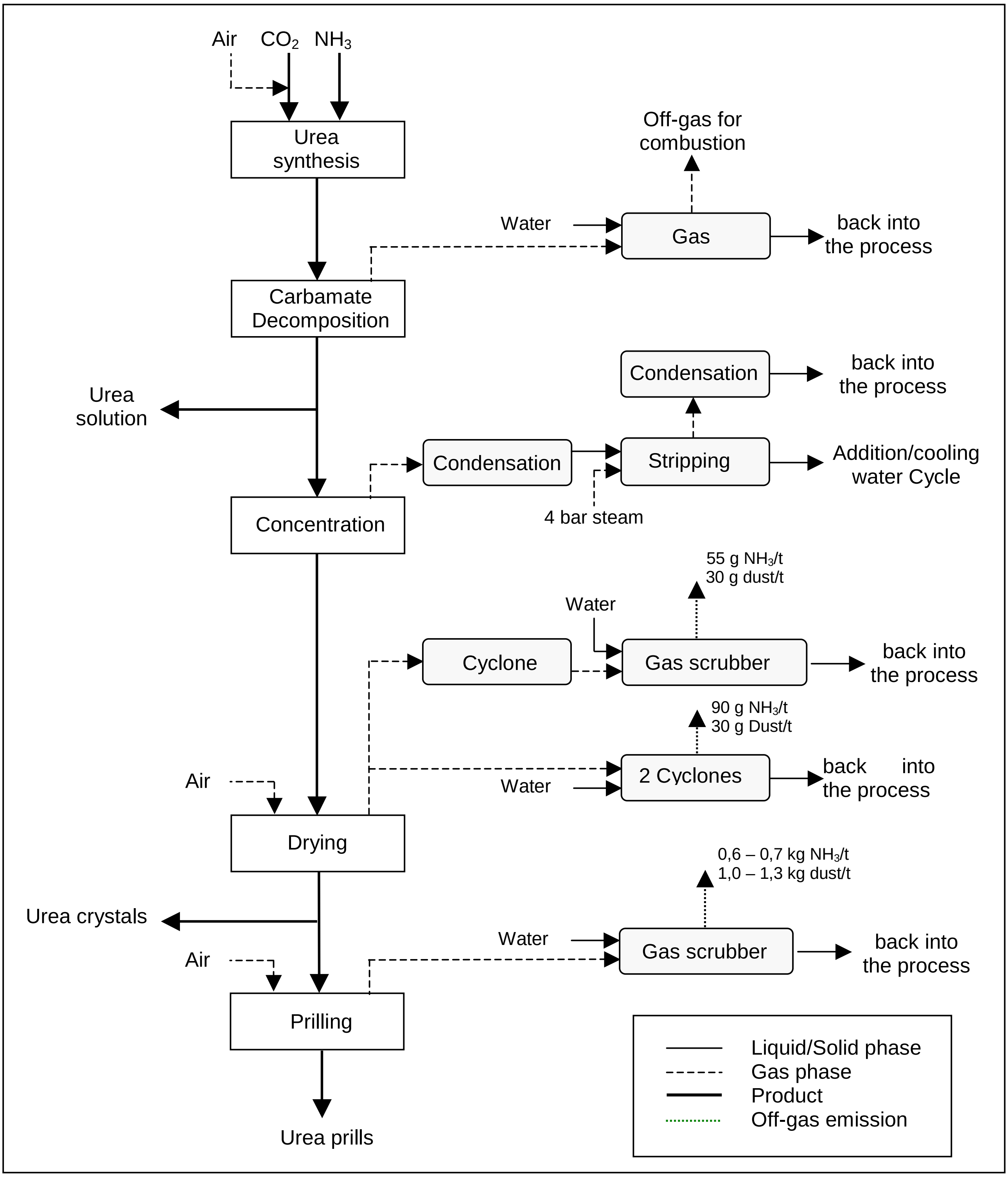

Figure 2: Emission Sources and Typical Volumes of the Total Recycle Technology

2.4 CO_2 Stripping Technology

2.4.1 Production Process

The CO_2 Stripping Technology of Stamicarbon has continuously been developed and adapted to the individual location structures. Meanwhile it is the most used procedure world-wide. Approximately 50 % of the annual world production are based on this technology. **Figure 3** shows the block scheme of the urea production of SKW Piesteritz GmbH in Wittenberg.

In the synthesis reactor ammonia and carbon-dioxyde are converted into urea at 140 bar and 180 °C and with a molar ratio of $NH_3 : CO_2$ of 2,8. Then the reaction melt is fed into a high pressure stripper, where the biggest part of the residual carbamate is separated by the help of CO_2 and indirect energy supply. In order to avoid corrosion air is added to the CO_2. In the following the gas phase of the stripper is led into a high pressure condensator, where it condenses with ammonia to a carbamate solution. The residual gases of the synthesis reactor are discharged into a high pressure condenser, where the gas together with a part of the condensed carbamateNH_3-solution is condensed from the low pressure rectification. Afterwards, the gas is decompressed from 140 bar to 4 bar. In a low pressure washer it is cleaned by the help of an low concentrated condensate from the ammonia water receptacle, before it is discharged into the atmosphere.

The reaction melt is decompressed from 140 bar to 3 bar and then separated in a low pressure decomposer from carbamate and other input-materials. The off-gas is condensed and after a pressure increase it is led into a high pressure washer and a high pressure condensator. From the low pressure rectification the urea solution is fed into a decomposer, where carbamate is disintegrated under vacuum. A 72 – 75 % urea solution is led into the receptacle. Then the urea melt is crystallized at the plant of SKW Piesteritz, through which the content of Biuret in the obtained urea can be minimized. Therefore the urea solution is pumped into the mother liquor receptacle, from where the evaporation is fed. A vacuum cristallization is also driven from this receptacle. A minor stream with a Biuret solution is finally led back into the process.

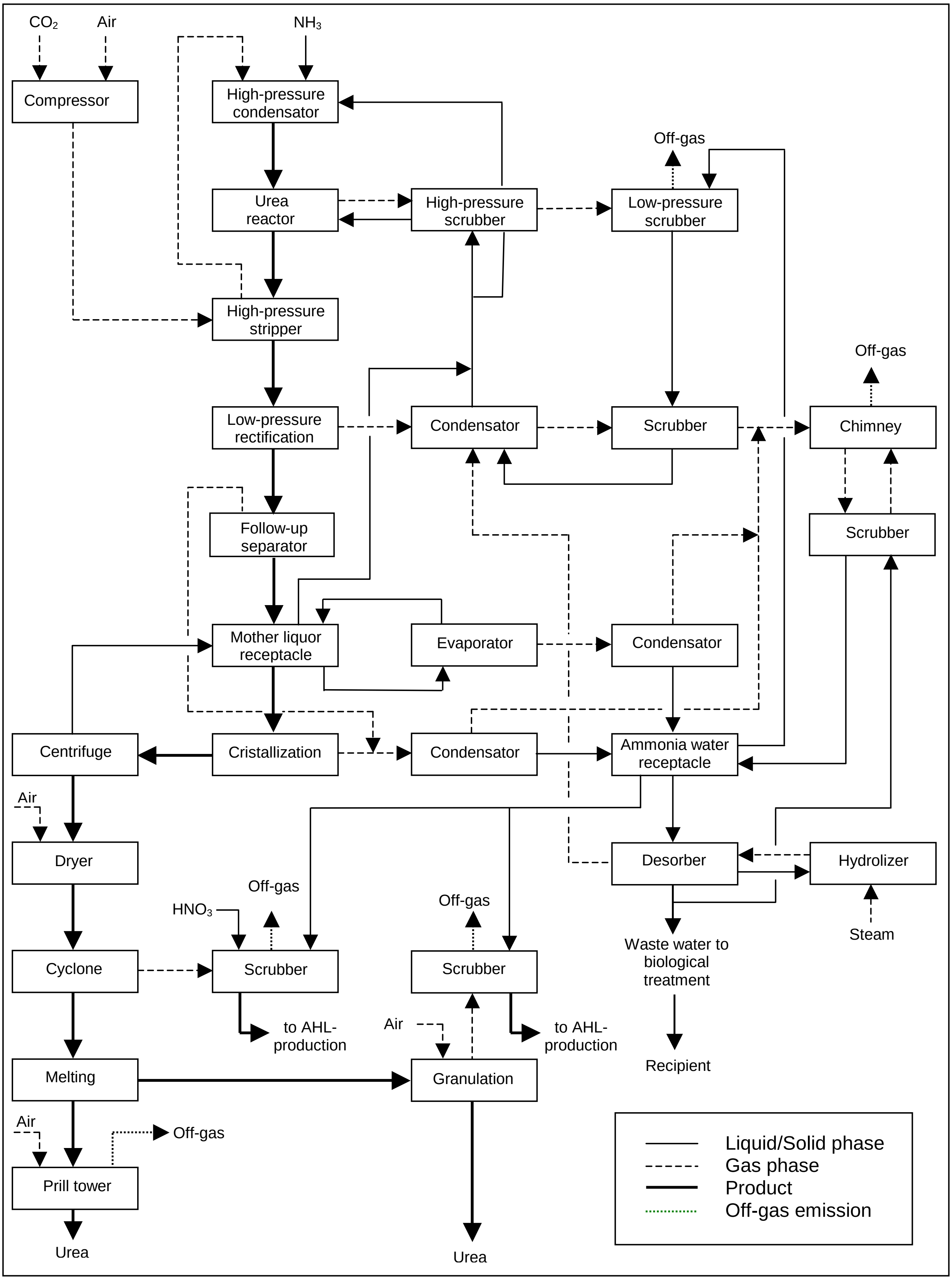

Figure 3: CO$_2$ Stripping Technology of the SKW Piesteritz

The steam from the evaporation and the crystallization is condensed The condensate is led as 6 – 7 % NH_3-solution into the ammonia receptacle. Together with the previously cleaned off-gas of the low pressure rectification the residual off-gas is discharged into the atmosphere.

The urea solution is drained in a centrifuge and the separated cristalls dried by hot air. The mixture of urea and air is separated in cyclones again, where the dried urea is smelted and either supplied to a prilling tower or is submitted to granulation. In case of prilling, the exhaust air is discharged into the atmosphere without further treatment. Because of the high level of dust emissions the prilling tower in Piesteritz does work with 35 to 70 % of its capacity only. The other urea is submitted a granulation and treated in a liquid fertilizer unit.

Prilled urea is mainly used for industrial purposes. The granular product is of higher solidity and the grains are bigger than prills. It is preferably used in the agriculture. SKW Piesteritz uses the technology of Toyo Engineering for the granulation, which is represented in **figure 4.**

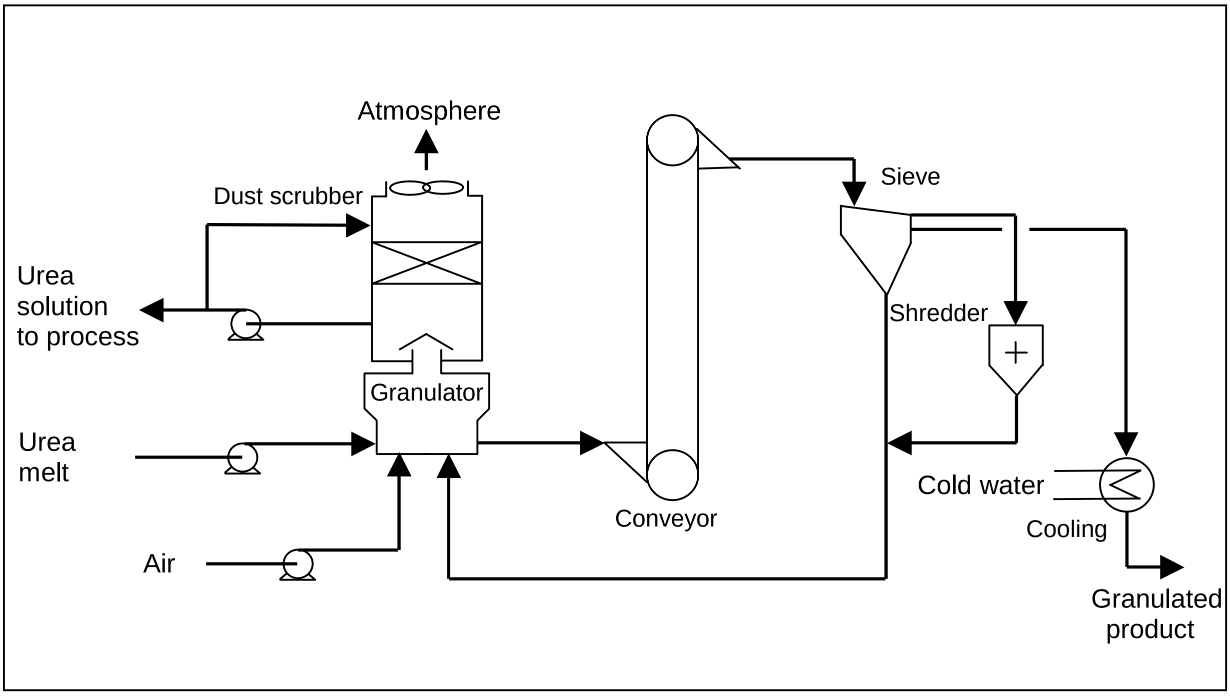

Figure 4: Granulation Technology of Toyo Engineering

In this granulation technology, the melt is fed into a fluidized bed dryer. The exhaust gas, polluted with dust and NH_3, is led into a scrubber. The separated dust is led back into the production process, while the off-gas is discharged after treatment in a washing unit into the atmosphere. The obtained granulate is screened. Too small grains are led back to the granulator, too big grains are shredded and led back into the fluidized bed dryer. Finally the product is stored and sold. Water as a side product is generated during urea production, which have contents of ammonia and carbon dioxide and is separated during cirstallization of urea.

The urea production causes a reaction water, which is mainly loaded with urea and ammonia. The sources are the condensates from evaporation and crystallization. In addition process waters are caused by vacuum generation. Because the process water is only slightly loaded with ammonia, it can partially be recycled as wash water for the low pressure washer and the washer of the low pressure rectification. Under addition of nitric acid it can be reused for the off-gas discharged from the cyclones as well as from the granulation process. By the addition of nitric acid, which is also produced in the plant, the absorption of ammonia is increased. The discharged wash water is loaded with ammonium nitrate and urea (AH-solution) and is used after evaporation in the production of liquid fertilizers.

The process water, which cannot be recycled, is discharged to a treatment as presented in **figure 5.** There, the water is warmed up and led into desorber 1, where NH_3 and CO_2 are separated by low pressure steam. The effluent is warmed up to 190 °C and fed into the hydrolysis reactor, where urea is decomposed at 9 bar to NH_3 and CO_2. After decompression of the water ammonia and carbon dioxide is separated in desorber 2. Finally the treated waste water is either discharged into a biological treatment plant or further used in cooling equipment.

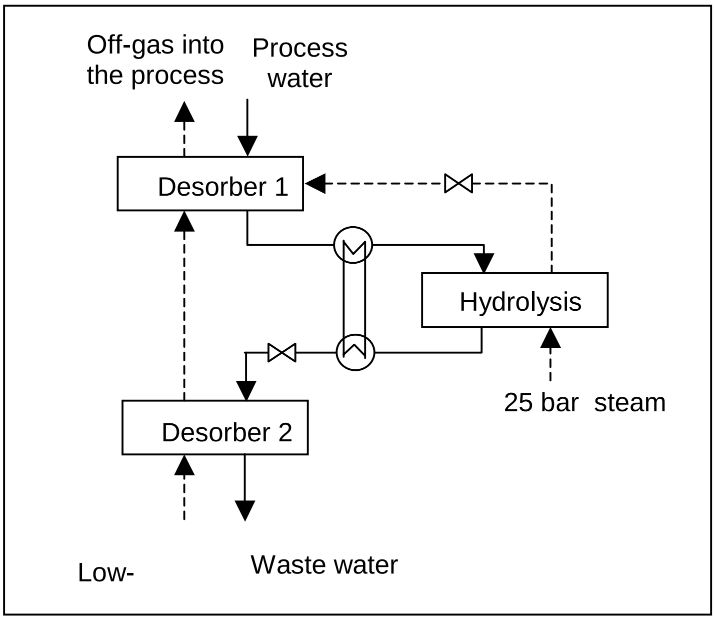

Figure 5: Block Scheme of the Process Water Treatment

2.4.2 Emission Data and Energy Demand

2.4.2.1 Emissions of Exhaust Air

The urea production at the SKW Piesteritz plant causes five different off-gas emissions (see figure 3):

- Low-pressure washers
- Chimney
- Urea drying with air (pneumatic transport)
- Prilling
- Granulation

Except the exhaust air from the prilling tower all off-gas streams are treated in a scrubber before being discharged into the atmosphere. The essential emission data are shown in **table 4**. In **figure 6**, the emission data are related to the different process steps.

Table 4: Emission Data of the Urea Production at the SKW Piesteritz

	NH_3		Dust	
	[g/t product]	[mg/m^3]	[g/t product]	[mg/m^3]
Low pressure scrubber (urea synthesis)	70	2.000	-	-
Urea drying	< 20	< 20	< 20	< 20
Prilling	1.600	60	1500 / 1.250 (∅ < 5 µm)	50/75
Granulation	300	50	200	50

* The stated dust concentrations are average ½ hour values on the basis of continous measurements. (SKW Piesteritz is the only urea supplier in Europe with a continous dust measurement). The ammonia values are average of single measurements.

2.4.2.2 Waste Water

During the urea production the following process water emissions are caused:

- Condensates from the crystallization and evaporation
- Ejectors for the vacuum production
- Rinse and cleaning waters

At the location Wittenberg, the process water is first collected in the ammonia water receptacle. The urea production of 1.000 t/d causes an average process water volume of approximately 500 m^3/d. The main source is the actual synthesis reaction, where stoichiometrically 0,3 t of process waters per ton of urea are provoked. Other sources are rinses and cleaning waters as well as steam, which is used in the process and in waste water treatment plant. The process water is loaded with 6 % NH_3, 4 % CO_2 and 1 % urea.

With a part of the process water collected in the ammonia water receptacle, all off-gas scrubbers of the urea production are driven at the SKW Piesteritz plant. After evaporization the wash water is partially used in the liquid fertilizer production or, after condensation, it is led back into the process. The predominant share of the process water is discharged into the process water treatment. There urea, NH_3 and CO_2 are separated from the process water, while the off-gas is led back to the urea synthesis. The treated process water is finally discharged into the biological waste water treatment plant. Per ton urea produced approximately 0,46 m^3 process water with a load of about 0,05 kg CSB and 0,1 kg N are discharged. Leckage waters are collected and treated separately. They are used either also for the liquid fertilizer production or discharged under control into the waste water treatment plant.

2.4.2.3 Energy demand

Altogether, the described process of the urea production generates heat in excess. Nevertheless, energy must be added to the process due to the different processing steps. The carbamate conversion in the high pressure condenser delivers a heat excess. The reaction heat is discharged by generating of a steam of 4 bar. A part of the steam is used for the carbamate decomposition, for the low pressure rectification and for the evaporation.

The high pressure stripper has a high energy demand (20 bar steam). This energy cannot be taken from the manufacture process itself, but must be supplied from outside. As at one location the urea synthesis is always connected to the ammonia synthesis, the necessary 20 bar steam is generally supplied from the NH_3-plant. Also for the conversion from urea into NH_3 and CO_2 25 bar steam are required in the process water treatment.

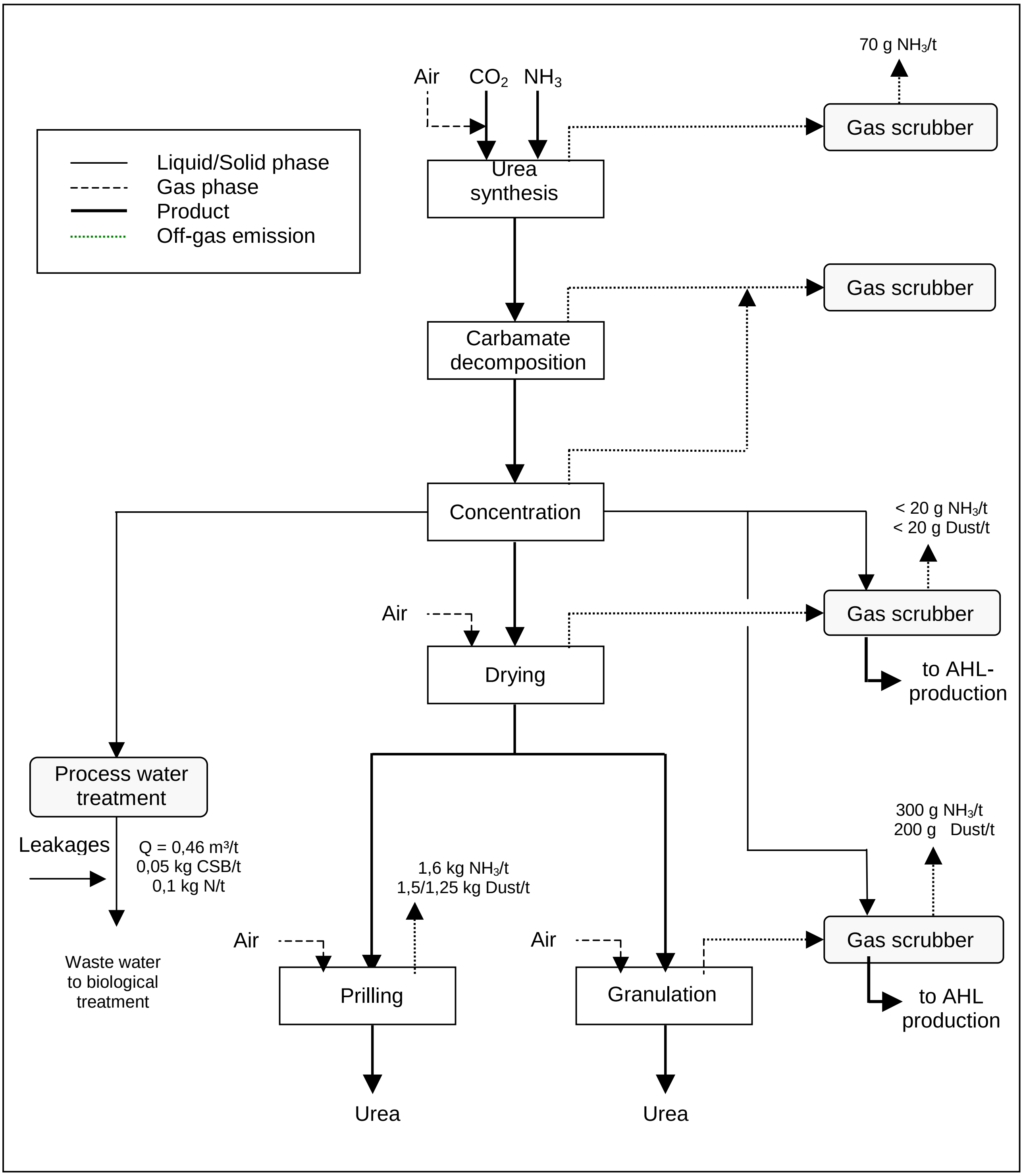

Figure 6: Emission Sources and Typical Volumes of the CO_2-Stripping Technology

According to supplier statements 0,92 t steam per ton produced urea are necessary for the urea production by the Stamicarbon technology.

The essential energy consumers in the urea synthesis are the compressors, which compress the input CO_2 to the required synthesis pressure, and the high pressure pumps, which compress the liquid ammonia to synthesis pressure and condens the reaction gases from 3 to 150 bar and lead it back into the process. The demand of electric energy amounts to approximately 43 kWh per ton urea produced without the CO_2-compressor. The additional energy demand amounts to 23 kWh/t for the granulation by the technology of the Toyo Engineering company.

The cooling water demand lies around 70 t per ton urea.

The indicated steam and energy demand can vary strongly at the different industrial plants. It depends on the fact, whether the CO_2 compressors are driven with steam or are equipped with an electric motor.

2.5 The NH_3 Stripping Technology

2.5.1 Production Process

The NH_3 Stripping Technology is installed at the plant of Hydro Agri in Brunsbüttel. **Figure 7** shows the block scheme of the urea production according to the Snam Progetti Technology. In this procedure ammonium and carbon dioxide are led into the synthesis reactor at 150 bar, 170 °C and a mole ratio of 3,5. The effluent is supplied to a stripper, in which the biggest part of the residual carbamate is disintegrated by discharging the surplus ammonia. The remaining carbamate as well as CO_2 are supplied to a predecomposer and then to two further decomposers driven at 17 bar respectively 4,5 bar. The obtained CO_2 as well as the NH_3 are condensed and as recycled carbamate solution mixed with the NH_3- and CO_2-steams from the stripper. Then this mixture is led into the carbamate condensator, afterwards into a separator and finally back into the reactor.

The residual NH_3-steams from the predecomposer and decomposer 1 are fed into a NH_3-condensator under addition of fresh NH_3. Then the liquid ammonia is pumped into the reactor. The inert gases leaving the NH_3-condensator and still loaded with ammonia are supplied to a double step scrubber and afterwards discharged into the atmosphere. The off-gas of decomposer 2 is also led to the second scrubber.

The urea solution from the decomposers is concentrated in a vacuum pre-decomposer followed by a two step evaporation. The obtained steam is condensed

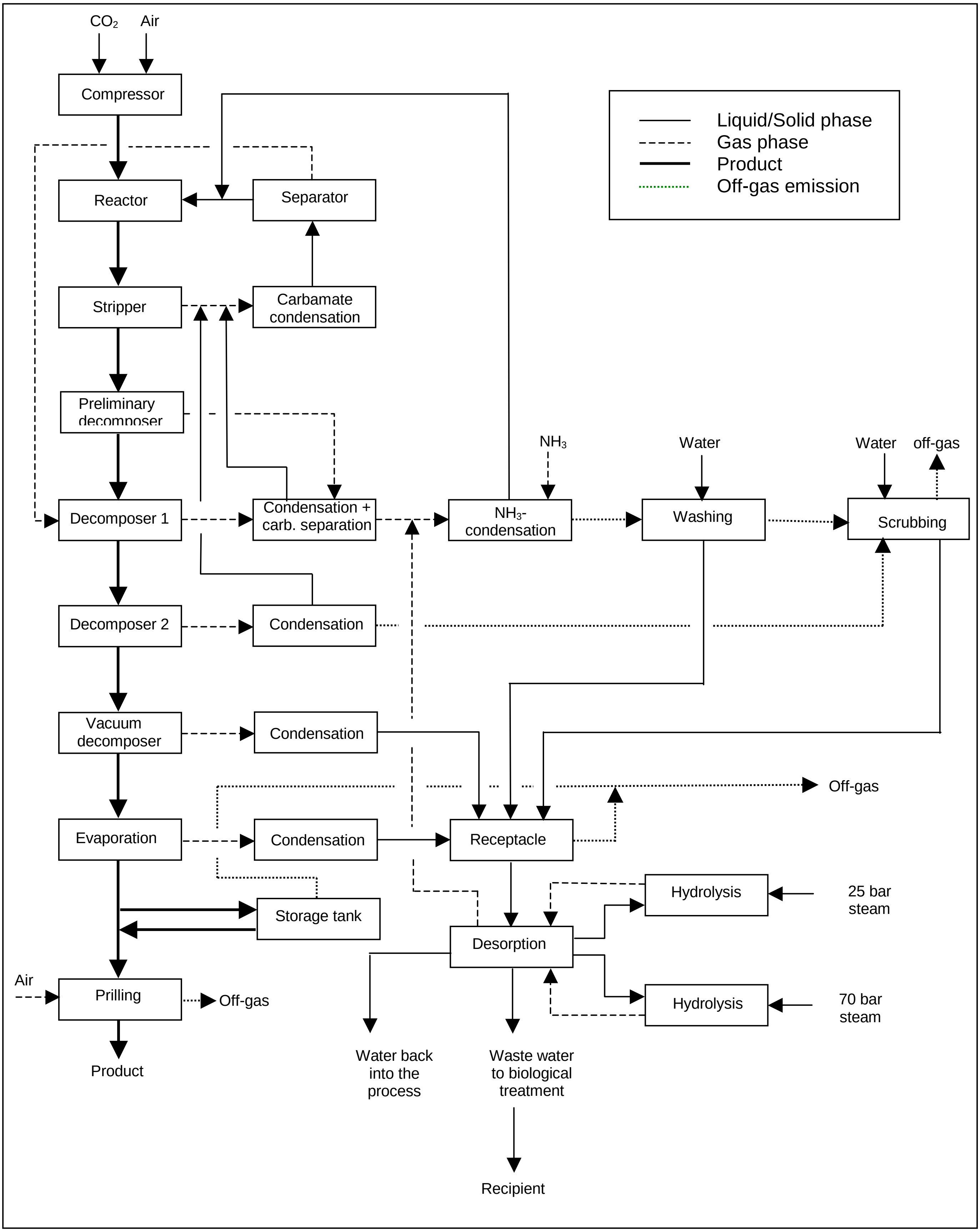

Figure 7: NH_3-Stripping Technology of Hydro Agri in Brunsbüttel

and supplied to a water receptacle. The exhaust air of the receptacle is discharged by a chimney into the atmosphere. In the process water treatment the volatile substances of the condensate, like NH_3 and CO_2, are desorbed and the residual urea is disintegrated in two hydrolizers. Hydro Agri adds steam of 25 bar respectively 75 bar to the two parallel operated hydrolizers. A part of the treated water is recycled for the process, the biggest part, however, is discharged into the waste water treatment plant.

Because the urea is available from the evaporizers as a melt, it can be prilled directly passing by an individual receptacle or indirectly by a collective tank. Hydro Agri disposes of a special prilling technology, which allows to select a relatively narrow distribution for the size of the prilling grains. Consequently, the dust share in the off-gas can considerably be reduced. The special characteristic of this technology is that the rays of the melt are cut in defined pieces by a rotation basket, so that the grain-size-spectrum shows a minimum of dust particles. The prilling tower itself has a natural lift, which means that no air is brought into the tower by ventilators. After the prilling, the product is stored and is sold.

2.5.2 Emission Data and Energy Demands

2.5.2.1 Exhaust Air Emissions

The essential emission sources of the urea synthesis at Hydro Agri in Brunsbüttel are the following (see figure 7):

- Carbamate decomposition
- Concentration
- Prilling

The exhaust air of the carbamate decomposition is treated by a scrubber before being emitted. The off-gas of the concentraton as well as of the prilling towers, however, is discharged into the atmosphere without any treatment. The essential emission data are composed in **table 5**. In **figure 8**, the emission data are related to the different processes.

Table 5: Emission data of the Urea Production at Hydro Agri in Brunsbüttel

	NH_3		Dust	
	[g/t product]	[mg/m³]	[g/t product]	[mg/m³]
Carbamate decomposition	180	16.700	-	-
Concentration	150	29.300	-	-
Prilling	400	30	510	40

* The ammonia and dust concentrations stated in table 5 are average half hour values, which are based on several measurements. In case of the prilling tower the NH_3 and the dust concentrations can temporarily be higher. The production-related emission values of the prilling are based on a theoretical off-gas volume calculation. The prilling tower of Hydro Agri has a natural air intake. This means that the air inflow at the bottom is not fixed. The obtained values have been compared to the measurement results of the current profile of the prilling tower.

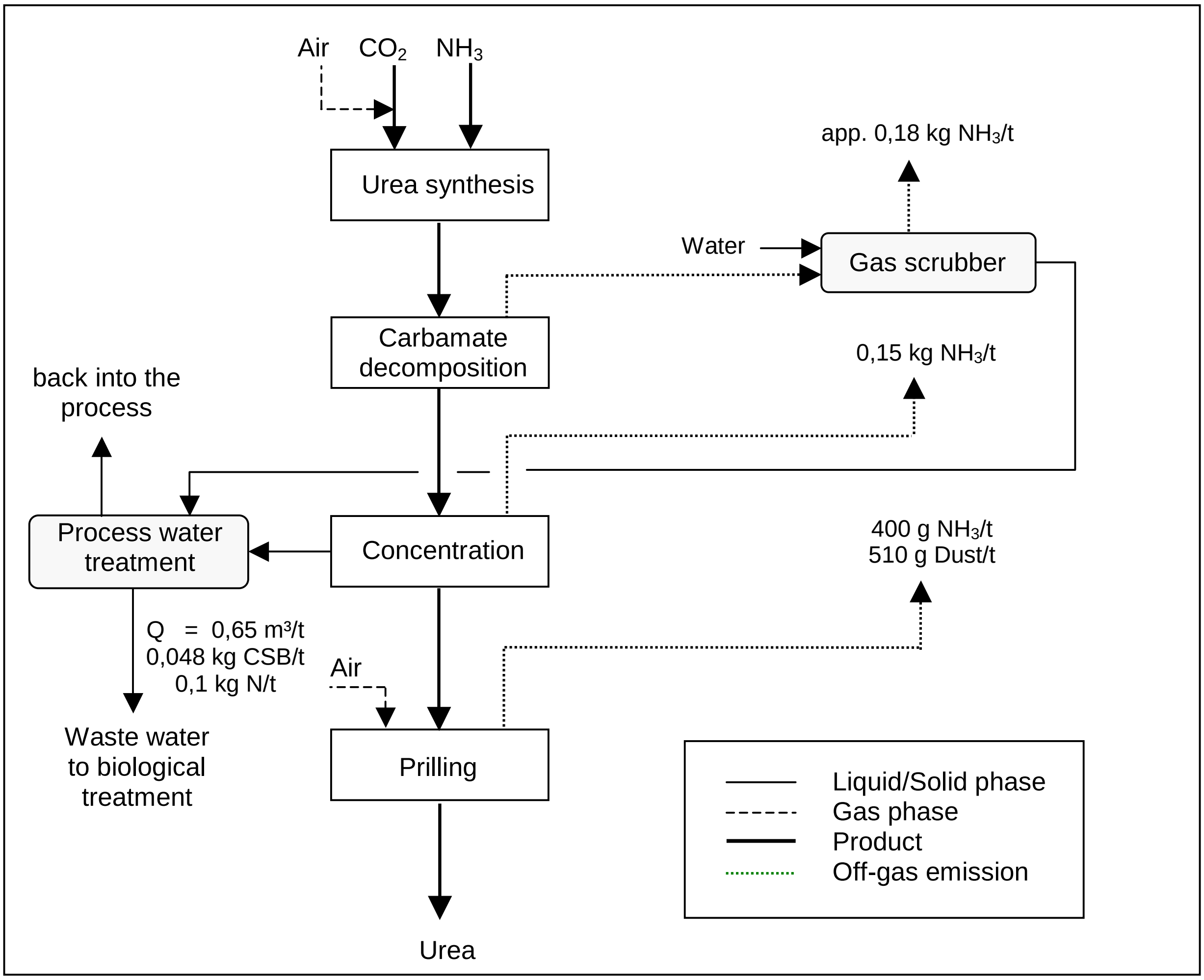

Figure 8: Emission Sources and Typical Volumes of the NH_3-Stripping Technology

2.5.2.2 Waste Water

Process water is caused by condensation process and the off-gas scrubber of the concentration process. Together with the rinsing and wash effluents it is discharged into the process water treatment. Approximately 0,65 m^3 process water per ton produced urea with about 0,08 kg NH_3 and 0,06 kg urea are emitted, which corresponds to a CSB-load of 0,048 kg/t.

2.5.2.3 Energy Demands

For the urea production by means of the Snam Progetti Technology the addition of an average pressure steam of 0,85 t per ton produced urea is necessary. The electric energy consumption amounts for the total installation to 115 kWh/t urea produced including and about 21 – 23 kWh/t urea without the CO_2-compressor.
The cooling water demand amounts to 75 t/t product.

3 Summary of the Emission Data

In **table 6** is all exhaust air emissions and concentrations for the different sources and procedures are summarized.

Table 6: Summary of the Off-gas Emissions and Concentrations

			Solution cycle	CO_2-stripping	NH_3-stripping
Urea synthesis	NH_3	g/t product	-	70	-
		mg/m³	-	2.000	-
Carbamate decomposition	NH_3	g/t product	-		180
		mg/m³	-		16.700
Concentration	NH_3	g/t product	-		150
		mg/m³	-		29.300
Drying	NH_3	g/t product	90 (55)	< 20	-
		mg/m³	60 (35)	< 20	-
	Dust	g/t product	30	< 20	-
		mg/m³	20	< 20	-
Prilling	NH_3	g/t product	600 – 700	1600	400
		mg/m³	30	60	30
	Dust	g/t product	1.000 - 1.300	1500/1250	510
		mg/m³	55	50/75	40
Granulation	NH_3	g/t product	-	300	-
		mg/m³	-	50	-
	Dust	g/t product	-	200	-
		mg/m³	-	50	-

For the evaluation of the specific energy consumption, the location-specific realities as well as the general conditions have to be considered. In all 3 companies the electric energy demand decisively depends on the CO_2-compressor. An urea manufacturing plant is always connected to an ammonia synthesis. At the SKW Piesteritz the required CO_2 is precompressed to 26 bar in the ammonia synthesis. In the urea synthesis, the CO_2 is further compressed to approximately 150 bar.

At Hydro Agri, however, the CO_2 is compressed in the urea plant from the atmosphere pressure to the synthesis pressure. The BASF disposes of a central compress station. There, the urea plant receives the CO_2 at the synthesis pressure of 200 bar directly from the pipe. Consequently, only the specific values of the electro energy demand without CO_2-compressor are actually comparable (see **table 7**).

Table 7: Specific Energy Consumption

	Spezif. electric energy demand without CO_2-compressor		Steam demand in tons of steam per ton of urea
	kWh/t Product	kJ/t Product	
Total Recycle Technology	70	ca. 0,25 x 10^6	1,3 (ca. 2,47 x 10^6 kJ/t Product)
CO_2-Stripping	43	ca, 0,15 x 10^6	0,92 (ca. 1,75 x 10^6 kJ/t Product)
NH_3-Stripping	21 – 23	ca. 0,08 x 10^6	0,85 (ca. 1,61 x 10^6 kJ/t Product)

All values refer to the urea synthesis with subsequent prilling. Besides the prilling, only the SKW Piesteritz also disposes of a granulation with a specific energy demand of approximately 23 kWh/t urea. As the synthetized urea melt is granulated to 50 % and prilled to 50 %, the total energy demand (without CO_2-compressor) amounts to approximately 55 kWh/t urea.

Besides the specific demand of electric energy, also the specific steam demand is composed in table 7. Only the conversion to kJ/t product reveals that the essential energy consumption results from the heat demand.