# Platform Climate Protection and Industry North-Rhine Westphalia – a multi stakeholder process for the advancement of energy efficiency and low-carbon technologies in energy intensive industries

Valentin Espert
Wuppertal Institute
Döppersberg 19
D-42103 Wuppertal
Germany
valentin.espert@wupperinst.org

Karin Arnold
Wuppertal Institute
Döppersberg 19
D-42103 Wuppertal
Germany
karin.arnold@wupperinst.org

Daniel Vallentin
Wuppertal Institute
ProjektZentrum Berlin der Stiftung Mercator
Neue Promenade 6
D-10178 Berlin
Germany
daniel.vallentin@wupperinst.org

Stefan Lechtenböhmer
Wuppertal Institute
Döppersberg 19
D-42103 Wuppertal
Germany
stefan.lechtenboehmer@wupperinst.org

Clemens Schneider
Wuppertal Institute
Döppersberg 19
D-42103 Wuppertal
Germany
clemens.schneider@wupperinst.org

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## Abstract

Energy intensive industries are one of the fields in which strong increases of energy efficiency and deep decarbonisation strategies are particularly challenging. Although European energy intensive industries have already achieved significant energy and greenhouse gas reductions in the past, much remains to be done to make a significant contribution to achieving European as well as national climate mitigation targets of greenhouse gas emission reductions by -80 % or more (compared to the baseline of 1990).

North Rhine-Westphalia (NRW) is a European hotspot for coping with this challenge, accommodating more than 10 % of the energy intensive industries of the EU28. It is also the first German state to have adopted its own Climate Law, enacting state-wide $CO_2$ emission reductions by 80 % until 2050 compared to 1990. The state government initiated the project "Platform Climate Protection and Industry North-Rhine Westphalia" to identify and develop the necessary far-reaching low carbon innovation strategies for energy intensive industries.

Heart of the project was a dialogue process, which involved a broad spectrum of stakeholders from steel, chemical, aluminium, cement, glass and paper producing industries. Besides enhancing and broadening the knowledge on high efficiency and low-carbon technologies within industries, the aim was to explore possible pathways and preconditions for the application of these technologies in energy intensive industries as well as to strengthen the motivation of companies for initiatives and investments in technologies with lower $CO_2$ emissions. The results of the dialogue shall provide a basis for a possible low-carbon industry roadmap NRW and may also serve as an example for other industrialized regions in the EU and globally.

The paper sketches the structured dialogue process with the stakeholders from companies as well as industrial associations and presents the learnings regarding the engagement of energy intensive industries into ambitious climate policies on a regional level. These include existing limitations as well as chances in the respective sectors on the state level, regarding their economic and technical structures as well as their innovation systems. The findings are based on more than a dozen stakeholder workshops with industry companies and more than 150 individual representatives of NRW's energy intensive industries as well as on background research in the initial phase of the project.

## Introduction: Policy context of the dialogue process

Energy-intensive materials processing industries emitted 13 % of all energy-related greenhouse gases in the EU28 in 2010 and are responsible for a large share of local air pollutants (Lechtenböhmer et al. 2015). Although significant improvements have been achieved over the past decades (Worrell et al., 2009; Fischedick et al., 2014a), meeting the EU 2050 emission reduction target of -80 to 95 % compared to 1990 (EC, 2011), requires extensive low carbon innovation. This is particularly challenging in energy intensive industries as most of them are characterised by long-term and capital intensive investments and are facing strong competition from other world regions. In spite of the relevance and complexity of deep decarbonisa-

tion of these industries approaches to speed up their innovation activities have been rare so far.

The German state of North Rhine-Westphalia (NRW) is important in this context due to the structure and extent of its economy and energy sector. A backbone of its economy is a large energy-intensive material producing industry. It accounts for more than 10 % of the energy intensive industries of the EU28, making NRW one of the largest industrial regions in Europe. 40 % of the German industrial electricity demand arises in NRW's large energy consuming companies, e.g. the steel, aluminium and chemical industry. The state's energy sector is dominated by extensive hard coal and lignite mining as well as coal-fired power production. About 30 % of Germany's electricity supply is produced in NRW (70 % coal-based, 90 % fossil-based). In NRW about 30 % of German greenhouse gas (GHG) emissions (305 $MtCO_{2eq}$ in 2012) are discharged, which is equivalent to about 6 % to 7 % of the entire EU GHG emissions (DEHSt 2014, LANUV NRW 2014). A climate-friendly transformation of the state and in particular of its energy intensive industry would therefore significantly contribute to compliance with European and national climate targets. Beyond that, it could also serve as a role model for the transformation of other industrial regions in Europe and worldwide, which are characterized by large energy-intensive industries and corresponding challenges for sustainability transitions.

In order to set a legal framework for regional climate protection measures and to contribute to national and European climate targets, NRW adopted its own Climate Protection Act. The Act obligates the state government to reduce GHG emissions by at least 25 % until 2020 and by at least 80 % until 2050 compared to 1990 levels (Landtag Nordrhein-Westfalen 2013). It mandates the development of a Climate Protection Plan which shall initiate a dialogue process with stakeholder involvement to break down the state-wide GHG reduction targets into sector-specific sub-ordinate targets (Vallentin et al. 2016). Stakeholders in the main GHG emitting sectors (e.g. industry and energy) were involved in six working groups throughout the years 2013 and 2014 in the development of climate protection strategies, measures and in the modelling of scenarios for GHG reduction pathways[1] (Lechtenböhmer et al. 2015a, Fischedick et al. 2015, MKULNV NRW 2014).

The dialogue within the industry working group and especially the participatory development of GHG reduction pathways in this sector made it clear that although NRW's energy intensive industry had already achieved significant energy and greenhouse gas reductions in the past few years, much remains to be done to make a significant contribution to achieving the NRW climate protection goals by 2050 (Lechtenböhmer et al. 2015a). It was therefore agreed among the stakeholders of the industry working group to resume and intensify the dialogue process in the aftermath of the Climate Protection Plan process. This follow-up process aimed at advancing the knowledge base in the field of energy efficiency and low-carbon technologies in energy intensive industries and identifying key topics for getting low carbon technologies needed for tapping substantial GHG mitigation potentials on track. This process was institutionalized within the framework of the project "Platform Climate Protection and Industry North-Rhine Westphalia"[2].

This paper describes the participatory approach, thematic focus, dialogue targets, stakeholders and structure of the dialogue process carried out within the "Platform Climate Protection and Industry North-Rhine Westphalia". Finally some learnings and insights from the dialogue process are presented. First some findings for the engagement of energy intensive industries for ambitious climate protection strategies and policies are described and second the existing limitations and chances on the state level, regarding economic and technical structures as well as innovation systems of each of the six energy intensive industries are presented.

## Participatory and transdisciplinary approaches – a paradigm shift in sustainability policy

The "Platform Climate Protection and Industry North-Rhine Westphalia" as a participatory, multi-stakeholder process was designed according to the emerging paradigm in sustainability policy towards innovative, actor-based approaches and research, which are often labelled as transformative or mode 2 science, transdisciplinary or participatory approaches (Lang et. al 2012). These approaches are applied to policy making but also in the realm of technological and infrastructural development processes, which are both increasingly conducted in an interplay between stakeholders of different social subsystems. In many cases, technological solutions to sustainability challenges call for integrated and comprehensive planning approaches in order to stimulate innovation. They often involve a large set of heterogeneous stakeholders from the scientific arena as well as from the private and public sectors. Consequently, tackling sustainability challenges successfully requires new collaborative approaches. The latter have in common that they involve actors within and outside academia, address real-world problems in an application oriented way and can be understood as new ways of knowledge production. By creating ownership for the addressed sustainability problems and by improving social legitimacy of governance results, these approaches are seen as important instruments for the implementation of sustainability measures and strategies (Lang et al. 2012).

Participatory multi-stakeholder processes offer a number of assets, which are deemed as beneficial for sustainability governance on the sub-national level. In the case of the "Platform Climate Protection and Industry North-Rhine Westphalia", they were used to identify key strategies for a low carbon development in NRW's energy intensive industries, understand leverage points for fostering low carbon innovation within the regional innovation systems and specify the policy support needed.

From a multi-level policy perspective, industry policy in the realm of energy efficiency and decarbonisation predominately takes place on the national and European level. Therefore, regional policy such as in NRW has restrictions with regard to regulative powers, which might bind companies to achieve low

1. A final draft of the plan was handed over to the state parliament in 2015. It is envisaged to conclude the process in 2016 with the legally binding enactment of the CPP (Vallentin 2016).

2. The "Platform Climate Protection and Industry North-Rhine Westphalia" was steered by the Wuppertal Institute and CleanTechNRW on behalf of the NRW Environment Ministry (MKULNV). The project started in April 2014 and was finished in summer 2015 (Lechtenböhmer et al. 2015b).

carbon production processes and products. By initiating a participatory process, the regional government therefore adopts an "enabling approach" of governance. This approach aims at the involvement and motivation of firms to self impose low carbon innovation strategies (e.g. negotiated agreements) and tries to identify capacities, which are necessary for the firms to do so. It serves as a supplement to policy making on national and European levels.

Furthermore, participatory approaches foster the establishment of new actor networks and initiatives, which can be understood as crucial for the implementation of low carbon strategies on the regional and local level. This is especially relevant for the low carbon innovation strategies addressed here, as they require a substantial amount of investment capital and R&D infrastructure which is more likely to be provided on an inter-firm level then by single firms alone – particularly but not only in sectors characterized by a large share of small and medium sized enterprises. Moreover, low carbon innovation is a long term process which rarely provides short term benefits, which is why networks of companies and research institutions in a competitive free environment can be seen as important first steps of developments in this technological realm.

## Thematic focus of the dialogue process

The discussions and outcomes of the industry working group of the preceding CPP formed the basis for the dialogue among energy-intensive industries within the "Platform Climate Protection and Industry North-Rhine Westphalia". Whilst it was recognized that the industry in NRW has already achieved significant energy and greenhouse gas reductions in the past few years, it was common sense among the participants that ambitious strategies for process optimization and innovation have to be applied in the next decades in order to achieve the state's climate target for 2050. For this to be successful, two strategies were identified (Schneider et al. 2014):

On the one hand, industrial decision makers should promote and use best available technologies (BAT) in all industrial operations. However, it was understood that, if applied solely, the BAT-strategy would not suffice to reach the ambitious climate protection targets. Therefore, this strategy was accompanied by an approach which combined BAT technologies with improved low-carbon technologies including breakthrough technologies. These technologies promise higher GHG mitigation potentials than most BAT through adjustments of production processes or products. Often, however, these technologies are targeting emission reductions by switching energy sources, e.g. renewable electricity or end of pipe technologies to reduce emissions. In these cases energy efficiency is typically not increased (Lechtenböhmer 2015a, Schneider 2014) which mostly functions as a strong incentive for companies to invest in new technologies (Nilsson 2015, Ahman 2016, Wesseling 2016). As a consequence, incentives for industry to invest into capital-intensive low carbon technologies are rather low in many cases.

In contrast to BAT, most low-carbon technologies are in a very early state of the innovation cycle (see Table 1 in Wesseling et al., 2016 where for a couple of such technologies the respective TRLs are given). So as a first step, it would be necessary to increase the knowledge base in this field of technology development. This should include answers to questions such as in which specific industrial processes low-carbon technologies might increase energy efficiency and which systemic conditions were required to support the prospective market introduction of these technologies. In order to fill this knowledge gap and to address these questions, the "Platform Climate Protection and Industry North-Rhine Westphalia" was initiated.

## Dialogue targets

Besides enhancing the knowledge on low-carbon technologies in energy-intensive industries, the aim of the "Platform Climate Protection and Industry North-Rhine Westphalia" was to explore possible pathways and preconditions for the application of these technologies in the private sector in NRW as well as to strengthen the motivation of entrepreneurs for initiatives and investments in technologies with significantly lower $CO_2$ emissions. The overall aim was to develop sector-specific low-carbon strategies and identify potentials for domestic industrial players, taking into account the existing regional innovation networks. The results were meant to provide the basis for a low-carbon roadmap for the industry in North-Rhine Westphalia.

The specific targets of the dialogue platform were:

- Deepening the dialogue with energy intensive industries with a focus on the specific challenges in each sector, as a follow up to the stakeholder process of the Climate Protection Plan;
- Identification of possible technological strategies in six energy intensive industries and evaluation of their potential contribution to climate protection in NRW;
- Derivation of challenges and existing networks for innovation among industries in the state;
- Discussion of the necessary systemic conditions and development of approaches for an innovation agenda for the energy-intensive industry in North Rhine-Westphalia;
- Identification of synergies and cooperation opportunities with other industries.

## Stakeholders

The basis for the selection of stakeholders for the dialogue process was the industry sector working group of the Climate Protection Plan NRW. It included representatives of companies and industries associations, trade unions, chambers of commerce, environment/conservation and consumer organisations, associations of municipalities, academia and others (Lechtenböhmer 2015a). For the "Platform Climate Protection and Industry" companies from six energy intensive industries and the respective industry associations were invited to participate. The focus hereby was on steel, chemical, aluminium industry, cement and glass industry as well as paper production. In total more than 150 single actors from the relevant energy intensive industries in NRW participated in the diverse dialogue formats of the project.

This approach of stakeholder selection corresponded with two central targets of the dialogue process. On the one hand, the previous dialogue of the Climate Protection Plan was meant to be resumed and intensified. On the other hand, it was envis-

aged to focus the discussion on specific low-carbon strategies in the addressed energy intensive industry branches and develop agendas with key topics for research and development to foster a low carbon development in all six energy intensive industries. This had not been possible in the participatory process of the Climate Protection Plan where a large number of industry branches with individual challenges and potentials were involved. Further to the representatives from the energy intensive industries, environmental organizations were involved in the dialogue process in order to incorporate the socio-ecological perspective in the discussions.

## Structure of the dialogue process

Figure 1 illustrates the structure of the dialogue process designed within the Platform Climate Protection and Industry North-Rhine Westphalia. It consists of four main phases which were conducted for all six industries in parallel.

In the **preparation phase**, a scientific background analysis was conducted which focused on existing low-carbon strategies and roadmaps of the invited industry branches. Especially at the European level several industries such as steel (EUROFER 2013), pulp and paper (CEPI 2011), aluminium (EEA (2012) and glass (Glass for Europe 2013) have developed roadmaps for ambitious energy efficient and low-carbon innovations. These roadmaps were used to identify starting points for the discussion of specific low-carbon strategies for energy intensive industries in NRW. In order to conduct a regionalization of these European roadmaps, questions concerning the industry specific structure of supply chains and production processes in NRW as well as the regional innovation systems were taken into account. For example, the paper industry in NRW doesn't comprise any facilities and R&D institutions for pulp production so that low-carbon innovations in this technology field are not relevant for NRW. Furthermore, in the first phase a stakeholder analysis was carried out with the objective to identify companies and actors with relevance for the dialogue process and the topics under consideration.

In the **conceptualisation phase**, preliminary talks were conducted with selected stakeholders from every industry sector in order to elaborate in-depth tailored dialogue concepts. These dialogue concepts included proposals for dialogue formats, thematic starting points and stakeholders to be invited for the identification of low-carbon innovations in the particular industry branches. Primary contact persons in this phase came from industry associations, which functioned as multipliers in their branch as well as key experts for the respective innovation chains. This procedure was in line with the transdisciplinary approach of the dialogue process, claiming that the stakeholders should already be involved in the setting up and conceptualisation of the process and in order to insure a larger degree of acceptance and commitment of the participants.

The **implementation phase** constituted the actual dialogue with the representatives from industry companies and associations as well as selected participants from scientific institutes and state government. Sector wise round tables and workshops were organized which served as a platform for the discussion of the central topics and questions of the dialogue process such as in which specific industrial processes low-carbon technologies might increase energy efficiency and which systemic conditions are required to support the prospective market introduction of these technologies. The specific sequence and amount of dialogue events differed slightly among the six industry branches depending on the need for discussion.

In the final **specification phase**, the findings of the dialogue process were consolidated and specified with a focus on their cross-sectoral relevance. The background for this is that key low-carbon innovations for energy intensive industries (in NRW), such as industrial symbiosis or carbon capture and use, concern multiple branches. Therefore, the dialogue platform aimed at engaging different industry stakeholders in a mutual dialogue to identify starting points for common innovation approaches in these technology fields. Furthermore, the results of the dialogue process were presented and discussed with representatives from environmental organizations in NRW in order to incorporate the socio-ecological perspective.

The main results of the dialogue process were consolidated within industry-specific strategy papers. Besides describing constraints and conditions for R&D activities these papers comprise as a central component an indicative proposal for low-carbon innovation agendas for the analysed industries. These agendas consist of low-carbon technologies (or technology fields) which were deemed by the stakeholders as innova-

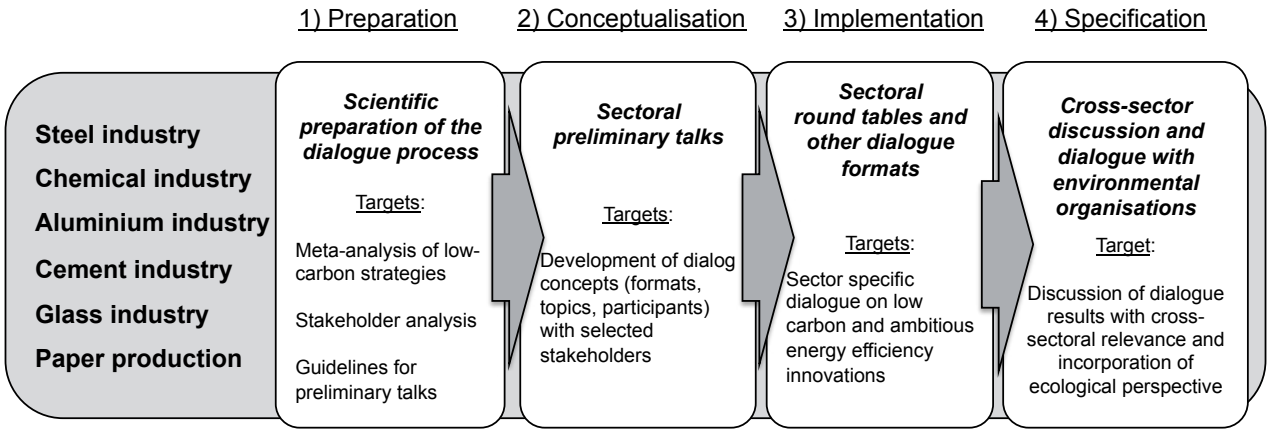


*Figure 1. Structure of the dialogue process with energy intensive industries in NRW (own figure).*

**Table 1. Content and structure of industry-specific low-carbon strategy papers.**

| |
|---|
| *1. Industry-specific constraints and conditions* |
| • Economic development prospects<br>• Specific NRW challenges and chances as opposed to national and European level |
| *2. Existing innovation system* |
| • Strategic factors with regard to research institutions and industry based innovation capacities<br>• Potential industry-specific and cross-industry research priorities for business and science in NRW |
| *3. Innovation agenda for NRW* |
| • Main low-carbon technologies for climate change mitigation paths of the North Rhine-Westphalia industry<br>• Derivation of necessary conditions and incentives for the implementation of the research priorities<br>• Derivation of possible next steps in developing an innovation strategy for NRW |

tions that could contribute to a climate-friendly transformation of energy-intensive industries in NRW in the long-term as far as supporting economic and political framework conditions are given (Table 1).

## Strength and weaknesses of a regional approach to industry decarbonisation – results by sector

As a part of the project all six industries were evaluated regarding their potentials and challenges for low carbon innovation in the companies located in NRW and with regards to their (regional) innovation network. In the following we briefly describe the respective conditions of all sectors by touching upon there respective innovation systems, their general economic structure in the country as well as technological or structural chances or limitations for the implementation of low carbon strategies.

### ALUMINIUM INDUSTRY

The aluminium industry is characterised by strong international competition. Globally, the largest producers of aluminium oxide are China and Australia whose production volumes sum up to a global market share beyond 60 %. With regard to primary aluminium, China, Russia and Canada hold more than 50 % of the global production volume. The market share of Western Europe is only 5 % (IEA 2009). In line with this development, primary aluminium production in Germany continuously declined in the last years. Today, four production plants are still operating mainly because their facilities are widely depreciated and due to their vicinity to aluminium processing plants (Fraunhofer ISI et al. 2011).

Contrary to primary aluminium production, processing aluminium to a broad set of products is a growing market in Germany. This implies that that the focus of the German aluminium industry lies on later stages of the value chain while it is a net-importer when it comes to earlier stages of the chain, such as production of aluminium oxide and primary aluminium. Nonetheless, the aluminium industry is of high economic relevance for Germany and North-Rhine Westphalia in particular where three major industrial players (Trimet, Aluminium Norf and Hydro) are being active. Overall, the German aluminium production and processing industry employs about 74,000 people (GDA 2011).

High cost pressure on the one hand and a strong focus on producing innovative products from aluminium require innovation activities both when it comes to production and processing of aluminium as well as the product set. In Germany and especially North Rhine-Westphalia, there is a broad network of experts from science and industry, which possess profound knowledge on technology innovations at the different value creation chain stages. Considering heat treatment and smelting of aluminium, the Institute for Industry Furnaces and Heat Technology (IOB) at the Technical University of Aachen (RWTH Aachen) as well as the Gas and Heat Institute Essen (GWI) hold important expertise. With regard to optimising the electrolysis process, there is expertise at the University of Wuppertal. Furthermore, the Aluminium Engineering Center (aec) at the Technical University of Aachen which is a consortium of ten different research institutes focusing on different dimensions of aluminium production and processing as well the Open-Innovation Cluster AMAP (Advanced Metals and Processes) are important players in driving and coordinating research and development in the German aluminium industry (Lechtenböhmer et al 2015b).

### CEMENT INDUSTRY

Cement industry in NRW relies on lime stone deposits situated in the rural north-eastern part of the state as well as blast furnace slag (as a by-product of steel production). There are several medium-sized companies managed by the owning families but also sites run by multinational players (HeidelbergCement, Dyckerhoff, cemex, LafargeHolcim).

Cement is still a regionally traded product. NRW's cement industry serves the home market (NRW) and adjacent regions, especially the Netherlands, where appropriate lime stone deposits are lacking. The clinker ovens in NRW are small to medium sized and relatively old. The latest investment into a new clinker oven took place in 2001.

The multinational companies do have their headquarters and R&D departments outside NRW but the most important European non-university cement research institute is situated in NRW's capital Düsseldorf. ECRA is a R&D service provider for the funding cement companies and coordinates most of non-university cement research in Europe including expensive CCS research with a pilot plant in Norway.

Another non-university research institute in NRW dealing with construction material is the FEHs (Building Materials Institute) at Duisburg, which is strongly connected to the steel industry and the manufacture of iron and steel slags which can partly substitute $CO_2$ intensive clinker production from limestone. Cement research at universities is quite weak in NRW. At the University of Siegen there is a chair on construction material chemistry, but the RWTH Aachen as the most promi-

nent technical university in NRW, does not have any chair on cement research any more. Outside NRW there are university chairs at Karlsruhe, Clausthal and Weimar.

Research on break-through technologies in cement production like carbon capture and storage (CCS) as well as alternative low carbon cements (Lechtenböhmer et al, 2015c) or electricity based cement production is capital intensive and can neither be carried out by single NRW situated companies nor funded by a single federal state. Fuel costs are an important economic factor for the cement industry, but, with very low costs for $CO_2$ emission certificates in the European Emission Trading Scheme (ETS) at the time, the micro economic incentives to invest in R&D of low carbon cements are very low and can only be provided by supra-company networks co-funded by public research funds.

#### CHEMICAL INDUSTRY

The chemical industry and their downstream value chain is a research-intensive industry. As well, the chemical industry demands highly qualified personnel. Thus, along the whole value chain, an intensive collaboration of universities, research institutes and industrial and commercial partners exists. Within that, the chemical industry benefits from an efficient and competitive basic research in many fields of chemistry as well as a good professional and university education of specialists.

The association of the chemical industry (VCI) is an active group, especially in NRW, where a dedicated working group on "innovation" exists that meets regularly and gave the PKI project the opportunity to participate and discuss the low carbon innovation systems.

Another resource has been an Enquete Commission by the state parliament on the "Future of the chemical industry in NRW, regarding sustainable raw material basis, products and production processes". This commission has been working from 2013 to 2015 and presented a detailed and broad overview of the challenges and barriers of the chemical industry in NRW. Regarding the innovation system, it mentions the strong and lively network of research and companies (Landtag Nordrhein-Westfalen, 2015).

The German chemical industry is one of the biggest German industries with half a million employees in about 2,000 companies and ca. EUR 190 billion turnover. Of those, about 400 companies with 100,000 employees and a turnover of about EUR 50 billion are based in NRW (VCI NRW 2016). Many of the bigger companies, such as Bayer/Covestro, Altana, Evonic etc. are firms operating internationally. In that case, the decisions about R&D are not always taking place in local branches. On the other hand, more than 80 % of the chemical industry's companies are medium-sized companies (VCI NRW 2016).

Large parts of the chemical industries deal with energy-intensive production processes, which are to a high degree dependent on competitive energy prices. Thus, regarding energy costs, the chemical industry in Germany and NRW is under pressure, as other countries have structural advantages on energy costs that probably will remain relevant in the future. For example the development of energy prices in the United States due to the availability of shale gas causes significant locational advantages and investments.

The situation of markets and market developments of the different segments of the chemical industry is quite complex, as the segments are very diverse: the production framework and market conditions of base chemicals, petro chemicals and special chemicals, to name only few of them, have each to be considered separately. Generally it has to be stated, that the markets are each characterised by their respective supply and demand, interdependencies of production processes and co-products, quantitative restrictions and the resulting economical feasible transport distance.

The chemical industry can be found in many value chains and is often located in the beginning of those. Inorganic and organic base chemicals are part of most industrial as well as consumer goods, for example as part of fertilizers and agrochemicals, washing and personal hygiene products, varnish and paintwork, adhesives, coating, in pharmaceuticals, in packaging material or as composite materials in the automotive sector.

Chemical industry in NRW therefore benefits especially from the high density of producing industries in the region as it strengthens networks and enables synergies between various chains and their parts.

#### GLASS INDUSTRY

Regarding R&D the current structure consisting of several small producers which are often part of larger multinational companies limits the available capacities as well as competence for decision making. There is, however, one larger company research centre as well as a university chair (Institut für Gesteinshüttenkunde) covering glass related research; both in the Aachen region. Furthermore, the Gas to Heat institute (GWI) in Essen is an important player with regard to combustion technology in the sector. Another relevant player in glass technology related research is University of Erlangen (Bavaria) as well as the industry's own research institution in Offenbach (Hesse).

Glass industry in NRW covers most sub-segments of the sector, particularly flat glass, glass containers and glass fibres. The industry itself is mainly supplying other industries such as construction (flat glass and fibres), car industry (flat glass) and food (glass containers). All sub-segments have a number of specialized production sites. European flat glass industry is dominated by four big companies, two of which (Pilkington, Saint Gobain) are operating five production sites in NRW, one of them being the largest in Europe (Lechtenböhmer et al. 2015b).

Due to strong and increasing competition from Eastern European and Northern African producers glass industry in general is under significant pressure. Apart from specialisation in several niches, particularly flat glass producers claim to be highly innovative delivering high tech glasses to construction and car manufacturing, which gives them a competitive edge over producers from outside the EU (Lechtenböhmer et al. 2015b).

Besides high CAPEX of the complex factories (mainly in flat glass production) fuel costs and emissions play a significant role making energy efficiency and GHG mitigation strategies (including the use of biogenic gases) relevant for the sector. Another important issue for the sector are possible future changes in gas quality, e.g. due to feed in of hydrogen produced from excess electricity – as the stoichiometrics of the gas is important for glass melting. Switching of the glass melting to electric heating is possible in smaller scales (and practised at some sites today). It does impose, however, technical challenges for larger scale production (Lechtenböhmer et al, 2015c).

#### PAPER PRODUCTION

An obstacle for a low carbon innovations in the NRW paper industry is the lack of sector specific R&D facilities on the regional level. Major research of the paper industry is conducted on the European level, for instance by the Confederation of European Paper Industries (CEPI) or in large company research centres outside of NRW and Germany (e.g. in the Scandinavian countries). Especially with regard to research on radical innovations in the field of low carbon technologies, CEPI plays an important role. This non-profit roof organization for the European pulp, paper and board industries provides the institutional capacities to bring different actors from the company level and research institutions together in order to conduct research and strategy development beyond the competitive environment of individual firms. With the "2050 Roadmap to a low-carbon bio-economy" (CEPI 2011) and the associated "Two Team Project" (CEPI 2013) possible technologies and pathways for a long term decarbonisation of the pulp and paper industry were explored. However, whilst the major paper producing firms in NRW are members of CEPI, the immediate impact of innovation strategies formulated on the EU level was regarded as rather low by the stakeholders of the dialogue process due to the above named characteristics of the innovation system of the paper industry in NRW.

The paper industry in NRW is characterized on the one hand by small and medium-sized enterprises which are only active in paper and cardboard production but do not produce pulp. Due to their position in the competitive environment and in particular their small amount of investment capital they do not see themselves in the forefront of their sector's technology development. On the other hand, large companies of the paper industry in NRW have their headquarters outside of NRW and Germany, for example in Scandinavia. Thus, major investment decisions and strategic research decisions are not made on the regional level of NRW. In addition the general economic challenges of the branch were regarded as limiting factors for low carbon R&D activities (Lechtenböhmer et al. 2015b). Major challenges for the paper industry are the international competitive pressure and excess production capacities partly due to declining demand in some segments, the costs and availability of resources (pulp, recovered paper) and the demand for skilled workforce (Dispan 2013). In particular small and medium enterprises therefore have as a major priority the safeguarding of economic activities in the short term whereas less resources are assigned to long term innovation strategies.

Despite the above sketched restrictions to low carbon innovation activities in the paper industry in NRW, energy efficiency measures are generally of high relevance for the industry due to its energy intensive structure and their high share of energy costs. However, as the sector already achieved significant improvements in the energy efficiency of production processes in the past decades (Dispan 2013), further innovations in this field face technological restrictions. Innovations in the paper industry in NRW are expected to be rather incremental – that is an optimization of existing processes and products – than radical. Because of the extent, capital need and complexity of the plants and machinery for paper production, breakthrough innovations are more likely on an inter-firm level, e.g. by industry associations on the European level, than by single actors on a regional scale. Potentially interesting issues hereby are in the long term the waterless paper production and cross-sectoral issues, such as cooperative innovation strategies with the chemical industry in the field of an integrated bio-economy (CEPI 2011).

#### STEEL INDUSTRY

The steel industry is a highly concentrated industry branch with few multi-national companies dominating the global steel production market. In Germany, the steel industry's employees number totals 85,000, more than half of which are based in Duisburg, North Rhine-Westphalia – the heart of Germany's steel industry. The value chain of steel production in North Rhine-Westphalia is widely closed as most steel production sites are designed as integrated plants, in which primary steel production is followed by further processing steps before achieving the desired end product. The product portfolio of North-Rhine Westphalia's steel industry is dominated by high-quality steel types, representing more than 50 % of the overall product portfolio (Rotering et al. 2012). These high-quality steel types are often tailor-made towards the needs of major steel-consuming industries, such as the automobile industry or the mechanical engineering industry. Both industries are also strongly represented in North Rhine-Westphalia. Therefore, the short distance among steel suppliers and users as well as long standing supply chain relations among these industries are important assets of NRW as an industry location.

Highly-specialised and high-quality steel types require specialised know-how and a well-established innovation system to constantly improve the product portfolio, helping to maintain competitive advantage towards other producers. For that purpose, there is a close collaboration among ThyssenKruppSteel and the University of Duisburg-Essen (especially the Department for Technologies of Metals) and the Ruhr University in Bochum, which focus on basic research as well as material science and simulation. Research activities of the steel industry itself are mainly based at the Steel Centre in Düsseldorf, capital of North Rhine-Westphalia. Among the organisations based under the roof of this Centre are the Research Association for Steel Utilisation (FOSTA), Max Planck Institute for Iron Research (MPIE) as well as the Steel Information Centre (S-I-Z).

Climate policy creates pressure on the value creation chain of the steel industry both from a process and a product perspective. With regard to production processes, the climate policy framework at all levels (European, federal and state level) brings along a clear message to the industry to optimise production processes and reap efficiency potentials as far as possible. However, efficiency improvements are also driven by competition with low-cost steel producers in emerging economies, especially in China. Tapping mid- to long-term carbon mitigation targets, in turn, requires substantial and partly even radical modification of production processes and plant designs, e.g. when using hydrogen for iron reduction or installing less energy-intensive furnace designs. Here, further technological innovations are needed in order to improve the economic viability of low-carbon steel production technologies. Considering the product side, steel products are facing increasing competition in some market segments by lighter alternative materials or products.

## Learnings for the engagement of energy intensive industries in ambitious climate policies

Generally speaking, the main targets of the dialogue process – to improve the knowledge base among the stakeholders in the field of low-carbon innovations and develop industry-specific R&D agendas for developing key low carbon technologies – was achieved. The stakeholders had a high degree of commitment in discussing and elaborating proposals for industry-specific innovation agendas in a both constructive and controversial manner. It can be assumed that the trust and cooperation patterns established in the preceding process of the Climate Protection Plan NRW was important to achieve a constructive and trustworthy dialogue. This dialogue process was characterized by a highly productive discussion culture, trust building among stakeholders that did not cooperate intensively before and created mutual awareness among stakeholders about diverging perspectives.

Next to the target of the dialogue platform of improving the knowledge base about low-carbon innovations among stakeholders, the process generated further learnings with regard to the engagement of energy intensive industries and their stakeholders in ambitious climate policies and in particular the participatory development of low-carbon innovation strategies:

- The long term perspective (e.g. until 2050) was difficult to discuss with industry stakeholders and particularly hard to convert into concrete R&D proposals, as the time span of conventional R&D activities in companies are short- or medium-term oriented. The deep decarbonisation innovations taken into account in the dialogue process, however, are long term oriented and partly radical. This means that they are not only expensive but their realisation could also have disruptive effects on existing industrial operation modes.
- Other problems could be identified in the economic and technical structures of some of the sectors in NRW:
  - Particularly cement, paper and glass but also aluminium processing industries are dominated by SMEs of which some are owned by larger multinationals who have their headquarters typically not in NRW. In all three sectors companies are struggling to fund innovations of a significant size, which are covering more than mere process improvements, either because of their size and limited financial assets or because of heavy competition within multinationals and strategic decisions in this field being made in company headquarters outside of NRW. For paper industry the lack of integrated domestic pulp production cuts them off from many of the low carbon visions, which have been put forward by their industry. Cement and glass industry, however, due to their regional concentration and possibly also because of historical reasons both operate important sectoral research facilities in NRW, offering them potentials to be among the forerunners of low carbon innovations. State R&D policy, however, could help those sectors by better supporting public funded as well as university research in low carbon technologies for those sectors, as this would strengthen the existing research structure of these sectors and improve their innovation potentials.
  - Steel and chemical industry are different. In both sectors important headquarters are located in NRW and both form important regional clusters in their industries. Both also obtain of extensive networks of company research, industry related research institutions as well as dedicated university research within the region and abroad. Limits for innovation here could result from fierce competition at least for most basic materials. Also some companies in NRW are economically profiting from existing assets which makes it more difficult for them to exploit more radical innovations. Therefore existing approaches, such as the Enquete Commission by the state parliament are important initiatives and need to be expanded and stronger targeted with regards to low carbon innovation.
- Another barrier with regard to the elaboration of innovation strategies was, that many LC-solutions (e.g. in steel industry) would not benefit from financial NRW-support as the needed capital is much too high (EU-level at least). Therefore, the regional political framework of NRW wasn't regarded as the appropriate address of the dialogue topics. European R&D efforts like the ULCOS project or even global approaches seem to be more appropriate. Therefore the state of NRW should try to identify how it could foster the strategic position of its industrial players in such international R&D efforts.
- Potentially interesting issues seem to be cross-sectoral topics (chemical industry with pulp and paper and with steel, steel & cement; e.g. industrial symbiosis, CCU) and include the process and value chain. Here a stronger integration seems to be a good idea but makes the dialogue broader and more complicated. Identification of innovations across sectors seems to be a promising field in which the assets of the diversified energy intensive industry structure of NRW could be an advantage. Apart from already on going cooperation projects between steel and chemical industry these, however, are still to be explored and developed. Due to the fact that concrete outcomes for the industries are still far ahead, this field should be supported intensively by public funded R&D.

Concluding, it can be stated that climate goals as well as long term economic development of industrial regions such as NRW are closely linked to progress in energy intensive producing industries. In spite of the fact that low carbon innovations in these sectors are very long term and will often not developed in one region alone they can play an active role in supporting their industries innovation systems and thereby fostering their capability to innovate.

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