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IGF CASE STUDY

Achieving a Successful Post-Mining Transition With Renewable Energy

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Photo: RAG Montan Immobilien

SUMMARY

The use of renewable energy technologies–including solar panels, wind turbines, and electric vehicles–has many benefits, from mitigating greenhouse gas emissions to diversifying the energy mix to reducing our dependence on fossil fuels.

In recent years, the mining industry has undertaken efforts to contribute to the renewable energy transition, including through the conversion of brownfields to brightfields. This entails transforming contaminated land or abandoned mine sites (brownfields) into areas that can generate renewable energy, most typically in the form of solar developments (brightfields). This practice not only contributes to the renewable energy transition but also serves to convert what would be a financial liability into an economic opportunity. Brownfield to brightfield conversion has increased significantly in recent years; for example, within the United States, the government vetted more than 80,000 brownfields for renewable energy development.

Former mine sites can be suitable locations for solar and wind power projects. The remediation process—the process of restoring the land—involves clearing the sites of any above-ground structures. Brownfields are then typically converted into sites suited to the installation of solar arrays and wind turbines. Former mine sites are also typically located in close proximity to power lines, which ultimately makes connecting to the grid easier.

This report shares case studies of renewable energy conversion from two different IGF member jurisdictions, both of which involved transforming a former mine site into a space used for renewables. The first case study outlines the efforts of SunMine, a solar farm within the interior of British Columbia. The second case study presents the conversion of a former coal mine site into a wind park in Ruhr, Germany.

MINING THE SUN IN BRITISH COLUMBIA, CANADA

Most of the power in British Columbia (BC), Canada, comes from hydroelectricity, but one of the main challenges in constructing dams is the ensuing damage caused by flooding to surrounding arable land. As a result, companies, government, and community members alike need alternative options for the development and deployment of solar energy.

In 2008, the City of Kimberley, BC, and Teck Cominco were approached by EcoSmart to leverage the region's potential for solar energy. Kimberley is one of the highest municipalities in Canada at 1,120 m MSL and has more than 300 days of sunshine. Moreover, the brownsite would be an ideal location for solar panels, given its southern-facing slope and surrounding electrical infrastructure. Given these factors, EcoSmart proposed using the land for a solar power plant and renaming the Sullivan Mine area SunMine to repurpose the land and generate revenue. Despite funding from various sources, it was decided that the City of Kimberley would be the primary owner and operator of SunMine, making the project distinctively community owned.

Since breaking ground in 2014, the benefits of SunMine have been widespread: contributing to the City of Kimberley's ecotourism efforts and local livelihoods and employment, mitigating greenhouse gas emissions, and providing clean energy to more than 275 local homes. SunMine also provides a good example of a project that has the full support of its surrounding communities, given the plentiful opportunities for local skills development in engineering and renewables that could be applied elsewhere. The success of SunMine has made it a model for future solar projects and mine reclamation initiatives.

The City of Cranbrook, for example, has already signed an agreement with P2 Solar for a 25-year lease of 2 ha of land for solar development. FortisBC, a private utility company, is also assessing solar investments in the region. In Alberta, there is massive potential for solar energy, given the number of brownfield sites and the minimal hydroelectric potential. In fact, while Canada is ranked 8th globally in solar energy production—behind Germany, China, and Taiwan, among others—its solar potential is estimated to be 30% higher than that of Germany. Given this potential, projects like SunMine provide fruitful opportunities for the mining sector to generate revenue from old mining sites.

FROM WASTE ROCK TO WIND PARK IN RUHR, GERMANY

The Ruhr region of Germany has depended on coal mining since the Middle Ages. With the quality and type of coal found in the area being nearly unmatched, the region became the industrial powerhouse of Germany. This led to innovations such as the steam engine, the rolling mill, and railway connections.

The coal mining industry peaked in the Ruhr region in the 1950s. Nearly 600,000 people were employed by the sector, and around 115 million tonnes of coal was mined. However, the sector began to face key challenges. Mining coal deep underground led to uncompetitively high costs. Coal was also being substituted for other energy sources, first oil then electricity. The first wave of coal mine closures hit the Ruhr region in the late 1950s and mid-1960s.

Unsaleable waste rock extracted during coal mining was mainly dumped on waste rock piles, like the Lohberg Nord Erweiterung in the Ruhr area. This waste rock pile was created in 1985 because the existing one (Lohberg Nord) was reaching its capacity.

In response to foreseeable changes in the coal mining industry, the German federal government, the Government of North Rhine-Westphalia, coal mining companies, and a trade union representing coal mine employees founded RAG Aktiengesellschaft in 1968 to consolidate 26 coal mining corporations that accounted for 94% of the coal production in the Ruhr area.

The early retirement of the nearby coal mines by 2008 made the Lohberg Nord Erweiterung waste rock pile unnecessary moving forward. It covered an area of about 80 ha, with some areas reaching a height of up to 117 m MSL.

RAG Aktiengesellschaft's subsidiary, RAG Montan Immobilien GmbH (RAG MI), oversaw a project to convert the rock waste pile into a wind park that would be a sustainable source of renewable energy.

There are three benefits to building the wind turbines on the Lohberg Nord Erweiterung waste rock pile:

- Higher altitudes provide a stronger wind speed, resulting in higher energy yields and more profits
- Preventing deforestation needed to build the wind turbines in other locations
- Distance from residential areas, ensuring local communities are less bothered by the noise or sight of the wind turbines.

RAG MI set up Windpark Hünxe GmbH, a limited liability company, which, together with Gemeindewerke Hünxe GmbH (RAG MI: 60%; Gemeindewerke Hünxe GmbH: 40%), a municipal utility, started planning the construction of the Windpark Hünxe atop the Lohberg Nord Erweiterung waste rock pile in 2015.

The project partners commissioned several external assessments to ensure the wind park construction fell within the Federal Control of Pollution Act, including hiring an engineering firm to assess the ground's suitability to hold the wind turbines and conducting a 1-year wind measurement from August 2015 to July 2016 to project the annual electricity generated. Finally, three wind turbines were erected, with a total project cost of EUR 15.8 million. Construction began in summer 2017, and the wind park was operational in July 2018. The wind park generated about 13,050 MWh from July to December 2018, 31,400 MWh in 2019, and 32,800 MWh in 2020.

CONCLUSIONS

A multistakeholder approach is crucial to the success of renewable energy initiatives. Communities and governments alike are contributing to the redesign of existing programs, such as creating government loans and grants for renewable energy projects on converted mine sites, working with mining companies for funding and support, and taking an active role throughout the consultation processes.

Converting old mine sites presents communities and developers with an opportunity for continued growth. Mining sites can provide a source of livelihoods and development for communities; when the mines close, the surrounding communities may lose these essential benefits. However, wind and solar projects can offer an alternative source of employment, income, and community development—in addition to contributing to the renewable energy transition.

Photo: Green Energy Futures (CC BY-NC-SA 2.0)

CASE STUDY 1: MINING THE SUN IN KIMBERLEY, BC

From 1900 to 2001, the Sullivan Mine in British Columbia (BC) was one of the largest lead–zinc mines in the world. When the mine closed in 2001, the surrounding community sought to use the brownsite for an environmental goal that would contribute to local livelihoods, community revenues, and sustainable development. Enter: the SunMine.

When mines close, companies are under pressure and obligation to restore the land to its original state and reduce their overall environmental impact. This process of reclamation can elicit high costs. The SunMine provides an innovative example of repurposing an old mining site—the Sullivan Mine—to generate revenue for a new purpose (Bakx, 2017). Opened in 2015, the SunMine is a 1.05 MW solar photovoltaic plant built on the brownsite of the former Sullivan Mine. Its construction and operation contribute to the environmentally conscious reputation of Kimberley, enhanced local knowledge and livelihoods in the field of renewable energy, national climate change mitigation efforts, and clean energy generation for more than 275 homes.

MINING HISTORY

The Sullivan Mine was named after one of the four prospectors who originally discovered the site in 1891: Pat Sullivan (City of Kimberley, 2020). After his passing shortly after the discovery, his fellow prospectors—Walter Burchett, E.C. Smith, and John Cleaver—created the Sullivan Group Mining Corporation in 1896 and began initial shipments of the mine's ore by 1900 (City of Kimberley, 2020).

The mine's rich deposits of zinc, lead, and silver were a source of great optimism for the nearby settlement of Mark Creek Crossing. So much so, the settlement renamed itself Kimberley, with the expectation that the mine's outputs would be comparable to the diamond riches of Kimberley, South Africa (City of Kimberley, 2020). In 1909, the Consolidated Mining and Smelting Company of Canada Ltd. (Cominco)—later Teck Cominco—acquired the Sullivan Mine (City of Kimberley, 2017).

With Teck Cominco at the helm, the mine quickly became one of the largest lead–zinc mines in the world, sparking considerable growth for the City of Kimberley. Between 1909 and 1999, the hard-rock mine produced more than 9 million tonnes of lead, 8 million tonnes of zinc, and 285 million ounces of silver—for a total value of more than CAD 20 billion by today's standards (Horswill, 2001). The mine's average number of employees exceeded 1,000 and contributed to local economic development through the purchasing of housing, goods, and services (Horswill, 2001). With its expansion, the site gained a steel mill, a fertilizer plant, and tailings ponds (Quinn, 2017).

Though its contributions to Kimberley were great, by 1968, the community recognized the finite nature of the mineral resources and began to plan for their eventual depletion (City of Kimberley, 2017). The city started to focus on its recreational resources—including by developing golf courses, ski hills, and adopting a new Bavarian theme—while planning for the mine's closure. Teck Cominco contributed to some of these endeavours, including the development of the nearby ski hill.

After more than 100 years of operation, Sullivan Mine closed in 2001 (Teck, 2015). Teck Cominco dedicated CAD 70 million toward the reclamation process, and in 2003 was recognized for outstanding achievement by the British Columbia Technical and Research Committee on Reclamation (SunMine, n.d.). By 2010, the reclamation process was complete (SunMine, n.d.).

FROM CLOSURE TO CONVERSION

Though Kimberley's newly established recreational facilities were a draw for tourists, the former mine site was considered a detraction. Now that Kimberley was no longer a mining hub, citizens wanted to increase the city's reputation as an environmentally conscious community and began searching for opportunities to utilize the former mine site toward this endeavour (Canadian Consulting Engineer, 2016; SunMine, n.d.).

Most of the power in BC comes from hydroelectricity; however, there has been some controversy in its proliferation. One of the main impacts of constructing dams is the ensuing damage caused by flooding to surrounding arable land (Coté, 2019). As a result, companies and non-profits like EcoSmart are committed to exploring other options for fulfilling BC's energy needs, including through the development and deployment of solar energy.

In 2008, the City of Kimberley and Teck Cominco were approached by representatives at EcoSmart who had analyzed weather patterns across Canada and discovered that Kimberley had enormous potential for solar energy (McCormick & Sommerville, 2017). Kimberley is one of the highest municipalities in Canada, at 1,120 m MSL and has more than 300 days of sunshine (City of Kimberley, 2017; Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development [IGF], 2018). Moreover, the brownsite would be an ideal location for solar panels, given its southern-facing slope and surrounding electrical infrastructure (McCormick & Sommerville, 2017). Given these factors, EcoSmart proposed using the land for a solar power plant—named the SunMine—to repurpose the land and generate revenue.

From 2008 to 2010, the city, Teck Cominco, and EcoSmart worked together to develop the SunMine concept further (Kimberley, 2019). In 2011, a city-wide referendum demonstrated that most Kimberley voters approved construction of the SunMine (City of Kimberley, 2017). The City of Kimberley and its partners worked from 2011 to 2014 to secure funders, conduct due diligence and feasibility studies, and delegate ownership (Resort Tours, 2019). Through these negotiations, it was decided that:

- Teck Cominco would provide the land, site infrastructure, and CAD 2 million to fund the project.

- B.C.'s Innovative Clean Energy Fund program would provide CAD 1 million through the EcoSmart Foundation.
- The Columbia Basin Trust would contribute CAD 300,000.
- The Southern Interior Development Initiative Trust would provide CAD 50,000.
- The City of Kimberley would borrow CAD 2 million to contribute, to be repaid through SunMine revenue (City of Kimberley, 2017; Government of BC, 2017; IGF, 2018; SunMine, n.d.).

Construction began in 2014, with Conergy Canada taking on the role of primary contractor, managing SunMine's engineering, construction, and procurement (City of Kimberley, 2017). Throughout the construction period, about 29 locals were hired full-time to support the process, contributing to local employment (Government of BC, 2017). It was decided that the City of Kimberley would be the primary owner and operator of SunMine, making the project distinctively community owned.

REPURPOSED FOR RENEWABLES

HOW SUNMINE WORKS

SunMine officially opened for commercial operation on June 22, 2015 (City of Kimberley, 2017). The site includes 96 sun-tracking solar masts with 42 solar modules each, amounting to 4,032 modules (BC Climate Action Toolkit, n.d.). SunMine is a dual-tracking 1.05 MW solar photovoltaic plant: the cells produce energy when solar radiation strikes the photovoltaic conductors to produce a difference in electrical potential (Canadian Consulting Engineer, 2016; SunMine, n.d.).

SunMine uses tracking technology: the panels adjust based on the position of the sun. This technology enables increased energy production earlier and later in the day, with peak production beginning at 9 a.m. and continuing until about 7 p.m. (Green Energy Futures, 2015). The trackers also allow for seasonal variations and accommodations for the weather—if snow accumulates, the panels can change angles to dump the snow before returning to their normal placement (Canadian Consulting Engineer, 2016). The tracking technology at SunMine generates 36% more energy compared to fixed solar projects (Berg, 2018). The energy is sold to BC Hydro through its Net Metering program.

SUNMINE IN OPERATION

In its first year of operation, SunMine generated more than 1,681 MWh of energy (Government of BC, 2017). By 2017, SunMine had generated more than 4,419 MWh of energy and garnered CAD 473,165 in revenue, a little under what was expected (B.C. Climate Action Toolkit, n.d.). Projections estimate SunMine will generate CAD 150,000 to 250,000 annually, based on a rate of $0.08 per kWh hour moving forward (Canadian Consulting Engineer, 2016). This revenue contributes to the city's initial CAD 2 million loan, with the remainder going into a reserve that will feed back into the local community (Quinn, 2017).

By 2018, SunMine had generated more than 4,900 MWh of electricity and turned a small profit (Berg, 2018). Moreover, it had exceeded initial expectations that it would provide enough energy for 200 homes, servicing approximately 275 homes instead (SkyFire Energy, 2019).

In 2020, Teck purchased SunMine from the City of Kimberley (Teck, n.d.). This is a first-of-its-kind project; SunMine is not only the largest solar project in BC and the largest solar tracking facility across Canada, but it is the first solar project to sell power to the BC Hydro grid (Teck, n.d.). This project generates 1.05 MW of energy, displacing approximately 1,000 tonnes of greenhouse gases per year (Canadian Consulting Engineer, 2016; Teck, n.d.).

AWARDS AND INTERNATIONAL ACCLAIM

Even before official operation, SunMine had already garnered multiple awards and international acclaim. It is Canada's only tracking solar power generation plant and the first solar project in the province to sell power to the BC Hydro grid (Teck, 2015). It is the largest solar facility west of Ontario and the first solar project to be developed on a reclaimed mine site in Canada (Teck, 2015). It is also the first large-scale solar project to be supported by a mining company (SunMine, n.d.). Since 2015, it has received several awards, including the Community of the Year award by Clean Energy BC in 2015 and 2017's Clean 50 award for outstanding achievement in clean capitalism.

As a result of these accolades, SunMine has received a generous amount of media attention—in Canada and around the world. It has also experienced an unexpected benefit in the form of tourism. From 2015 to 2018, more than 2,000 visitors—from scientists to school groups—toured SunMine (Berg, 2018).

CHALLENGES AND LESSONS LEARNED

Though the benefits of SunMine have been many for the City of Kimberley and its communities, there have been a number of challenges in its construction and operations—some of which are ongoing.

Throughout the construction process, the topography of the land proved to be a challenge; the reclaimed land had considerable sedimentary variability, presenting a challenge for the contractors (SunMine, n.d.). Consequently, the City of Kimberley and its partners took away the valuable lesson to consult experts early in the planning process (BC Climate Action Toolkit, n.d.).

In its first year of operation, SunMine generated approximately 1,681 MWh of electricity. Though considerable, it was only 87% of what was projected (Quinn, 2017). This deficit was the result of four inoperable inverters (out of 32 total) (Quinn, 2017). Though new parts were ordered, there were lengthy delays in finding the appropriate parts and installing their replacements, contributing to the generation shortfall. Lessons learned from this experience include creating more generous contingency plans when parts break and keeping spare parts in storage to account for future setbacks.

Finally, while SunMine's unique tracking technology can account for variabilities in the weather, it has some limitations. In 2018, electricity production was stunted by smoke from a series of forest fires in the area (City of Kimberley, 2018). Despite this setback, SunMine continues to be financially self-sufficient.

NEXT STEPS

Due to the success of SunMine, there have been talks of its expansion. According to experts, SunMine has enough land and transmission capacity to expand from a 1-MW photovoltaic plant to 200 MW, which could provide enough power for all of Kimberley and its surrounding communities (Bakx, 2017).

In Teck's 2020 announcement about purchasing the project, the company also mentioned there is a possibility for future expansion (Teck, 2020). The project also provides learning lessons for Teck's other mining facilities. Don Lindsay, President and CEO of Teck, stated, "SunMine will help us gain firsthand experience with solar power generation as we advance the use of solar power at other operations" (Teck, 2020).

Photo: RAG Montan Immobilien

CASE STUDY 2: FROM WASTE ROCK TO WIND PARK IN RUHR, GERMANY

MINING HISTORY

Coal mining started in the Middle Ages in the Ruhr area, a region located in the present-day Western German federal state of North Rhine-Westphalia. The real breakthrough dates back to the 1830s when bituminous coal could be accessed for the first time, as this rock is covered by a layer of marlstone roughly 100 m thick in the Ruhr area (Butzin & Pahs, 2003). This layer, however, is highly water-bearing and can only be intersected by a mine shaft if it is carefully sealed during construction. Because of its temperature-related physical and chemical properties, coke obtained from bituminous coal was indispensable for the new generation of blast furnaces for iron and steel production. The quality of the type of coal found in the Ruhr area was practically unmatched elsewhere (Ruhr-Guide, n.d.-a). This paved the way for the region to become the industrial powerhouse of Germany due to its innovative technologies, such as the steam engine and the rolling mill, and advancements in transportation, including the launch of railway connections.

Given the fast economic expansion of the coal and related iron and steel industries, demand for labour was high. As a consequence, the region attracted many domestic and foreign migrants, so that the total population exploded from around 400,000 to nearly 4 million between 1850 and 1925 (Ruhr-Guide, n.d.-a). Until today, the Ruhr region is the largest metropolitan area in Germany and one of the largest in Europe (Städtekooperation Integration. Interkommunal, n.d.).

Coal mining reached a peak in the Ruhr region in the 1950s when about 115 million tonnes of coal was mined, and close to 600,000 people were employed by the mine companies (Butzin & Pahs, 2003). However, comparably high costs due to the need to mine coal deep underground meant that it was more expensive and no longer competitive with cheaper imports. In addition, coal was increasingly substituted by other energy sources, including oil and, later, electricity produced from nuclear power plants. The local iron and steel industry also started to face difficulties due to increased competition, which reduced demand for coal mined in the Ruhr area. All of these factors resulted in the first wave of mine closures in the late 1950s and mid-1960s, and consequently, a strong decline in the people employed in coal mines in the Ruhr area (Czierpka, 2019).

In response to this crisis, the German federal government, the Government of North Rhine-Westphalia, coal mining companies, and a trade union representing the coal mine employees (IG Bergbau) founded Ruhrkohle AG (later renamed RAG Aktiengesellschaft) in 1968 to consolidate 26 coal mining corporations that accounted for 94% of the coal production in the Ruhr area (RAG Aktiengesellschaft, n.d.-a). Supported by large federal and state subsidies, RAG Aktiengesellschaft continued coal mining in the Ruhr area until 2018, when it completed the phase-out as per the 2007 coal compromise (WDR, 2007).

A side product of coal mining is the extraction of largely unsaleable waste rock. Since the 1920s, some waste rock was returned to the shafts to improve underground stabilization, though the majority was dumped on waste rock piles located near the mines, growing to considerable heights over time. The highest waste rock pile in the Ruhr area towers over the surrounding area by 140 m, which makes it the highest artificial elevation in the Ruhr area (Ruhr-Guide, n.d.-b). The Lohberg Nord waste rock pile in the Ruhr area is one example (Bottmeyer, 2013).

According to a historical overview written by engineering firm Ahlenberg Ingenieure GmbH (n.d.), at the end of the 1970s, it became apparent that the capacity of this waste rock pile would be exhausted by 1988, and additional stockpile space would be required for the surplus waste rocks accumulating at the nearby Lohberg mine. Therefore, the Lohberg Nord Erweiterung waste rock pile, located in the municipality Hünxe (county Wesel; district Düsseldorf), north of the already existing waste rock pile, was filled from 1985 onward. With the early retirement of the surrounding coal mines by 2008, the Lohberg Nord Erweiterung waste rock pile was no longer needed for the discharge of waste rocks, despite the fact that only around 23 million m^3 of the permitted 30 million m^3 of waste rocks had been poured yet. This waste rock pile covers an area of about 80 ha, and the eastern part reaches a maximum height of 117 m MSL, while the western part reaches a maximum of 89 m MSL (Ahlenberg Ingenieure GmbH, 2016).

To ensure there is no further danger from such waste rock piles, a final operating plan had to be approved by the district government, according to paragraph 53 of the German Federal Mining Act (German Federal Law Gazette, 1980). For the Lohberg Nord Erweiterung site, this plan included filling the remaining 7 million m^3, ensuring the pile had a proper top for aesthetics and drainage reasons, and cultivating forests and building hiking paths (J. Meier, personal communication, August 2021). This plan was submitted in August 2011 and approved in April 2015 (Ahlenberg Ingenieure GmbH, n.d.).

FROM CLOSURE TO CONVERSION

RAG Aktiengesellschaft's subsidiary RAG Montan Immobilien GmbH (RAG MI) has overseen the revitalization of the company's old mine sites for more than 35 years. As such, it manages around 9,000 ha of land and transformed the completed sites primarily into modern industrial and technology parks, livable residential and urban neighbourhoods, sustainable leisure and recreation areas, vibrant creative districts, and efficient logistics parks (RAG Aktiengesellschaft, n.d.-b, 2018). In the mid-2010s, RAG MI began setting up wind parks on waste rock piles to generate renewable energies. To date, it has built 11 wind turbines on four waste rock piles (RAG MI, n.d.).

Germany is one of few industrial countries that is simultaneously phasing out nuclear and coal. To provide sufficient electricity in the future to keep the grid stable, it is inevitable that the country's renewable energy capacity, including onshore wind, will expand drastically throughout the entire country—which the federal government has been actively supporting since 2000 through the Renewable Energy Act (German Federal Law Gazette, 2000). The act emphasizes a preferential feed-in of electricity from renewable sources into the power grid and fixed feed-in tariffs for producers of electricity from renewable sources for 20 years.

Constructing wind turbines on waste rock piles can contribute to increasing renewable energy capacity, as it makes sense both economically and politically. Wind turbines built on top of waste rock piles can operate in higher altitudes where the wind speed is generally greater. This results in higher energy yields and thus makes them more economical—a factor that should not be underestimated, especially if wind turbines are to be located in regions that are generally characterized by only medium-strong wind speeds, such as the Ruhr area. Waste rock piles can also be an adequate site for wind turbines for political reasons. Even though public support for the German energy transition remains high (German Renewable Energy Agency, 2021), local opposition from residents living in areas where wind parks are planned has grown and is considered one of the reasons why the expansion of wind power has considerably slowed down in the late 2010s (Wehrmann, 2019). Due to the larger distance from residential areas and lack of the need to clear any forests, wind turbines on waste rock piles are less likely to meet resistance from local citizens and are more likely to be backed by local governments, who have a responsibility to promote renewable energies within their territories.

The main and finance committee of the Municipality of Hünxe had expressed its willingness to contribute to the energy transition by expanding renewable energies in 2014. The municipal land-use plan was amended in 2016 to specify several concentration zones for wind energy, a common practice to support this expansion while preventing a "blot of the landscape" (Municipality of Hünxe, 2016). One of these concentration zones included parts of the Lohberg Nord Erweiterung waste rock pile, with space for up to four wind turbines.

Together with the Gemeindewerke Hünxe GmbH, a municipal utility in which the Municipality of Hünxe has a 51% stake, RAG MI started planning the Windpark Hünxe located on the Lohberg Nord Erweiterung waste rock pile in early 2015. In the end, three wind turbines would be built on the plateau (the fourth could have only fit on a steep slope deemed far too challenging [J. Meier, personal communication, August 2021]). The total cost of the project was EUR 15.8 million, or around EUR 4.62 million per wind turbine (GELSENWASSER AG, 2020).

A specific feature of the site was that the final operating plan had to be adjusted to account for the changes required for setting up the foundations of the wind turbines and slightly relocating the new forest planned on the area (RAG Aktiengesellschaft, 2016). In addition, waste rock was moved to the area to even out the waste rock piles that had not been completely filled (due to early retirement of the mine).

As the project partners sought a permit for constructing the wind park under the Federal Control of Pollution Act examined by the county government, several external assessments were required. For instance, an engineering firm was contracted in August 2015 to assess whether the ground where the wind turbines were going to be constructed was suitable (Ahlenberg Ingenieure GmbH, 2016). This assessment, which included exploration drillings and dynamic probing, concluded that additional measures were required to make the waste rock pile suitable in areas where the foundations of the proposed wind turbines would be constructed. Moreover, this evaluation suggested using soil improvement measures in the form of vibro stone columns. Given that it was a unique location for the construction of a wind park, due to the topography of the waste rock pile, the banks involved in financing the project also required a wind measurements be recorded for 1 year to evaluate the profitability of the wind turbines, in addition to the two obligatory wind reports. The wind measurements carried out between August 2015, and July 2016 projected the annual electricity generation of the three wind turbines combined at 32.150 MWh (J. Meier, personal communication, August 2021). The wind measurement was conducted by placing a box on the waste rock pile where the future wind turbines would be located that produced and recorded an acoustic sound once per minute to determine wind strength.

In September 2016, the Main and Finance Committee of the Municipality of Hünxe unanimously decided to have no reservations about the planned wind park. Its construction was, however, subject to the pending approval of the land-use plan amendment on concentration zones for wind turbines by the district government (RP Online, 2016). The county government issued the permit required under the Federal Control of Pollution Act at the end of December 2016 and ordered "immediate enforceability" due to special public interest. This order meant that potential legal challenges had no suspensive effect, and construction could start immediately after obtaining the permit (County of Wesel, 2017).

Construction began in late summer 2017 with the preparation of the foundation soil. After 10,000 truckloads of tailings were relocated within the waste rock pile to achieve the final height where the wind turbines were planned, 450 20-m vibro stone columns were inserted into the ground below the foundations to improve the subsoil, for which 15,000 m^3 of gravel was used (RAG MI, 2018). Subsequently, the foundations of the wind turbines were concreted at the end of 2017 and the beginning of 2018, the access road was expanded, and the crane sites were constructed. Installation of the wind turbines was completed in May 2018. In parallel to the construction of the wind turbines, the cable route for connecting the wind farm to the local power grid was set up. The wind park was fully operational in July 2018 (RAG MI, 2018).

REPURPOSED FOR RENEWABLES

The three Enercon E115 wind turbines built as part of the Windpark Hünxe have a 3-MW capacity (GELSENWASSER AG, 2020). They have a hub height of around 149 m and a total height of around 207 m; the rotor diameter spans around 115 m.

Because the permit for constructing the wind park was issued in December 2016, the project was subject to more favourable conditions under the Renewable Energy Sources Act. Until that year, the feed-in tariffs paid to all generators of renewable energies for 20 years were set by the government. However, the German government amended the Renewable Energy Sources Act in 2016 so that, from 2017 onward, financial support for wind, solar, and biomass is determined through tenders to reduce costs (German Federal Law Gazette, 2016). Therefore, Windpark Hünxe benefits in two ways from the fact that its permit was granted before the new regulation came into force:

1. This increased the certainty of receiving the feed-in tariff since, under the new regulation, fixed quantities of wind power capacities are put out to tender with a risk of not being awarded a contract.
2. The competition for the limited tender quantities generally reduces the level of the feed-in tariff. The Hünxe wind farm, for example, receives the higher government-set feed-in remuneration

of EUR 0.0731 for each kWh of generated electricity for 20 years (J. Meier, personal communication, August 2021). In contrast, the highest feed-in remuneration determined by the first tender in 2017 was EUR 0.0578,[1] almost 21% lower than the feed-in remuneration provided to the Windpark Hünxe under the previous regulation (German Federal Network Agency, 2017).

As of the publication of this case study, the wind park has been in operation for 2 full years. It generated about 13,050 MWh in 2018 (from July until December only); 31,400 MWh in 2019, which was slightly lower (around 2%) than projected through the wind measurement carried out during the planning phase of the project; and 32,800 MWh in 2020, which was higher than previously projected (J. Meier, personal communication, August 2021). So far, the output of Windpark Hünxe has been slightly higher than the output of the Windpark Hünxe Heide, another wind park owned by RAG MI in very close proximity. Windpark Hünxe Heidewhich has four windmills, but three of them are smaller than those at Windpark Hünxe. This higher output can be attributed primarily to the higher altitude of the waste rock pile on which Windpark Hünxe was built.

Overall, Windpark Hünxe generated total revenues from the feed-in remuneration of around EUR 5.65 million between July 2018 and December 2020. In addition, Windpark Hünxe supplies around 9,100 three-person households with renewable electricity and saves 24,000 tonnes of carbon dioxide emissions per year (RAG Montan Immobilien, 2018).

CHALLENGES AND LESSONS LEARNED

Even though Windpark Hünxe can be considered a great success, RAG MI and its project partner have nevertheless faced several challenges during the project's planning and construction phases.

First, constructing a wind park is generally a very bureaucratic process that demands various documents and expert assessments. To prevent any delays, all these tasks have to be carried out with the greatest care. In the case of the Windpark Hünxe, there was the additional complication that it was planned on a unique site, whose final form was not yet complete, so the final operating plan had to be adjusted in order to carry out the project. Early consultations with the relevant authorities and the fact that both RAG MI and the authorities had experience carrying out projects with similar characteristics in the past proved helpful (J. Meier, personal communication, August 2021).

Public opposition to wind parks, often organized as local citizens' initiatives, has increasingly delayed or even prevented many projects from going forward in Germany in recent years (Wehrmann, 2019). The Windpark Hünxe was not spared from this development: two legal challenges were initiated against it. RAG MI had tried to counter any opposition with high levels of transparency. For instance, a public announcement of the project and an interpretation of the application and the documents for the permit granted in December 2016 were unnecessary because RAG MI chose a simplified procedure. However, it asked the county government to publish it anyway in its official gazette to provide interested parties with the

[1] To take locations with weaker and stronger winds into consideration for the tenders, the amount of feed-in remuneration is multiplied by a location-specific correction factor, which can increase the actual level of remuneration by up to 29%. Even though other wind energy projects in the region tend to receive an increased feed-in remuneration of between 20% and 25% due to this provision, no specific correction factor was calculated for Windpark Hünxe, and the possibility for a higher feed-in remuneration on this basis is therefore unknown (J. Meier, personal communication, August 2021).

opportunity to read through the permit (County of Wesel, 2017). Shortly after receiving the permit, RAG MI also held a voluntary public information event in February 2017, where various external experts were invited to speak, and roughly 100 interested people attended (RAG Aktiengesellschaft, 2017). In addition, as with its previous projects, RAG MI developed the wind park together with local municipal utility and set up a limited liability company to jointly operate the project. The fact that the majority stake of this municipal utility is owned by the Municipality of Hünxe can be regarded as beneficial for building political support for the project and increasing the likelihood that the permit would be issued without delays.

Finally, the topography of the waste rock pile proved to be a challenge throughout the construction process. Given that this site is artificially created, significant measures to ensure its stability were required. Furthermore, not all components of the wind turbines could be transported by truck onto the waste rock pile because the serpentine access road was narrow and, in places, very steep and muddy. As a consequence, some of the rotor blades were brought to the site by self-propelled vehicles, which is more expensive than transportation by a normal truck (GELSENWASSER AG, 2020).

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