CO_2 reuse opportunities in the Netherlands

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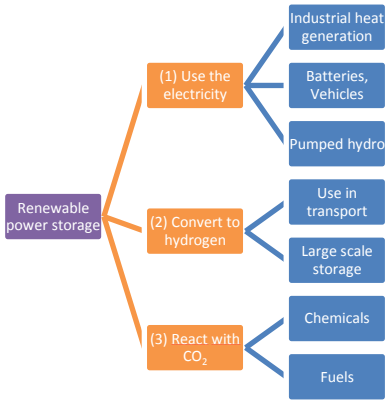
1 Executive Summary

This work package was meant for substantiating choices to be made for the follow-up program of Cato2. To this end, current activities within and outside the Netherlands have been followed In two ways, literature and topical conferences and the debate enrolling every time this subject is brought up. CO_2 capture and use (CCU) is generally viewed as a means to produce chemicals from CO_2 and sustainable power sources that are subject to curtailment when demand is low. Taking into account the strong opinions in the field a more subtle approach is presented in the figure below.



The first point of criticism is that electricity should be used as electricity. This can be adopted in industry provided the infrastructure is fit for electricity use in e.g. heating utilities. Depending on the capacity electricity can be stored on different scales. The second stage would be that if this is not possible the excess power can be converted to hydrogen, provided there is direct use for it, which depends on the local infrastructure, driving trains in transport, or the availability of large scale storage options. If also this proves to be not feasible, CO_2 comes in as a "carrier" of hydrogen, both for chemicals and fuels production. Of course these options decrease in overall efficiency going from top to bottom.

The RD01 report addresses the potential of CO_2 utilization in industrial and power producing processes. First, an enormous gap exists between the current capacity of industry of using carbon dioxide and the amount of carbon dioxide emitted by power production, corresponding to 2 to 3 orders of magnitude difference. CCU is therefore complementary to CCS as far as CO_2 abatement is concerned. In any case, avoided use of fossil fuels in industrial sectors such as plastics, cement, concrete etc is the target to strive for.
The report concludes clearly that the role of the conversion of power to fuels is far more important in energy processes than chemicals production since it enables the use of variable power supply - produced by renewable sources- by providing a means to store energy at large scale when excess power is produced. In addition, it may secure the long term availability of liquid fuels in sectors where hydrogen or electricity will not play a role on the short and medium term, e.g. aviation fuel. In the case of other means of transportation these synthetic fuels ensure a longer use of the large and expensive infrastructure already available.
From the cost point of view one must conclude that the calculated product prices are not competitive compared to the current market price. However the study shows that there is less than an order of magnitude difference between fuels produced from CO_2 by using renewable power and fuels produced by conventional fossil fuel routes. Interestingly the study shows that for low carbon price (<20 US$/t), the surplus cost related to CO_2 utilization is not significant in the cost of fuels. For higher CO_2 price however more in-depth study of the effect of the CO_2 capture cost, the CO_2 storage cost and capacity, and the CO_2 market prices on the cost competitiveness of CO_2 utilization technologies would be necessary.
An important factor for further research is the price of electrolysis technology in the first place. Of course the price of electricity plays a role and optimization of the sustainable sources as to price and efficiency is of utmost importance. The fact that the availability of different renewable energy sources is far lower than 100% hampers the amortization of the electrolyzer and contributes to making the hydrogen expensive. Therefore renewable power supply must come from a broader portfolio of renewable power sources (wind offshore, tidal, solar power, biomass etc…) rather than a single source.

It is obvious that CO_2 is in a transition from being a waste product to being a feedstock to chemicals and fuels. Technologies developed in efficient production of fossil carbon lean products will therefore also serve as an example for improving conventional technologies where the emphasis on sustainability has not been as stringent. Here the technological developments to be pursued encompass low temperature processes, separation enhancement, modular reactors and innovative integrated and flexible chemical conversion chains.

Distribution List

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Document Change Record

(this section shows the historical versions, with a short description of the updates)

Version	Nr of pages	Short description of change	Pages
See header	1 - xx	First version	
See header		2nd version including RD01 conclusions	

Table of Content

2 Applicable/Reference documents and Abbreviations

2.1 Applicable Documents

(Applicable Documents, including their version, are the "legal" basis to the work performed)

	Title	Doc nr	Version
AD-01d	Toezegging CATO-2b	FES10036GXDU	2010.08.05
AD-01f	Besluit wijziging project CATO2b	FES1003AQ1FU	2010.09.21
AD-02a	Consortium Agreement	CATO-2-CA	2009.09.07
AD-02b	CATO-2 Consortium Agreement	CATO-2-CA	2010.09.09
AD-03g	Program Plan 2013b	CATO2-WP0.A-D03	2013.04.01

2.2 Reference Documents

(Reference Documents are referred to in the document)

	Title	Doc nr	Version
RD-01	**Options for CO_2 use in chemical processes** Stéphane Walspurger (ECN), Mary Bastian (Shell), Donald Reinalda (Shell), Joost Smits (Shell), Hans Geerlings (Shell), Wim Haije (ECN)	CATO2-WP1.7-D01	2013.03.27

2.3 Abbreviations

(this refers to abbreviations used in this document)

CCU	Carbon Capture and Use
EOR	Enhanced oil recovery
EGR	Enhanced Gas recovery
WGS	Water-Gas Shift

3 Synopsis

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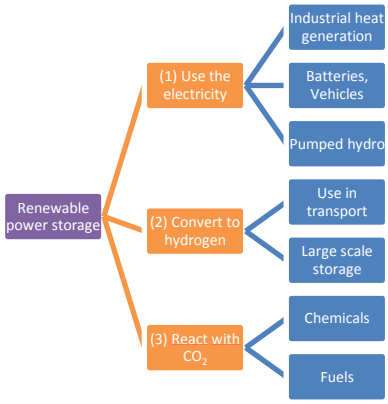

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4 Activities

Apart from some incidental meetings on Cato3 and reviewing parts of documents that have been used in the process of getting to the actual writing of the work plan, the most substantial information gathering has been through actively presenting the CCU subject at different places.
Internally this has been done at the Cato2 day end 2012, and in several ECN colloquia. Externally this has been done at the **Deltalinqs Workshop** in Rotterdam (2012), the **CO_2 as feedstock** conference in Essen (October 2013), Germany, and **the Clearwater Clean Coal Conference** in Clearwater (June 2013), Florida, USA (all invited lectures).
Observations at the international front are that CO_2 reuse in the USA is for >90% related to EOR or EGR which means CO_2 has a price. In Germany the most striking observation was the vast amounts of money that are reserved for the research needed. There were several individual projects that had budgets in excess of 50 million Euro's! The subjects were related to the production of polymers (Bayer, BASF in cooperation with a number of knowledge institutes and universities).

In relation to the RD01, the deliverable of the study performed with Shell (focus on fuel production from intermittent renewables), the opportunities for CCU are also emerging in the non-fuel branch. CO_2 as feedstock to industry, via the reverse WGS reaction is prominent at DOW Terneuzen. CO_2 emission prevention in steel works through CO export to neighbours in need of C1 feedstock is another example (indirect CO_2 use).