Workshop report on electrification in climate protection scenarios

Deliverable 4.6

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Introduction

Background

Among the options for greenhouse gas mitigation in the heavy industry, electrification of processes is considered an important pillar. Since renewable energy potentials in North Rhine-Westphalia are limited, its actual implementation admittedly represents a challenge. So far, potential ways forward have been described in a variety of scenario studies. However, these are rather general and not location-specific. Therefore, in the framework of the REINVENT project we aim at creating viable location-specific scenarios for the steel, chemicals and pulp and paper industry, which show how industry clusters could achieve far-reaching electrification.

Objective

During our workshop we conducted an in-depth exploration of potential electrification storylines. The aim was to enrich existing storylines with regard to the roles of industrial companies, utilities, consumers, politics, society and research. Furthermore, feasible combinations of pathways and related timelines as well as possibly fore-running regions should be identified. In order to achieve this, we combined the unique knowledge of the SCI4Climate and REINVENT projects, thus inviting experts from North Rhine-Westphalia (NRW) and different European countries from industry and science. The results of the discussion provide valuable input into scenario storylines for the EU framework scenarios to be calculated in REINVENT (by WI and PBL) and also for NRW scenarios to be developed later on in the SCI4Climate project.

Participants

Name	Institution	
Max Åhman	Lund University	
Valentin Vogl	Lund University	
Mariësse van Sluisveld	PBL/Utrecht University	(online participation)
Harmen-Sytze de Boer	PBL/Utrecht University	(online participation)
Theresa Overbeck	VDEh Institute for Applied Research	
Rüdiger Franck	Currenta	
Ulrich Seifert	Fraunhofer UMSICHT	
Clemens Schneider	Wuppertal Institut	
Katharina Knoop	Wuppertal Institut	
Mathieu Saurat	Wuppertal Institut	(online participation)
Frank Merten	Wuppertal Institut	
Stefan Lechtenböhmer	Wuppertal Institut	
Dario Zander	Wuppertal Institut	

Agenda

Friday, June 28th, 2019, 10:00-14:00

Wuppertal Institute for Climate, Environment, Energy, Döppersberg 19, 42103 Wuppertal, Germany

Time	Agenda item
10.00 – 10.10	Welcome and introduction
10.10 – 10.20	Introduction projects REINVENT & SCI4Climate.NRW
10.20 -10.50	**Session 0: All-electric industry 2050** Thought experiment
10.50 – 12.15	**Session 1: Electrification of steel, chemicals and pulp & paper industry** Presentation: Future primary steel production in Europe based on hydrogen-based DRI (Max Åhman, Lund University) Presentation: Chemicals and paper – a future union in an electrified (and circular) world? (Clemens Schneider, Wuppertal Institut) Discussion in smaller groups Plenary
12.15 – 12.45	Lunch
12.45 – 13.45	**Session 2: How can industrial regions adapt to an electrification strategy?** Presentation: Impacts of far-reaching electrification on EU regions (like NRW) (Clemens Schneider & Stefan Lechtenböhmer, Wuppertal Institut) Discussion in smaller groups Plenary
13.45 – 14.00	Feedback & Goodbye

This workshop report summarises key messages from the presentations and subsequent discussions.

Session 0: All-electric industry 2050

After introducing the participants to the REINVENT and SCI4climate.NRW projects, the background and objectives of the workshop (see Introduction) were recalled before starting with Session 0. In the framework of this 'warm-up session', participants were asked to imagine work life in a steel or paper producing company or a chemical park in 2050. Each of the companies in the break-out groups should focus on electricity as an energy carrier. One chemical park and two companies from the pulp and paper sector resulted from this exercise:

"Chemical Park"

Chemical Park relies on existing processes to refine basic chemicals but replaces conventional by renewable feedstocks. For security of supply it needs both electricity and gas supply. Hence, its energy partners are producers of renewable energy (e.g. wind parks) and gas (renewable base chemicals such as H_2, CH_4 (or H_2 and CO_2) and clean liquid base chemicals (feedstock) e.g. from waste pyrolysis and internal CO_2 recycling). Heat is stored on-site (which is also a good way to store some electricity indirectly on-site with the option to produce electricity in a CHP). For more electricity storage, external partnerships are required. The market will regulate which and how much storage options are available. Processes remain continuous processes (i.e. no flexibility there) but flexibility can be provided by the energy system around it (amongst others heat and electricity storage). Process operations will be controlled by a digital system.

"Innopaper"

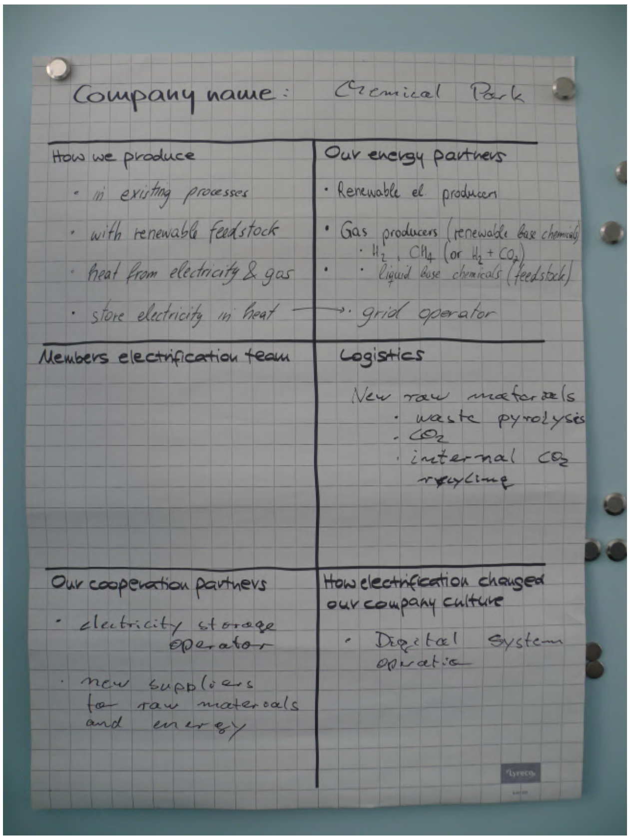
InnoPaper is a very innovative SME (pretty rare) producing paper (not pulp). It produces (almost) without water[1] , maybe by means of alcohol, so the energy need for drying is massively reduced compared to today's levels. Furthermore, it reduces its primary energy consumption processing waste heat of other sectors (e.g. H_2O electrolysis) and using heatpumps. From the partnering hydrogen facility also residual oxygen can be used for bleaching. Although the company produces a comparatively sustainable product (compared to plastics), it still needs to work a lot with its customers on innovative designs and with universities on innovative production processes. This is due to the focus on electrification, which resulted in higher innovation pressure and customer orientation.

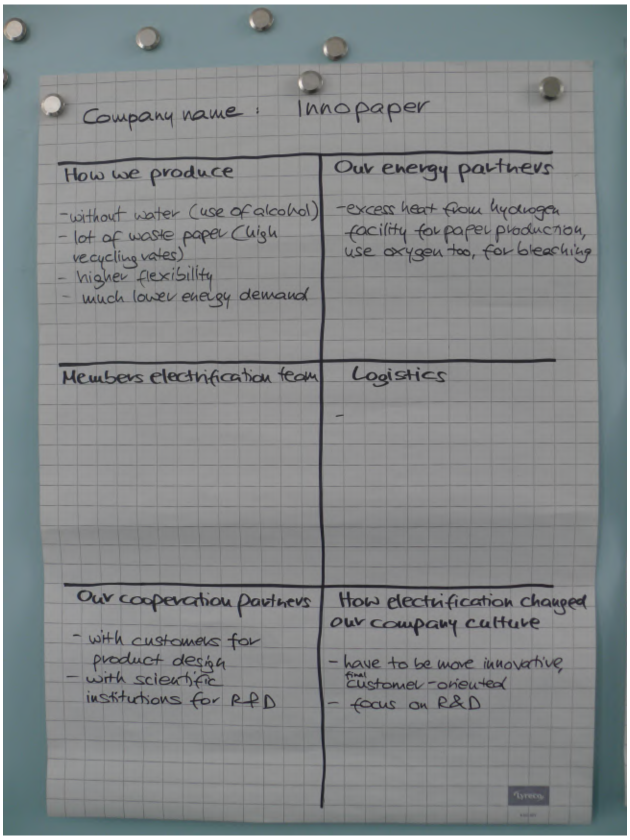
P&P 2050

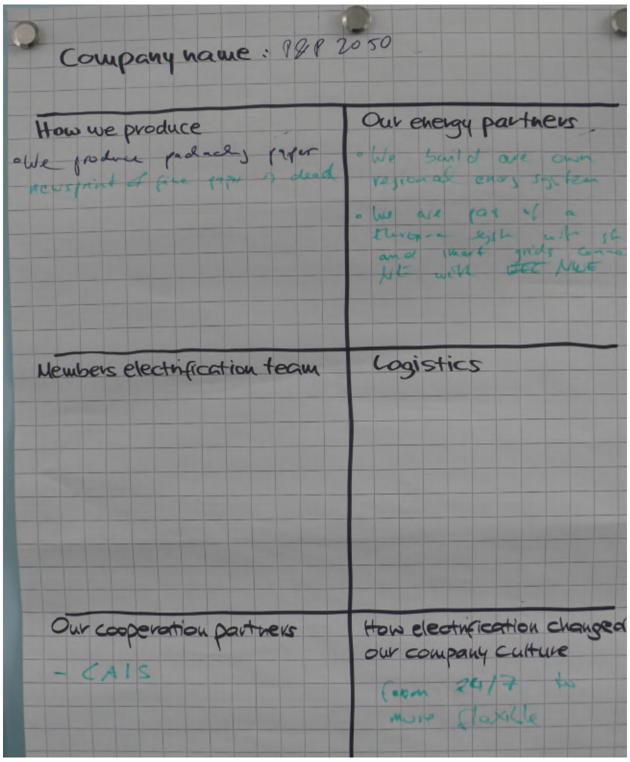
P&P 2050 is also a company from the paper sector which produces pulp and packaging paper as there is no market anymore for newsprint and fine paper. It owns a lot of forestland with plenty of biogenic resources in Scandinavia. Regarding energy supply, the firm has built its own regional energy system sourcing wind and bio energy. Furthermore, it is part of a European energy system, where smart electricity grids connect Northern Europe with North-Western Europe. With increasing electrification of its production processes, production and working times have been becoming more and more flexible during the last decade from 2040 to 2050.

[1] for more information on dry defibration see e.g. a presentation by T. Schrinner, TU Dresden (2017): https://www.gzs.si/LinkClick.aspx?fileticket=V2PkLoeeuOA%3D&portalid=183

Flip charts from the Session 0 break-out groups:







Session 1: Electrification of steel, chemicals and pulp & paper industry

In the framework of Session 1, workshop participants discussed the potential role of electrification in the sectors steel, chemicals and pulp & paper as well as for utilities. While electrification represents kind of a 'megatrend', it is not a target of its own but can support the avoidance of fossil-based energy carriers (if electricity comes from renewable sources). Generally, direct use of renewable electricity in industry is the most efficient way of using a final energy carrier. In contrast, indirect electrification (transforming electricity into a new final energy carrier such as H_2) is the most inefficient way to use primary energy – at least in a static way of looking at the energy system.

Steel

Outlook (based on the presentation by Max Åhman, Lund University)

With regard to future primary steel production in Europe, electrification represents the alternative production route to current blast furnaces (the GHG emissions of which could be mainly reduced by CCSU). In order to reach net-zero emissions, the use of fossil fuels as reduction agent and energy source is required. On the one hand, this can be achieved by electrowinning, i.e. the direct electrolysis of iron ore fines into iron. On the other hand, coke (or natural gas) can be replaced by 'green' hydrogen in the direct reduction process.

Such radical changes in the steel production process bring along new challenges regarding framework conditions. Large amounts of renewable electricity or hydrogen are required and become the main cost component for steel producers. Furthermore, the appropriate infrastructure is needed in form of a transmission/distribution grid and/or hydrogen pipelines.

For Europe, an important question is how much primary production will be required by 2050 since demand for primary steel could decline. In conjunction with the saturation of consumer demand, the main reason for this would be the increasing availability of scrap, which contributes to higher levels of secondary steel production (in electric arc furnaces).

The potential decoupling of the iron making and the steelmaking step in an electrified process layout allows for greater geographic flexibility regarding the site selection of steel production facilities: The most energy intensive reduction process could take place at iron ore mines (e.g. in Sweden, Ukraine, Australia, Canada), at hydrogen production sites (e.g. in Saudi Arabia, Mexico, USA) or using the infrastructures at existing steel mills (e.g. Duisburg/Germany or Luleå/Sweden).

Discussion in the break-out group

With regard to an electrification of the steel industry, the following issues have been discussed by the break-out group:

- **Technological issues**
  Industry experts in the break-out group on steel believe electric arc furnaces (EAF) will play a bigger role in the future. Besides their use for secondary steelmaking on the basis of scrap, EAFs allow for a greater flexibility since they can also be used to produce direct reduced iron (DRI) from iron ore pellets. From today's view, DRI appears to be a robust technology. In a transition phase DRI could firstly be produced on the basis of natural gas, which could later be replaced by

H_2. More DRI would also include changes in ore supply as more DRI pellet suppliers (currently rather a market niche) would be needed.

- **Energy system**
  The potential source of hydrogen was discussed controversially. On the one hand, it could be produced on-site, but then ore and additional scrap would have to be imported. On the other hand, the best way to transport hydrogen could be either as a liquid or in other chemicals. There could e.g. be pipelines from Dutch or Belgian port to North Rhine-Westphalia. Generally, solutions for H_2 supply will be site-specific.

- **Industrial symbiosis**
  Carbon capture and storage (CCS) is (maybe surprisingly) considered more future oriented than CCU (carbon capture and utilisation). This is due to the fact that chemical companies will probably eventually turn away from dirty steel production gas to get CO_2 for their feedstock. CCU could thus be a bridging technology including a potential lock-in effect.

- **Competitiveness**
  Regarding competitiveness, the early use of electrified steel production technologies does not necessarily constitute a first-mover advantage. Instead, framework conditions such as exclusive markets, border taxes and infrastructure developments (especially H_2 supply) will probably be very important factors for the location of future primary steel production facilities.

Chemicals and pulp & paper

Outlook (based on the presentation by Clemens Schneider, Wuppertal Institute)

The topic of electrification of the chemicals and pulp & paper sector was discussed in one group as companies from these sectors could form a future union in an electrified (and circular) industry. This option arises from the chemical industry's need to compensate for carbon losses in the system, which result from a number of causes. These include the export of plastics and goods containing plastics to other regions as well as a future build-up of additional plastic stock. Furthermore, losses occur in the use phase and as some plastics are 'contaminated' and thus non-recyclable.

If the pulp & paper industry's steam supply was electrified, biogenic residues from the pulping process could be gasified and fed into the plastics production process (instead of being used for the pulp & paper industry's own energy supply). In case 28 Mt of chemical pulp would be produced in the EU by 2050, 8 Mt of biogenic carbon could be made available annually for the plastics cycle.

Besides the use of biogenic hydrocarbon feedstock, other decarbonisation options for the chemicals industry also rely on a change in feedstock for its production processes, on CCS or electrification. Alternatives comprise (1) an import of platform chemicals together with waste CCS, (2) steam cracking of fossils with CCS and waste CCS or (3) 'carbon looping' with additional hydrogen input. Electrification could e.g. play a role if steam cracking processes were "fuelled" with renewable electricity to supply the required high-temperature heat. If additional hydrogen was introduced into the carbon cycle, this could be 'green' hydrogen from indirect electrification processes.

For the pulp & paper industry, decarbonisation options include the use of biogenic by-products for heat and steam generation (in conjunction with bioenergy with carbon capture and storage (BECCS)). An important alternative is the electrification of steam supply in the pulp and paper mills. This could set free biogenic “waste” streams today used in the CHP plants in order to maximise the possible hydrocarbon by-product volumes (biorefinery output).

Discussion in the break-out group

With regard to an electrification of the chemicals and pulp & paper industries, the following issues have been discussed by the break-out group:

- **Climate regime and EU policy**

Industry demands from policymakers to establish a global level playing field to secure the local industry’s economic competitiveness. Regulation should e.g. include the consistent pricing of carbon emissions (carbon tax or emission certificates) and an instrument guaranteeing low (renewable) electricity prices. Furthermore, a general political support for non-fossil inputs into production processes is regarded as desirable.

Focusing on the pulp & paper industry, there should be a market/incentives to sell biogenic waste (e.g. as a feedstock to the chemical industry) instead of using it for energy purposes themselves. In addition, an explicit innovation agenda with accompanying subsidies for R&D in the small SME paper companies is considered helpful.

- **Technological issues (R&D)**

Currently, 30 bar/230 °C electrical steam production is (cheaply) available[2], but 100 bar is not available. The incentive to develop such a process does not seem to be very strong at the moment because it is relatively cheap to burn natural gas for steam production. In the future, cheap hydrogen from excess renewable energy could displace natural gas. If renewable electricity prices were cheap, steam generation could also be based on direct electrification.

- **Value chains/ industrial symbiosis**

If the pulp industry electrifies its energy needs, a new value chain and industrial symbiosis may emerge: The pulp industry could also engage in biorefining or sell its black liquor to others (such as chemical companies) that will process it into other products.

- **Energy system**

In order to electrify the chemicals and pulp & paper industries in the future, there is a need for cheap and clean electricity supply. Less sustainable energy sourcing could be disincentivised. High prices for fossil inputs would, e.g., provide an incentive for the chemical sector to consider other feedstocks, including black liquor.

- **Competitiveness**

Industry representatives consider a more level global playing field as crucial for future economic competitiveness (see ‘Climate regime and EU policy’). Furthermore, there is a need for a market for sustainable products such as clean paper and chemicals. Some customer groups need to be willing to pay the premium. Sustainably operating companies could be supported by subsidies.

[2] There are several such electro-boilers in Germany, which are usually used for hot water but can also be used for steam.

Energy utilities

Outlook

If the heavy industry in Europe followed an electrification pathway, this would also strongly affect energy utilities and their business models. Compared to today, much more electricity and/or hydrogen or synthetic fuels would be needed and thus also require further technological development and a suitable infrastructure. Electricity, steam and hydrogen production have to be climate neutral in the mid of the century. Thus, flexible production, energy storage and load shift services will be needed.

Discussion in the break-out group

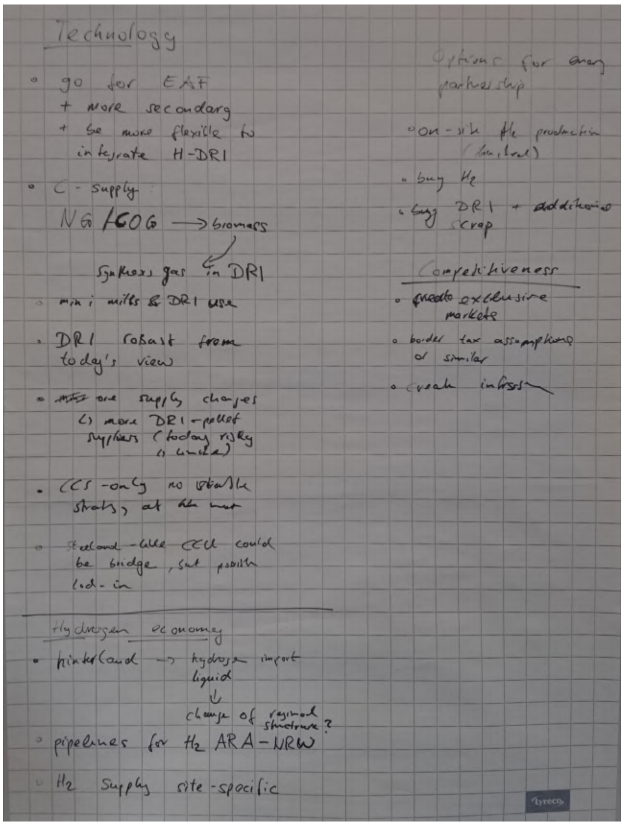
Regarding future changes for energy utilities, many developments and the (new) roles for these players are still unclear and depend on a lot of parameters. There seems to be a chicken-egg problem: Due to uncertainty (e.g. on future policies and prices), the heavy industry does not communicate its expected future electricity/hydrogen/heat needs. As a result, energy suppliers do not plan to build the corresponding infrastructure (e.g. for short-time electricity storage), which in turn keeps the industry from expecting such an infrastructure in the future. Workshop participants concluded that industry should communicate at least its theoretical needs to break this circle and achieve investments in infrastructure.

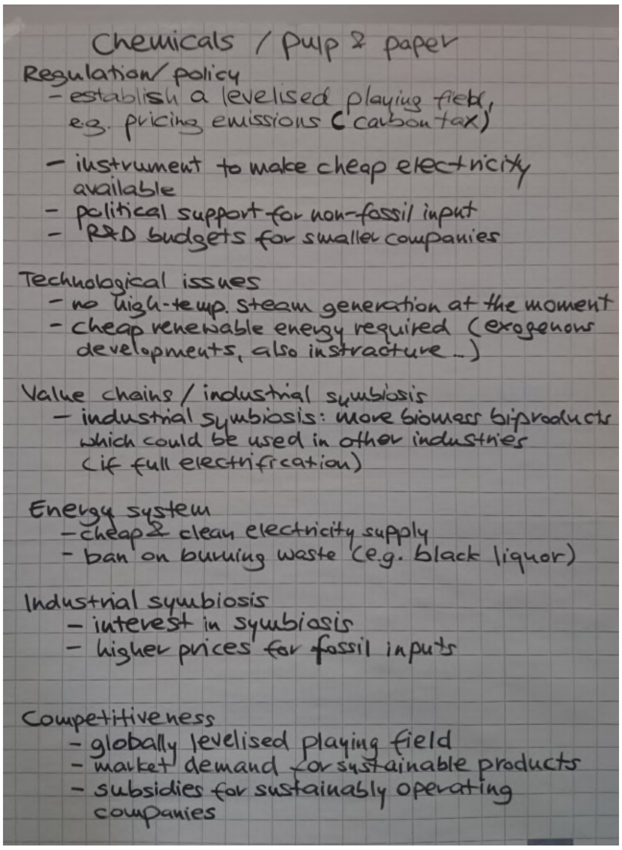
Generally, if the chemical industry increasingly electrifies its processes, chemical production and energy production systems will be linked more closely. For example, an energy suppliers for a chemical park would have to act as a flexibility provider and would face a lot of continuous heat demand.

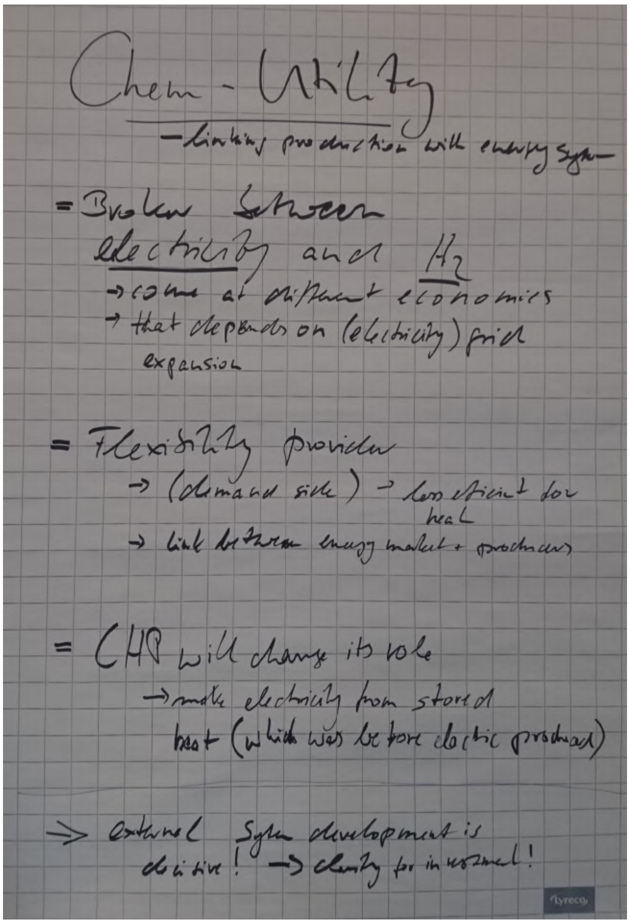
Combined heat and power (CHP) generation could be used to produce electricity from steam originating from a chemical park at times of cheap electricity and then stored in on-site heat storages (= short-time electricity storage (12-24h)).

Depending on the expansion of the electricity grid, there could be a competition between electricity (low production costs at times but high grid costs) and hydrogen (higher production costs but low infrastructure costs). The utility would play an important role in buffering these effects for the chemical parks.

Flip charts from the Session 1 break-out groups:





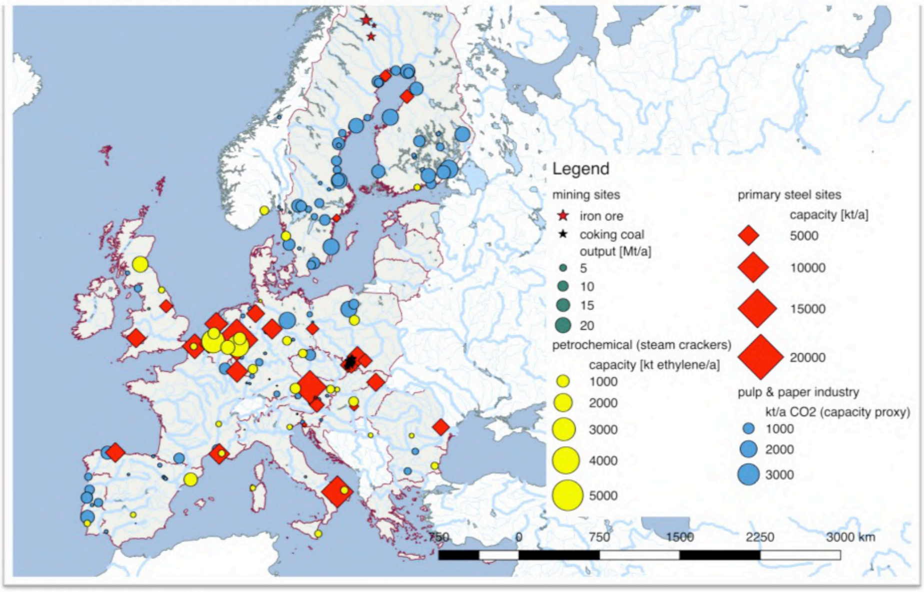


Session 2: How can industrial regions adapt to an electrification strategy?

Outlook (based on the presentation by Clemens Schneider and Stefan Lechtenboehmer, Wuppertal Institute)

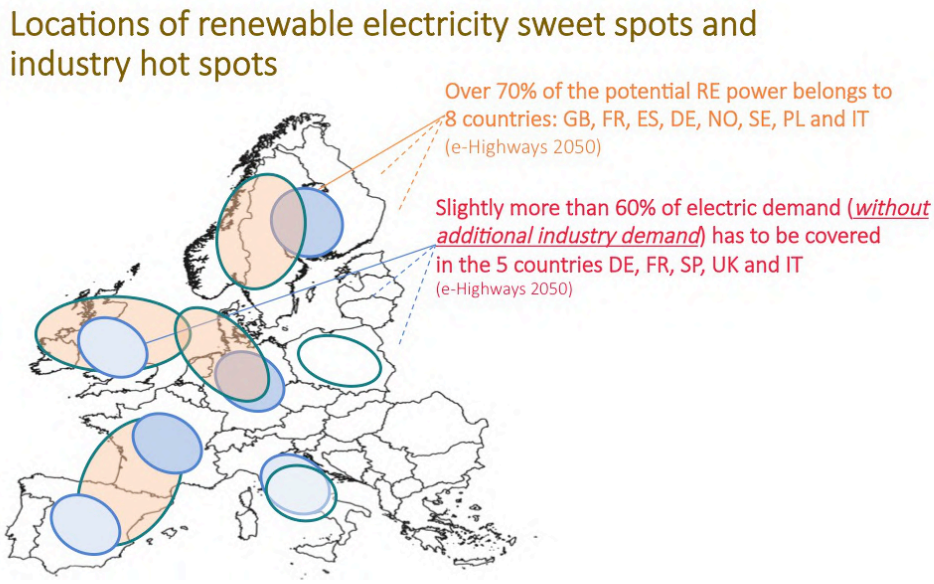
As the following figure ‘Geographical clusters of the REINVENT sectors’ shows, sites of the steel, chemicals and pulp & paper industry are currently clustered in certain European regions.

Geographical clusters of the REINVENT sectors



Source: Wuppertal Institute

If these sites were to be electrified to a great extent, significantly larger amounts of renewable energy (especially electricity) would be needed to operate these sites. Thus, it has to be considered whether a current industry site is located in an area with comparatively high renewable energy potential or whether continued site operation would require increasing electricity transport.



The figure 'Locations of renewable electricity sweet spots and industry hot spots' demonstrates that there is actually a rather good match between potential renewable electricity production sites (orange circles) and the location of industry hot spots (blue circles). Nevertheless, the distribution of renewable electricity potential (often near the coast) will lead to a considerable demand for electricity transport to the demand regions (hot spots), especially towards North-Western Europe.

The current and potential future situation of three industrial hot spots, namely the (1) ARA ports (Amsterdam, Rotterdam and Antwerp), (2) North Rhine-Westphalia and (3) Northern Europe (Scandinavia) was discussed in three break-out groups.

Break-out groups

ARA ports

Major players

Among the ARA ports, at least the Port of Rotterdam (PoR) wants to position itself as a sustainable port (or even the most sustainable) for the future. While its long-term goal is the electrification of its industrial facilities, there is no short-term focus on this objective. Due to the PoR's climate obligations, it is currently rather pushing for emission reductions, especially by means of CCS. PoR and also e.g. Shell as partly public industries are thus on the forefront of achieving both, environmental goals as well as the preservation of heavy industry jobs in the Netherlands.

There are ambitious government plans to reduce emissions and decarbonise electricity. However, a successful implementation of an electrification strategy probably requires policy support as electricity prices in the Netherlands are usually high.

Opportunities and challenges

At 15 percent of total electricity consumption in 2018, the share of renewably sourced electricity is still rather limited in the Netherlands but there are goals to improve this.

The future of renewable energy generation appears to go towards offshore wind (as onshore wind and PV have a NIMBY problem). Since both Amsterdam and Rotterdam are historically fossil-focused ports, they potentially represent a threat for wind offshore because of the "ship highways" going to and from the ports cannot be used to implant offshore wind parks.

Besides those challenges, there are opportunities as well. The extensive Dutch gas network (on- and offshore) could be used/ converted, e.g. for hydrogen transport. Similarly, the ARA ports – which are to date import/export hubs mainly for fossil energy – could be used in the future for the transshipment of feedstocks from waste (export) or synthetic fuels (import).

If current CCS projects turn out successful, in the future CO_2 could also be imported from Germany and stored in former Dutch gas fields. Since already problems with natural gas production are occurring in the North of the Netherlands, similar problems could arise regarding CCS, though.

North Rhine-Westphalia

Major players

Electrification could be fostered by new models of industry collaboration such as opportunities for sector coupling. Furthermore, since public acceptance for CCS seems to be rather low, other decarbonisation options such as electrification become more viable alternatives. Currently, an implementation of CCS in NRW appears realistic only if CO_2 would be exported and e.g. stored in former Dutch gas fields. The process of planning the electricity and gas grid organized in Germany on the federal level by a public agency offers the possibility to articulate possible future electricity and/or hydrogen demand but there is lack of commitment.

Opportunities and challenges

There are several factors which foster the implementation of an electrification strategy in North Rhine-Westphalia. Firstly, due to the presence of many companies, universities and research institutes, a lot of industry and research competence is available in NRW. Existing clusters of industrial companies could become starting points for industrial symbiosis. The infrastructure is as well suitable for electrification purposes, e.g. with regard to power grids. CHP and high-temperature heat pumps could complement the portfolio of options to supply energy to industrial clusters.

The fact that renewable energy potentials in NRW are lower than in other parts of Germany is a challenge for widespread electrification. It would thus be necessary to transport energy to the industrial spots in NRW, e.g. from offshore wind parks in the North Sea. This requires the maintenance and expansion of existing power infrastructure.

Scandinavia

Major players

In Scandinavia/Northern Sweden, the major utility (Vattenfall) has been pushing for industry electrification (since the business problems in 2009). They are working with the main heavy industries: cement, paper, petrochemicals and steel. Renewable electricity potentials are considered sufficient for the implementation of an ambitious electrification strategy, especially considering onshore wind energy potentials in the North.

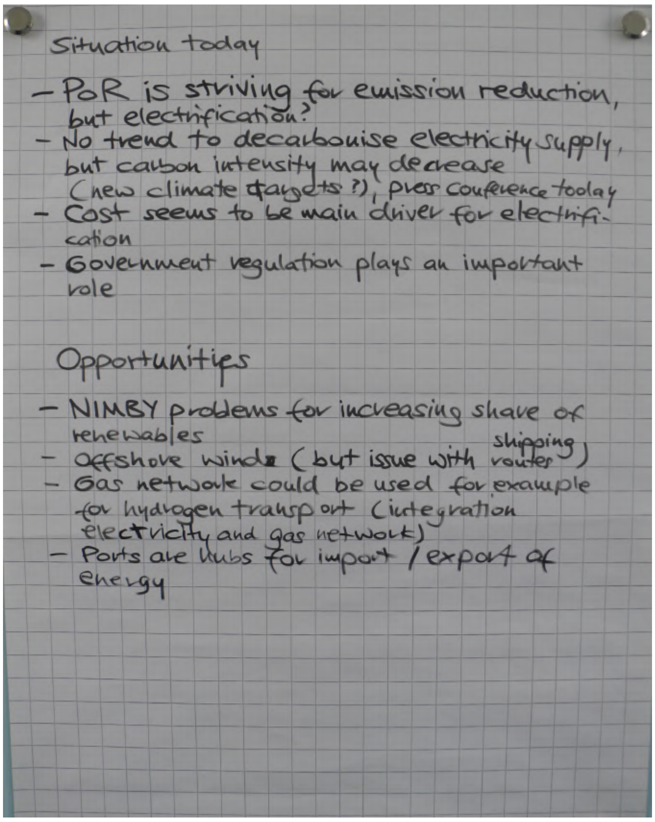
CCS is only barely considered an alternative decarbonisation option in Sweden, since there is hardly any coal power. The opposite is true for Norway. In Sweden bioenergy with CCS is rather taken into consideration.

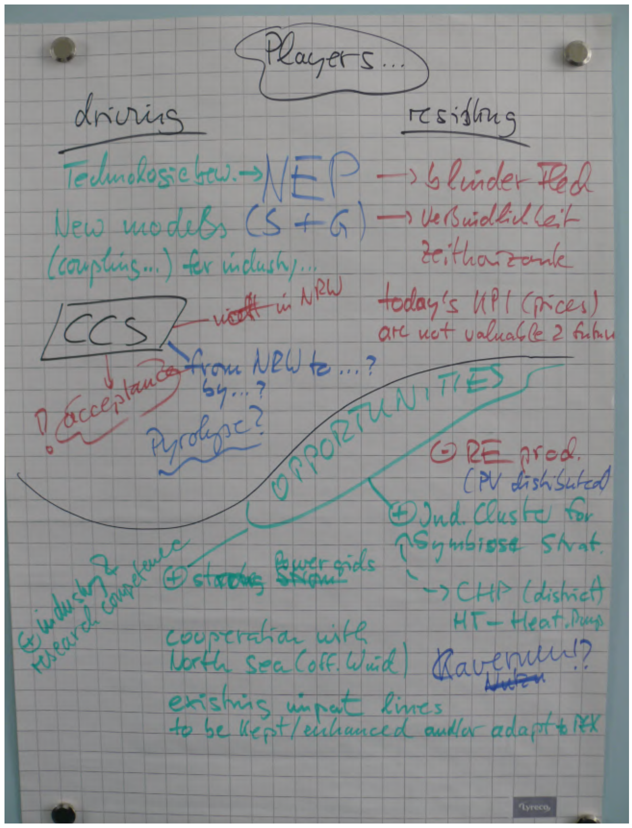
Opportunities and challenges

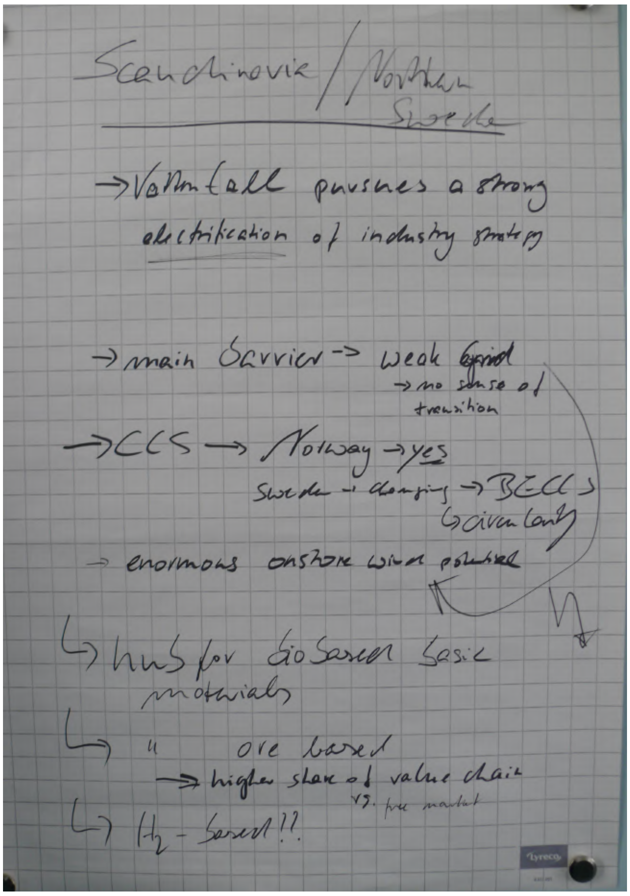
Scandinavia sees itself as a future clean electricity or clean raw materials provider for the rest of Europe. However, going forward with the electrification strategy, there is the problem of distribution to be faced. While renewable electricity potentials exist, the transportation as well as distribution grid is rather weak and there is no sense of transition in this area. The gas grid is weak as well.

Due to the natural resources available in Scandinavia and because of the weak grids for energy carriers, the region could also become an exporter for of bio-based chemicals or DRI based on iron ore. Production sites could be mid-scale and distributed with onsite hydrogen production.

Flip charts from the Session 2 break-out groups:







Conclusion

The joint REINVENT SCI4climate.NRW Workshop on electrification in climate protection scenarios aimed at an in-depth exploration of potential electrification storylines. The main target groups were practitioners from industry and regions as well as scenario modelers and analysts. The combination of both groups as well as the workshop structuring along concrete industries and concrete regions was meant to enable a co-creation process of visions and storylines on the so far very new concept of intensive electrification of basic industries.

The aim was to enrich existing scenario storylines from REINVENT as well as other work with regard to the roles of industrial companies, utilities, consumers, politics, society and research. Furthermore, feasible combinations of pathways and related timelines as well as potential fore-running regions should be identified. In order to achieve this, the unique knowledge of the SCI4Climate.NRW and REINVENT projects was combined. Experts from North Rhine-Westphalia (NRW) and different European countries from industry and science were invited.

The combination of the various backgrounds – but always of industry experts and scientists with a thorough understanding of the challenges of deep decarbonisation via electrification – enabled in fact joint scenario experiments on the sub-sectors and the exemplary regions covered.

Main findings from the workshops were, a concrete view on the challenges for different regions, particularly NRW and the Netherlands regarding the immense need of electric energy needed for the decarbonisation as well as insights into the strategic positioning of Scandinavia and in particularly Sweden, which might be an important provider of green electricity and biogenic resources as well as potentially a place to generate negative emissions. The latter could be an option for local pulp and paper industries if a combined electrification and CCS strategy would be pursued.

Further findings were on changing roles of actors such as operators of chemical parks and energy utilities. The sectors could become much closer linked to each other due to the high energy demand and content of basic chemicals as well as due to the fact that chemical clusters could become providers of large-scale demand flexibility to the electricity system. These trends would also incentivise closer cooperation between the relevant actors, i.e. operators of chemical parks and energy utilities.

Regarding modelling and creating future scenarios it became clear that spatially explicit works taking into account energy infrastructures and well as locations of future demand hot spots would become increasingly important.

The results of the discussion provide valuable input into scenario storylines for the EU framework scenarios to be calculated in REINVENT (by WI and PBL) and also for NRW scenarios to be developed later on in the SCI4Climate project.