Project Information Sheet

Producing sodium bicarbonate using carbon dioxide captured from the flue gasses of waste incineration (NaHCO3)

Programme area:	Recycling of materials
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Benefits (max. 150 characters incl. space):	An innovative technology for re-using carbon dioxide by capturing the product from the flue gasses of the Twence Waste-To-Energy (WTE) plant and using it for the production of sodium bicarbonate as a result of the alkaline reaction with soda. The sodium bicarbonate will be used for flue gasses cleaning purposes (removal of acid components), thus avoiding the current expensive purchase of the product.
Keywords:	Carbon dioxide capture + sodium bicarbonate production + re-use at incinerator for flue gas cleaning purposes
Sector:	Recycling
Type of solution	New technology
Duration:	01/07/2011 – 30/06/2014
Budget:	€ 2.044.412,-- (EU contribution: 42,76%)
Contract number:	ECO/10/277332

Summary

The increase of carbon dioxide emissions is the main reason for the global warming up causing disastrous environmental effects. In order to reduce the greenhouse gas emissions, several large-scaled carbon capture & storage (CCS) technologies and methods are in operation all over the world. The current techniques however have major technical and economic disadvantages. For example deficits in issues such as energy consumption, investment costs and consumption of absorbents. CCS is not the only option for reducing the greenhouse effects. Other options are mostly related to re-using the carbon dioxide. Recycling is likely to offer environmentally and financially sustainable responses to the global challenge of significantly reducing greenhouse gas emissions.

In this project Twence will demonstrate an innovative technology for re-using carbon dioxide by capturing the waste product from the flue gasses of the Waste-To-Energy (WTE) plant and using it for the production of sodium bicarbonate ($NaHCO_3$) as a result of the alkaline reaction with either sodium hydroxide (NaOH) or with soda (Na_2CO_3). The choice for the product to be used is largely depending on the price level and large-scaled availability of the raw materials. The sodium bicarbonate will be used at the incinerator for flue gasses cleaning purposes (removal of acid components), thus avoiding the current expensive purchase of sodium bicarbonate.

The overall objective of the project is to build an unique on-site carbon dioxide capture unit as well as a downstream sodium bicarbonate reactor geared to the future consumption of this flue gasses cleaning product by Twence. The production capacity of the demo plant is indicated at 8,000 tons of sodium bicarbonate on an annual basis. As a result the project will have major environmental benefits. The reduction of carbon dioxide consumption as a result of the innovative technology is calculated on 2,000 to 3,000 tons on an annual basis.

The main partial objectives of the demo project are:

- Demonstration of an unique carbon dioxide capture technology leading to lower operational costs (financial aspect) as well as lower consumption of absorption liquids (environmental aspect);
- Demonstration of the re-use of the captured carbon dioxide for the on-site production of sodium bicarbonate to be used in the flue gasses cleaning system of the WTE plant;
- Evaluation of the concept of on-site production, storage and re-use of carbon dioxide;
- Review of the financial-economic perspective of the new technology.

The project has started on 1 July 2011. The duration period of the demo project was originally calculated on 36 months. It is actually calculated that the project will be performed in 48 months. On July 1st 2014 the construction and assembling of the demo plant is in the finalizing stage. The start-up and commissioning of the demo plant will start in July 2014. The performance of the $NaHCO_3$ project is structured according to work packages (WP).

Expected and/or achieved results

Expected results

The demo plant will initially aim at acquiring knowledge and know-how related to the proposed innovative technology in the shape of testing, validating and - if necessary - adjusting the production process. At the same time by realizing the installation the operational objective of the project is the production of the required volume of sodium bicarbonate to be used for flue gasses cleaning purposes at the Twence site.

The major results of the project to be expected are divided into know-how, technical and economic outcomes:

Know-how:

- Validation of the chemical, thermodynamic and physical properties of the system;
- Validation of the process models, model calculations and simulations;
- Validation of the effects of the process conditions on the product properties.

Technical deliverables:

- Detailed design of both the carbon capture plant as well as the sodium bicarbonate reactor;
- Construction of a demo plant with a capacity of 8,000 tons of sodium bicarbonate on an annual basis;
- Technical evaluation of both the carbon capture process as well as the re-use process;
- Integration of the demo plan with the regular WTE-plant (specifically with the flue gasses cleaning system).

Economic deliverables:

- Availability, volumes and prices on the raw materials;
- Evaluation of the storage, transport and recycling of raw materials and finished product;
- Business process evaluation (operational costs, level of investment and return-on-investment);
- Calculation of the market volume of the demonstrated technology.

Achieved results

WP1 (project management)

At the start the project management has been installed. Project director is Ir. H. Middelkamp (Manager Processes & Technology of Twence) and project manager is A. Roeloffzen Bsc (senior staff member Processes & Technology of Twence). During the project period the staff and management has been reinforced by allocating more time and employees to the project, both originating from Twence as from external organizations. External capacity related to the project management was hired by appointing a senior process engineer originating form Procede Group as assistant project manager. Reinforcing the project staff and management has resulted in a higher level of engagement as well as the prevention of further delay. The generated attention allowed for speeding up the activities in the last 18 months of the project period. More activities were performed and the tempo of these activities was also speeded up. As a result in the second half of the $NaHCO_3$ project an increase in hours spend is reported. Despite this situation the time schedule of the project had to be revised.

In the course of the project period an International Advisory Board (IAB) has been installed. The IAB monitored the project activities and consisted of three persons. Chairman of the board was J. Rooijakkers Msc (Chief Business Development of Twence). Other members of the board were Ir. G. Timmer (manager at Brewa GmbH in Bremen Germany) and Prof. G.F. Versteeg (manager of Procede Group in Enschede). The board advised the project management on activities to be performed and also acted as sounding board for the project staff involved. In the eligible project period several meetings of the IAB have taken place.

WP2 (evaluation of the process plant design)
This WP is completed. In 2012 a study concluded that the original intended technology would not be feasible in financial perspective. The ROI-period would be long and the cost price of the sodium bicarbonate would exceed the actual market price. It was also concluded that both investment budgets as well as operational costs would exceed the original estimations. In reaction several adjustments were proposed. The first adjustment related to the use of 100% ('pure') carbon dioxide for the sodium bicarbonate production. The second adjustment consisted of eliminating drying the sodium bicarbonate and using slurries of the product. In the original plan the assumption was made that sodium bicarbonate will be unstable at high temperatures, thus leading to thermal decomposition. Due to several measurements the temperature will be reduced and as a result the drying process will be avoided as well as crystallising and sifting of the sodium bicarbonate.

It was decided that more information on the technical and financial implications of the proposed adjustments to use slurries of sodium bicarbonate instead of dried sodium bicarbonate was needed in order to be able to proceed with the $NaHCO_3$ project. Following this decision a study regarding this subject was performed. The focus of the study was to be able to evaluate the effectiveness of using slurries for flue gas cleaning purposes instead of dried sodium bicarbonate. Using slurries of sodium bicarbonate must be effective in technical and environmental perspective, but must also result in reduced exploitation costs (economic perspective).

The overall goal of the study was to realize a sodium bicarbonate slurry injection installation for the efficient removal of acid gas components (like HCl and SO2) from flue gas. The study was performed in the period from May until November 2012. In the study an extensive test program has been set up. The first part of the study concerned testing slurry injection at room temperatures and ambient conditions. The second part of the study concerned testing slurry injection at elevated temperatures in the actual flue gas of the WTE-plant. In the study the proposed innovative concept was investigated in detail in order to develop deeper understanding and faith in sodium bicarbonate slurry injection. The results of the study focused on necessary technical modifications in the demo technology were discussed intensively by the technical experts of Twence. The overall results of the study were evaluated positive and resulted in an adjusted technology for sodium bicarbonate slurry injection for the efficient removal of acid gas components from flue gas. The results were evaluated positive by Twence, thus leading to a complete oversight of all technical aspects related to the demo technology.

Following the technical evaluation also the financial implications of the proposed adjustments were investigated and evaluated. Price indications for the demo plant equipment (including integration with the operational WTE plant) were collected from potential contractors, thus resulting in detailed budget estimations for the investment. Based on the technical as well as financial input a revised business case was made up focused on the realization of a carbon dioxide capture plant in combination with a downstream sodium bicarbonate reactor with a capacity of 8,000 tons on an annual basis. The business case was evaluated positive by the project management and presented to the board of directors as well as the supervisory board of Twence. Final approval of these boards was received on June 13th 2013, thus enabling to complete this WP.

WP 3 (acquiring permissions)
The process of acquiring the permissions is also completed. It was investigated which permissions are required and what actions should be taken. It turned out that Twence is operating under the conditions set out by a framework environmental permission, resulting in degrees of liberty to act. In order to execute the possibilities to act stated by the framework an internal environmental audit was made focused on the effects of capturing carbon dioxide from the flue gas of the WTE plant and using it for the production of a slurry of sodium bicarbonate to be injected in the flue gas cleaning unit. The audit focused on the implications on emissions in the compartments soil, air and water. The audit report has been submitted for approval to the licensing authority. Since no obstacles were indicated approval of the Province of Overijssel was received on January 31st 2013.

WP4 (detailed engineering en dimensioning of the pilot plant)
The activities related to the engineering of the demo plant (including integration with the operational WTE incineration plant) were completed in 2013. The work consisted of the basic and detailed engineering (both mechanical and electrical) of the carbon dioxide capture plant in combination with a downstream sodium bicarbonate reactor. Specific attention was given to the unit and reactor design & configuration, specification of process equipment, control & safety aspects as well as process monitoring & analysis. Since slurries of sodium bicarbonate will be used special attention is also given to the integration of the demo plant with the operational WTE plant. In total 10 interfaces (SLIF's) between the pilot plant and the operational WTE plant are identified. The demo plant consists of 4 main subsystems (soda dissolving system, CO_2 capture plant, sodium bicarbonate production plant and injection system). The main utilities are steam injection, cooling water and heat recovery.

WP5 (tendering procedures)
The performance of the tendering procedure (WP5) is also completed. The activities started by drafting up the procurement procedure in order select the best candidate for the construction of the carbon dioxide capture plant and downstream sodium bicarbonate reactor. The procurement instructions focused on the detailed engineering of the plant equipment as well as constructing and turn-key delivering. Integration with the WTE plant is partly included. Major integration systems are realized by the general contractor whereas utility systems and electrical integration systems are realized by other partners of Twence. The general contractor is responsible for engineering and purchasing of the equipment as well as for assembling the equipment into an operational plant.

The procurement instructions and the procurement contract were made public for interested and eligible contractors on June 17th 2013 through the website www.negometrix.com. The website was also to be used to submit a proposal. Final proposals were to be submitted before July 15th 2013. Based on the thorough evaluation of all proposals by the evaluation committee the construction contract was finally awarded to Bouman Process Technology since this company submitted the bid offering the best value for money. The company has also extensive experience in the turn-key deliverance of process technology demo plants. Twence has had positive references on this contractor in the recent past. On July 19th 2013 the awarding decision was made public by Twence and on July 22th 2013 the construction contract was signed by Twence and Bouman Process Technology.

The tendering procedure for selecting suppliers for the soda as raw material is also competed. Out of three high-standard producers Solvay Chemicals is selected to supply the soda in the start-up phase of the demo plant. In 2015 another tendering procedure will be organized in to select one or more final soda suppliers.

WP6 (construction demo plant)
The construction and assembling of the demo plant is in the finalizing stage. The start-up and commissioning of the demo plant is expected to start in July 2014. It can be concluded that WP6 is largely performed (circa 85 - 90%). The activities related to this WP started almost immediately after signing the construction contract. At first Bouman focused on the detailed engineering and dimensioning of the demo equipment based on the output of the engineering of the process design (WP4). In respect to the dimensions of the demo plant it was an extensive task and it took therefore a lot of time and effort. Following the output of the equipment engineering & dimensioning process the procurement of the equipment has taken place the last months of 2013. At the same time the construction of the piping was started. After receiving the equipment in the beginning of 2014 the actual construction of the demo plant was started by Bouman and the subcontractors.

During the detailed engineering and dimensioning process of the demo equipment also extensive HAZOP and risk analysis studies by external experts were performed as well as supporting studies with regard to CE marking and the classification/verification of the Safety Integration Levels (SIL). Resulting the safety studies performed several (minor) modifications in the demo equipment were needed, thus resulting in some delay.

The construction activities are performed by the contractor in cooperation with several subcontractors. Bouman focusses on constructive and mechanical activities, whereas electrical & instrumentation has been subcontracted to Van Lenthe. Major integration systems are realized by the general contractor whereas utility systems and electrical integration systems are realized by subcontractors of Twence. Electrical & instrumentation concerning the integration of the demo plant with the operational WTE-plant has been subcontracted to Imtech. Realization of the steam injection has been subcontracted to Stork Thermeq. In February 2014 the third incineration line of the Twence WTE plant has been put out of operation for some time in order to be able to facilitate the integration of the demo equipment with the operational WTE-plant (sub-systems such as CO_2 capture, supply of soda, injection of sodium bicarbonate into flue gasses, cooling water, steam, heat, etc.).

The constructive, mechanical and electrical activities are in the finalizing stage at the moment and Bouman is preparing the transfer of the demo plant. The start-up and commissioning of the demo plant is expected to start in July 2014 and will last three months until the end of September 2014. Twence has installed a commissioning team in order to perform these activities. A detailed commissioning programme is also available. At first a Factory Acceptance Test (FAT) will be performed. The objective of the FAT is to examine the demo plant on its completeness and compliance with the design specifications. In addition mechanical, electrical, software and functional tests will be performed. All main subsystems of the demo plant will be tested separately, including utilities (cooling water, heat and steam). The interfaces with the operating WTE plant will also be taken into consideration.

The FAT will be started by examining the waterproofness of the demo plant. De pipes will be filled with water. Functional tests and trails using soda will be performed. As a result of the FAT subsystems are functional and able to operate. After completion of the FAT the Site Acceptance Test (SAT) will be performed. Additional mechanical, electrical and software tests will be performed, not only focussed on the carbon dioxide capture unit and downstream sodium bicarbonate reactor, but also on the integration with the operational WTE-plant. During the start-up and commissioning procedure also the training program for operators of Twence will be contines to make them able to operate the demo plant. Training comprises introduction of and familiarization with the demo plant.

WP7 (experimental demo programme)

No results in this WP can be reported in the FR since the activities have not started yet. After starting-up and commissioning the demo plant it will be subject to an experimental program. It is expected that WP7 will start in October 2014 and be completed in March 2015. In WP7 several test runs in various conditions will be performed. The performance of the demo plant will be monitored and analysed intensively. Major subjects related to the experimental demonstration program are validation of the technology in operational status as well as insight into optimal performance rates and process conditions based on test runs performed.

The subjects will be detailed into an experimental program describing the test runs to be performed and the criteria to be handled. The program will be available at the start-up of the demo plant. In the experimental demo program relevant process variables and parameters will be varied, such as solvent composition and consumption, pH levels, carbon pressure levels, gas volume concentration, drying temperatures and conditions, composition of sodium hydroxide, acceleration factor, etc. The results of the test runs will be analysed in a chemical laboratory. The procedures to be handled in the test runs and lab analysis will be drawn up and monitored by the project management. Resulting the experimental demo program several (minor) modifications may be considered, thus resulting in optimizing the demo plant.

WP8 (technical and economic evaluation)

Also no results in this WP can be reported in the FR since the activities have not started yet. Following the results of the experimental program (WP7) the performances of the demo plant will be evaluated (WP8). It is expected that WP8 will start in April 2015 and be completed in June 2015. The output of the experimental program will be monitored to determine and document the effectiveness of the project compared to the initial situation, objectives and expected results. The main focus is whether the performances of the demo plant are in accordance with the expectations. Before starting the process a monitoring protocol will be drawn up. Monitoring indicators and sources of verification will be identified. The result of the evaluation process will be reported. Discussions on the report by the project management and IAB are intended. Resulting the monitoring and evaluation results again (minor) modifications may be considered, thus resulting in optimizing the demo plant.