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SPECIAL ISSUE ARTICLE

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Visible winds: The production of new visibilities of wind energy in West Germany, 1973–1991

Nicole Hesse

Department of History of the Impact of Technology, Editorship of the Journal TECHNIKGESCHICHTE, c/o University of Stuttgart Historical Institute, Stuttgart, Germany

Correspondence
Nicole Hesse, Department of History of the Impact of Technology, Editorship of the Journal TECHNIKGESCHICHTE, c/o University of Stuttgart Historical Institute, Keplerstr. 17, 70174 Stuttgart, Germany.
Email: nicole.hesse@hi.uni-stuttgart.de; schriftleitung.technikgeschichte@hi.uni-stuttgart.de

SPECIAL ISSUE
Making power visible: Codifications, infrastructures, and representations of energy

GUEST EDITORS
Felix Frey and Jonas Schädler

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Abstract

The use of energy from wind has a multi-faceted relationship to visibility. Between 1973 and 1991, various actors in the West German environmental movement made assertions about the visibility of renewable sources of power, but wind energy took on a particular prominence. In this article, the question of how different actors have used knowledge and the materiality of wind turbines for competing purposes is explored. Environmentalists attempted to create visible signs of a valid alternative energy future by tinkering with small, decentralized wind turbines, while the Federal Republic of Germany's Ministry of Research and established energy providers used the failure of the state-subsidized large-scale wind-energy project GROWIAN to criticize renewables and brand their application as misguided. In both cases, actors created new wind energy visibilities to convey their conflicting interests—pitting those advocating a new, environmentally friendly energy system against those who sought consolidation of the large-scale fossil-nuclear energy system.

KEYWORDS
energy industry, environmentalism, GROWIAN, materiality, symbolism, visibilities, West Germany, wind energy, wind tinkerer

1 | VISIBILITIES OF WIND ENERGY—AN INTRODUCTION

On the eve of the 1973 oil price crisis, wind energy occupied only a marginal role in West Germany's energy mix. Despite this, the technology has entered strongly into the public awareness since then, encouraging energy-intensive companies to use wind turbines in their advertising in the 2000s as symbols of taking a more sustainable approach.[1] In an effort to greenwash their industry, even the German nuclear lobby has used wind turbines in their advertisements—until the Berlin Regional Court banned them from doing so in 2011.[2] Despite protests against wind turbines in the past 20 years, they have become and remain an iconic symbol of environmental awareness. This symbolism is directly connected to their physical appearance. This paper proposes the notion of visibilities as a concept to analyze how wind energy use has entered public discourse since the 1970s.

The human use of wind energy is characterized by a multi-faceted and sometimes contradictory relationship to visibility in both a physical and discursive sense. Wind arises just above the surface of the Earth and must be harvested there. Thus, wind power plants always have a spatial dimension that is shaped by towers or buildings, mobile rotors, foundations, drainage and supply routes, plants, and transmission lines and substations, to name just a few examples. From a material point of view, the generation of wind energy has always been impressively visible—even in the pre-industrial era—whether as an individual building becoming a landmark in rural areas or through the extensive drainage structures they were at times used to maintain, for example in the marshlands of northern Germany.[3] Even today's wind farms, no matter whether onshore or offshore, are, as one account puts it, "unavoidably visible, even intrusive" upon land- and seascapes.[4] As we shall see, their visual and aesthetic reception bears more than just this physical impact. Wind, as energy source, is itself not visible nor visually perceptible. Rather, wind more obviously appeals to auditory and haptic perception and can only be experienced visually by means of the things it sets in motion. Following Latour's notion of agency, we could say the wind itself has affordances.[5] Wind is often omnipresent in coastal areas and in low mountain ranges, and this invites its use, encouraging wind-centered socio-technological cultures and local-wind-specific knowledge.[6]

The localized visibilities of wind are demonstrated via two case studies, first that of environmental wind tinkerers, and second, one located amid the Große Windenergieanlage (GROWIAN) project in West Germany.[7] This paper's focus centers on three decades between 1973 and 1991 as a period of transition in which tensions were created by existing energy conditions and social demands and helped establish new forms of awareness surrounding the conditions for wind energy use. West German environmentalists were encouraged to turn to wind turbines in the 1970s due to that decade's energy crisis. This paper analyzes how such tinkering practices established a visible sign of a new, small-scale, environmentally friendly energy future. Tinkering is understood as a handicraft way of *doing technology*. Creativity, knowledge, and materiality, as well as individuals, sometimes institutions, and ideas, are constituents of the practice of tinkering. In contrast, the state-funded GROWIAN project was meant to be a large-scale wind turbine project run by the established West German energy industry and state institutions. This paper examines how, in both cases, aspects of visibility were used to pursue specific interests. The wind tinkerers questioned the established energy and economic systems, or at least promoted the use of renewable energy as an alternative to nuclear power, by directing their efforts towards politics and West German society more generally to

[1]For example, the Toyota Prius was advertised next to wind turbines, as were beauty products and many others: Hirsh & Sovacool (2021, pp. 712–713).
[2]Landgericht Berlin (2011).
[3]Until the middle of the 19th century, travel diary authors repeatedly complained about the ugliness and noise pollution of windmills. In 1838, the railway engineer Alois Negrelli (1838, p. 109) recorded in his travel diary about the northern French coast that ugly windmills had further defaced the inhospitable coastlines. In addition, for example, in 1843 William John Hamilton (1843, pp. 149–150) wrote in his travel diary: "I was amazed by the contrast between the two coasts: Tenedos almost desolate and treeless, while enormously ugly windmills near the city destroy any thought of beauty."
[4]Pasqualetti, Gipe, & Righter (2002, p. 4).
[5]See Latour (2008).
[6]The perception of wind and how to deal with it is a common aspect of the human experience. It is therefore important to point out the different forms of knowledge and to distinguish between tacit knowledge and expert knowledge. See, for example, Knorr-Cetina (1999); Hård & Jamison (2005); Fried & Stolleis (2009).
[7]GROWIAN is an abbreviation of GROße WIndenergieANlage, that is, "large wind turbine."

gain support for their ideas. The GROWIAN participants embraced the idea that a large-scale energy system based on nuclear power and fossil fuels was the best path forward, and could be achieved via the stepless technological up-scaling of a well-functioning and already-established wind turbine design. They addressed national and international technicians, politicians, and proponents of renewable forms of power.

Since the last third of the 19th century, the use of wind energy in Germany has oscillated between a sense of its social insignificance, the protection of it as an aspect of industrial cultural heritage, and seeing it as a constituent of energy-policy-related conflicts. Unlike water power, wind energy was technically harder to integrate into an electrical grid, due to its intermittent nature. Accordingly, it was not adopted in the nascent German grid in the first decades of the 20th century.[8] The number of wind turbines and their economic importance decreased considerably in Germany—and most industrialized countries—with the rise of fossil fuels. In the 1950s, the West German Federal government set up a decommissioning program that combined shutting down windmills as active energy producers with simultaneously restoring them as part of the nation's industrial cultural heritage.[9] Similarly, wind energy played a subordinate role in East Germany (GDR); although in the first third of the 20th century, the area around Dresden had been a center of medium-sized wind turbine manufacturing. The GDR also launched initiatives after World War II to explore the possibilities of using wind energy.[10] However, these were not seriously pursued much further. Nor was there a comparable scene of wind tinkerers or state-funded wind energy research. As late as 1988, the West German journal *DDR Report* stated that although small irrigation and drainage pumps in agriculture were operated by mechanical wind turbines in the GDR, they were not likely to play a role in electricity supply any time soon.[11] Given the lack of interest in the East, this study is instead focused upon West Germany. Between 1930 and 1970, wind turbines not only vanished from the landscape, but their material disappearance was also related to the absence of wind energy use in broader social and technical debates on a discursive level. Though somewhat marginal, essential scientific and technical knowledge was generated in this period.[12]

With the advent of the environmental movement in the 1970s, a new aspect of wind energy became of central importance: wind energy was seen as a resource that was both renewable and environmentally friendly. The question in this paper considers the extent to which wind energy use between 1973 and 1991 was shaped by competing visualization strategies. The timeframe is based on the trailblazing period for wind power generation in West Germany.[13] The German development strongly correlated with developments in the pioneer markets of California/USA and Denmark.[14] But apart from Denmark, Germany was the only country in which the introduction and establishment of wind energy was successful at an early stage, and, in addition, in which an internationally successful plant industry was established.

1.1 | Historical wind energy research

In sociology, geography, and landscape studies, the relevance of visibility as a concept of energy research has been recognized and intensely researched in recent years, but only a few studies in historical wind energy research exist that address

[8]Heymann (1995, pp. 449–467). The first grid-connected wind turbine in Germany was established in 1982. For more, see Ohlhorst (2009, p. 100).

[9]See Erhaltung von Wind- und Wassermühlen Nds. 600, Acc. 52_83, Nr. 488, 1953-1969, Landesarchiv Niedersachsen, Hannover, Germany (hereafter NLA HA); Freiwillige Stillegung von Getreidemühlen Nds. 600, Acc. 153/92, Nr. 196 Bd.1, 1958-1961, NLA HA.

[10]König, G. (1947). Der Verbundbetrieb bei Großnetzen zwischen Kohle, Wind und Wasser. *Die Technik 2 (12)*, pp. 524–526; Witte, H. (1947). Der Stand der Windkraftausnutzung. *Die Technik 2 (11)*, pp. 465–470; Kloss, M. (1947). Probleme in der elektrischen Anlage von Windkraftwerken. *Die Technik 2 (11)*, pp. 471–479; Pantell, K. (1947). Gedanken über die Weiterentwicklung der Windkraftmaschinen. *Die Technik 2 (11)*, pp. 480–482. In October 1989, the first and only East German industrial wind turbine (Vestas) was installed.

[11]In the first half of the 20th century, the USSR and Eastern European countries initiated a few wind power projects on a large scale, especially in agriculture. But here too, research petered out due to the availability of large quantities of fossil energy resources: "Gesellschaft für politische Bildung e.V. Würzburg" (1988). The monthly journal *DDR Report* was published between 1968 and 1988 by the West German Gesellschaft für politische Bildung. The magazine evaluated numerous GDR magazines and newspapers and reviewed important articles. For more, see Ziegler (2001, pp. 50–51).

[12]Heymann (1995, pp. 444–465).

[13]The period under study came to an end with the first Electricity Feed Act, which for the first time established a legal obligation to purchase and pay for electricity: Neukirch (2010, pp. 179–180).

[14]Christensen (2013, pp. 42-44).

visibility in both material and discursive terms.[15] In their 2012 essay, "Winds of Change: Communication and Wind Power Technology Development in Denmark and Germany from 1973 to ca. 1985," Kristian H. Nielsen and Matthias Heymann analyzed and compared the communication practices of Danish and German engineers and technicians. The researchers discovered that the Danish strategy had seemingly led to swifter success and greater acceptance of wind energy than the German one.[16] Communicative practices that mediated between technical and social discourses strengthened public knowledge and acceptance. From this research, it can be inferred that communicative practices are of essential importance in the constitution of visibilities. In 2013, Richard F. Hirsh and Benjamin K. Sovacool published one of the few historiographical essays that seeks to provide a historical explanation for the current opposition to wind turbines.[17] With the aim of analyzing different influences on energy policy, the two authors examined protests against wind turbines. They argued "that opposition to visually obvious and numerous wind turbines stems, at least in part, from the long and successful history of an electric utility system that made its product largely invisible, both in its manufacture and physical manifestation." The authors suggested that the visibility of electricity generation by wind turbines "reminds observers that electricity does not emanate magically or inconsequentially from wall sockets."[18] According to Hirsh and Sovacool, the materiality of wind turbines clearly addresses the question of environmental, or perhaps energy, awareness. Their essay offers a helpful approach to addressing visibility as a concept for historical wind energy research, although it could have been better substantiated by further sources.[19]

History, as a discipline, has also dealt with resource and energy issues in relation to urban and metropolitan areas. Wind energy was mainly generated and used in rural areas. Thus, the question of visibility raises issues concerning rural sites of electricity production and of inequalities between the urban and rural. Hirsh and Sovacool, for example, pointed out that the presumed invisibility of the electricity system has had an impact on the perception of wind turbines. According to these authors, the experience is such that wind power industrialization more often takes place in the countryside to supply the energy consumption of urban centers.[20] Whereas power generation by wind turbines in the countryside is impressively visible in a physical way, power supply in cities is rendered almost invisible.[21] However, these approaches neither address the question of how and why visibility might be purposefully produced, nor do they examine the relation between material and discursive visibilities.

1.2 | Concept of wind energy visibilities

In this article, the focus is on the linkage between materiality and public or expert attention. Therefore, it situates practices of visibility at the center of its concerns and asks: why is visibility meaningful for the social significance of technologies? The analysis of visualization practices highlights a new dimension of technological change. Historians and social scientists stand to benefit from such analysis in their debates regarding the technological challenges, for example, of energy transition and climate change. A systematic study of visibilities is based on empirical examples that contribute both to the expansion of the research approaches outlined here and to current energy discourses. Additionally, this paper addresses a gap in wind energy history: to what extent was the visibility or even the invisibility of wind energy technology used in specific practices and applied to specific interests?

[15] For example, Pasqualetti, Gipe, & Righter (2002); Apostol, Palmer, Pasqualetti, et al. (2016); Schöbel (2012); Küster (2012); Bruns, Köppel, Ohlhorst, & Schön (2008).
[16] Nielsen & Heymann (2012, pp. 11–13).
[17] Hirsh & Sovacool (2021, pp. 705–734).
[18] Hirsh & Sovacool (2013, pp. 706, 707).
[19] Furthermore, a comprehensive, almost-20-year-old anthology by Martin J. Pasqualetti, Paul Gipe, and Robert W. Righter presented various approaches dealing with the visibility of wind energy use in a material, medial, and philosophical sense. The studies focus on aesthetics, nature-culture relationships, the perception of landscape, and questions of costs and benefits. Pasqualetti, Gipe, & Righter (2002).
[20] See Hindelang (2021); Hirsh & Sovacool (2021, pp. 706–707).
[21] Sociologist Andrea Brighenti (2007, p. 324), for example, in his research about visibility as a category in social sciences, underlined the notion that light "is not simply visible. It constitutes a form of visibility." With the implementation of street lighting, for example, social milieus became visible that had previously literally disappeared into darkness. A new visibility emerged.

According to the editors of this special issue, visibility is an analytical tool for highlighting power relations, identifying objectives, and deconstructing the concerns of specific historical actors.[22]

In this author's understanding, materiality creates discourses, which in turn stabilize or even destabilize material structures and vice versa, as the case studies presented here seek to demonstrate. The nexus of both produces visibility. The practices of wind energy use under consideration also constitute new forms of visibilities that include knowledge about the energy carrier, sustainability and technology, weather and climate, low- and high-tech, transition, and power relations and specific ways to deal with them: "it is a real social process in itself."[23] Power does not simply come out of the socket any longer. Wind energy practices also produce, whether purposefully or accidentally, a new visibility regarding environmental issues from so-called "soft" energies to landscape degradation cause by wind plants. Even though wind energy visibilities are not determined by the resource, wind has certain preconditions. Furthermore, visibilities address and achieve either public or expert audiences. Reciprocally, without an audience there are no visibilities. To explore the interface of material and discursive aspects, this paper discusses the following questions: What was made visible or invisible? The answer to this first question depends on our line of vision. Visibility can be aimed at a physical or material level as well as at a discursive level. The former level points towards technical artifacts, materials used, or even the energy resource itself, whereas the latter level addresses knowledge and societal discursive processes. Who made wind power visible or invisible and why? These two questions focus on groups of actors with specific interests and draw attention to relationships of power. It is about the construction of wind energy use in a specific way: how was it made (in)visible and to whom?

The paper examines these research questions using various sources on practices of low-tech wind energy use, such as instruction manuals, political pamphlets, documents published by educational institutes, and so on, which were linked to the goals of environmental movements in Germany. I also use information pertaining to the large-scale project GROWIAN, such as company documents, information brochures, newspaper articles, and documents from state and federal governments.

2 | PRACTICES OF VISIBILITY

Wind energy research activities during World War II had an impact on the post-war period.[24] Among others, Ulrich Hütter, an engineer with a PhD from the Technical University at Stuttgart, seamlessly transitioned from working at the wind turbine manufacturer Ventimotor GmbH in the early 1940s to being employed at Allgaier Werke in the 1950s and 1960s.[25] With the development of one of the first free-running wind turbines, the W 34 concept, he laid the technological foundation for modern wind turbines (the basis of GROWIAN as well as the American MOD-Program).[26] Moreover, sources dating back to the mid-1950s show that, in expert circles, wind energy concepts of the interwar period were discussed in relation to the goal of saving "more valuable" fossil fuels.[27] Within agriculture,

[22]See Frey & Schädler (2021).

[23]Brighenti (2007, p. 325).

[24]Heymann (1995, pp. 161–268); Reichsarbeitsgemeinschaft "Windkraft" (1940), Denkschrift 1 über die Arbeit der Reichsarbeitsgemeinschaft "Windkraft" im Geschäftsjahr 1939–1940, Universitätsarchiv, Stuttgart, Germany (hereafter UAS); Reichsarbeitsgemeinschaft "Windkraft" (1941), Denkschrift 3 über die Arbeit der Reichsarbeitsgemeinschaft "Windkraft" im Geschäftsjahr 1940–1941, UAS; Honnef (1932); Kleinhenz, F. (1942). Projekt eines Großwindkraftwerkes. *Der Bauingenieur. Sonderdruck 23 (23/24)*, pp. 1–5, UAS. The used archive stocks of the Stuttgart University Archives are not listed. Consequently, there are no signatures.

[25]Ventimotor GmbH was to supply Eastern European territories with wind turbines after the successful end to the war: Heymann (1995, pp. 260–268).

[26]Hütter's so called W 34 concept is considered a milestone in global wind energy development: for the first time, he designed a pendulum hub and wings from a glass-fiber composite material. Dörner (2002); Heymann (1995, pp. 317–339); Hütter, U. (1942), *Beitrag zur Schaffung von Gestaltungsgrundlagen für die Windkraftwerke*, UAS.

[27]See for example, Schmidt, K. O. (1955), Die Windkraftanlage der Deutschen Bundespost auf dem Schöneberg, *Elektrotechnik 37*, Abt. J 14, Nr. 99, Kreisarchiv Nordfriesland, Husum, Germany (hereafter KANF); Witte (1947); Juchem (1955); Baumeister, F. (1955), Ein Windkraftwerk zum Betrieb von Seezeichen, *ETZ 7*, pp. 437–441, Abt. J 14, Nr. 99, KANF.

wind energy use, from mills to pumps, had long been part of traditional energy practices and tacit knowledge. According to historian David Edgerton's well-known research about the persistence of old technologies, wind energy then was still part of specific energy practices.[28] Thus, while social awareness of this ancient resource had declined sharply in the first half of the 20th century, knowledge about wind power had been retained and expanded within different expert groups. At first, a broader audience was not confronted with wind energy, nor were such turbines physically present in most West German regions.

In the period this paper is concerned with, environmental activists proposed the use of wind energy as an alternative to the large-scale, centralized, high-emission energy system. Conversely, the German Federal Ministry of Research and Technology—in collaboration with Maschinenfabrik Augsburg-Nürnberg (MAN) and the major energy suppliers Rheinisch-Westfälische Elektrizitätswerke (RWE), Schleswig-Holsteinische Stromversorgungs-Aktiengesellschaft (Schleswag), and Hamburgische Electricitäts-Werke (HEW)—used the GROWIAN project's failure as an example to attempt to discredit wind energy use in public.

A variety of events encouraged the emergence of German and international environmental movements in the early 1970s. Various events and publications brought forth new social discussions about the potential of wind energy. The first United Nations Conference on the Human Environment, the Club of Rome study on the *Limits to Growth* in 1972, the first and second oil price crises in 1973 and 1979, the internationally acclaimed publications by Ernst F. Schumacher and Amory B. Lovins, the nuclear power plant incident in Harrisburg/Three-Mile-Island in 1979, protests against nuclear power plants, and the social movements in general—all helped trigger and sustain debates about the future of the established nuclear-fossil energy system.[29] Sustainability and resource conservation became central topics, alongside what looked like contradictions: environment awareness and (energy) technologies.[30] The gap between technological enthusiasm and a more general pessimism regarding technology was widened by the competing goals of environmental protection and nature conservation movements.[31] Energy technologies stood at the center of these competing discourses, which shaped the first period of the German environmental movement: on the one hand, they were regarded as risk-laden technologies and cause for anxiety; on the other, some hailed such technologies as future-oriented and a cause for great hope.[32]

OPEC's oil production limitation in 1973 created a new awareness of energy issues in general, particularly affecting import-dependent countries such as the Federal Republic of Germany. As a result, West Germany launched new energy research programs to diversify and reduce their overall resource dependency. Initially, the goal of these programs was to reduce crude oil's share of power generation and increase their "crisis preparedness through a broader energy supply, through better use of domestic energies, through geographical diversification of the necessary imports and, last but not least, through energy conservation."[33] Renewable energies were included on the agenda from the outset, albeit to a limited extent. The actual design parameters of a future German energy system became a field of conflict.

Klaus Traube, a manager in the German nuclear energy industry who later became one of its opponents and an environmentalist, wrote in 1978: "Renewable energies are indeed very important and philanthropic developments, but they could be adapted to the industrial system. This would require changing the state of resources and the environment to stabilize the current industrial society."[34] Being an insider and expert on the German energy industry, Traube emphasized the role of renewable energies as part of a future energy system.

[28]Edgerton (2006, pp. x–xviii); regarding water power, see Zumbrägel (2018).
[29]See Schumacher (1973); Lovins (1977); Radkau & Hahn (2013).
[30](July 10, 2020) retrieved from https://digitallibrary.un.org/record/523249?ln=en.
[31]Radkau (2011, p. 72).
[32]Blackbourn (2013, p. 13).
[33]Bundesministerium für Wirtschaft und Energie (2017, p. 14).
[34]Traube (1978, p. 94).

2.1 | Environmental wind tinkering

From the beginning of the environmental movement in Germany, activists focused on energy processes. They tried to steer power generation into a fundamentally new and more decentralized direction. Engineer Horst Crome, the person in charge of a wind energy test field near Bremen and a developer of small to medium-size wind turbine concepts, stated that "at the earliest before Harrisburg and at the latest since Chernobyl … even laypersons can guess that in principle we are doing something wrong if we are not prepared to draw practical conclusions from the information available."[35] Due to numerous reports on air pollution, acid rain, nuclear accidents, and forest dieback, the energy issue became increasingly important in public perception. Protest movements put the existing structure of the energy system on the agenda and made its complexity visible for a broader public.

All over the country, initiatives, communities, associations, or projects emerged that had one thing in common: they questioned and challenged the economic system and sought new forms of common life, work, and economic activity. In some of these projects, decentralized forms of energy production were discussed, developed, and tested. This was not a homogeneous and networked community, even though comprehensive institutionalization ultimately emerged over time. Rather, it was individuals, groups at universities and in living and working communities, teachers, pupils, and farmers who once again became involved with wind energy. In the 1990s, a more permanent period of professionalization began when the wind energy industry association, the Bundesverband Windenergie e.V., was founded and regular wind energy fairs took place.[36]

Discourses on environmental protection and resources triggered a recurring interest in wind energy. There was consensus among the various actors that the Western way of life, or at least the practices of energy supply, needed to be changed. The above-mentioned groups revived technical concepts of wind turbines and brought them back into public discourse through different practices. Wind turbines were often built by groups of environmentalists and engineers. As numerous construction manuals show, the collective experience was part of the performative act of environmental wind tinkering (Figure 2). The collective work offered a space for political discussions and the exchange of knowledge and arguments. These practices, which will be described in the following as practices of environmental wind tinkering, created a new visibility of wind energy that, for the first time, was environmentally minded. The paper identifies three main elements of environmental wind tinkering: do-it-yourself (DIY), the generation and distribution of knowledge, and the development of so-called low-tech concepts. These aspects were intertwined, but for analytical reasons will be looked at separately.

2.1.1 | Do-it-yourself

As a result of the oil price crisis, some environmentalist DIYers did not want to link their energy consumption to the large-scale energy industry. They wanted to produce energy independently.[37] The actors of the early 1970s benefited from the persistence of rural wind energy use and returned to technological concepts from the first half of the 20th century.[38] DIY has to be understood as a creative act that meaningfully connects people and their ideas to the surrounding environment and its materiality. As part of environmental wind tinkering, it can be characterized by developing or selecting of a turbine concept, obtaining materials, taking wind measurements, and hammering, drilling, screwing, filing, or sawing. DIY first establishes public awareness in the local area—among neighbors, friends, the

[35]His most successful concept, KUKATE, was not only used in Germany but also exported abroad. The concept was named after the first test site. Crome (1987, p. 9).

[36]Ohlhorst (2009, p. 145). The first German Wind Energy Fair, the Husum Wind, was held starting in 1989, followed by further initiatives.

[37]See Premiere für die Mühle von Moorlage. Energiegewinnung ohne Emissionen (1988, Nov. 28), *Lingener Tagespost*, Mühlen-Archiv für Niedersachsen und Bremen, Schortens, Germany (hereafter MANSB); Pinzek, G. (1986, Jul. 16), Kampf gegen die Amtsmühlen, AVZ no. 161, MANSB.

[38]For example, water supplies or drainage systems were powered by wind motors, thus helping to improve hygiene conditions in rural areas beyond the grid. See Hesse (2021). On North German islands and Halligen (small marshland islands), which were not connected yet to the general power grid by submarine cables, wind power ensured a limited but useful supply of electricity. Schleswag (n.d.), *Strom für die Halligen*, p. 6, Abt. B4, no. 3063, KANF. Research was also conducted at universities, but this did not lead to more extensive practical use until the 1980s. See Heymann (1995, pp. 269–339). On the recourse to old concepts, see Crome (1987, p. 9).

scrapyard operators, and passers-by. Farmers were among the first to install wind turbines. Wind energy use was a beneficial rural practice. The advantages of independent maintenance, operation, and repair provided high practical value, a contribution to the local economy, and, ultimately, infrastructural modernization in certain regions.[39] For economic, technical, and ecological reasons, most farmers built their own turbines until the mid-1980s.[40] The wind turbine construction by farmer Böse of Päpsen in Lower Saxony in 1980 is an illustrative example. Lacking a connection to the electrical grid, the power supply for his cow barn, and specifically its supply of hot water, was not ensured. Influenced by the oil price crisis, he first built a solar installation in the 1970s, and then, to compensate for the weak winter sun, he followed up by building a wind energy plant for the cost of around DM 5,000. Böse and his sons built the energy plants as a collaborative work. The turbine generated 4,000 kWh for electrical heating elements, a 1,000 L water tank, and hot water supply.[41] Spurred on by environmental movements, this and similar projects generated huge amounts of media attention. Not only local and regional media, but also the national press reported on individual private users' construction and use of wind turbines.[42] The practices of DIY connected physical and discursive elements. DIYers entertained curious visitors and provided information about plant concepts, materials, energy yield, consumers, and the problems and resistance caused by nature, technology, and administration. They invited members of the press and their neighborhoods to attend inauguration celebrations for the commissioning of the plants.[43] DIY involved practices of visualization that were subsequently used to increase attention. The discursive practices of DIY wind power construction were closely related to the materiality of the plants. DIYers cleverly connected the unavoidable visual impact with socio-technological messages and demands, thereby enhancing the notion that DIY constituted a new visibility of wind energy use. This approach was mostly successful as the public became actively involved in environmental politics and the initial procedures for gaining official approval set a trend for those that followed.[44] With the increasing professionalization and technical maturity of small-to-medium-size facilities, do-it-yourself wind turbine construction began to decline. Since the end of the 1980s, it has largely been replaced by the installation of large-scale professional facilities.[45] Nevertheless, the interdependence between material and discursive practices as a visualization strategy has remained largely the same.

2.1.2 | Knowledge generation and distribution

The practice of DIY was accompanied by knowledge distribution. Environmentally minded wind tinkerers organized events, exhibitions, and excursions. Organizations like the Arbeitsgemeinschaft Sanfte Energie were founded by teachers and students, in this case at the technical college in Frankfurt-Höchst. This association merged into the Energie- und Umweltzentrum am Deister, and would go on to develop the exhibition “Es geht auch anders—Ausstellung über Energiealternativen” (Figure 1).[46]

The exhibition travelled through Germany for more than 5 years until the mid-1980s and was displayed at 30 different locations, attracting more than 250,000 visitors.[47] The exhibition “Umdenken—umschwenken” (“Rethink—Change Direction”), conceived by Hanswerner Mackwitz and students at the University of Zürich and Eidgenössische Technische Hochschule Zürich in the wake of the oil price crisis, also toured in West Germany in 1976–1977.[48] In this pedagogical context, nationwide competitions for young scientists such as “Jugend forscht,” environmental engineering as a field of study, educational trips, and technical aid projects for developing countries,

[39]Hesse (2016, pp. 143–145).
[40]“Energie vom Eumel” (1983).
[41]Stampa & Bredow (1987, p. 24).
[42]“Energie vom Eumel” (1983).
[43]Premiere für die Mühle von Moorlage. Energiegewinnung ohne Emissionen (1988, Nov. 28), *Lingener Tagespost*, MANSB.
[44]Ohlhorst (2009, p. 118).
[45]Premiere für die Mühle von Moorlage. Energiegewinnung ohne Emissionen (1988, Nov. 28), *Lingener Tagespost*, MANSB.
[46]The center still exists today (https://www.e-u-z.de/).
[47]AGSE (1979, p. 173); Beer (1983, p. 76).
[48]Arbeitsgemeinschaft Umwelt Zürich (1978).

FIGURE 1 Renewable energy exhibition “Es geht auch anders” in 1980. Different wind and solar energy concepts were presented to a broader public. From *Natürlich, endlos, frei: Sonnenenergie als Alternative zur Atomkraft. RET.Con 2020 Nordhausen* (p. 13). by B. Spessert, 2020, Nordhausen, Germany: Hochschule Nordhausen. With many thanks to Bruno Spessert

as well as events in public spaces, functioned as practices for knowledge generation and distribution.[49] Engineers used small models to demonstrate the basics of wind technology in public places, and these efforts generated public awareness about alternative energy. Their political message was clear: they proposed a critique of Germany's and, more generally, the West's large-scale, centralized, and high-risk energy system. In this context, and in open contrast to the DIY-farmers, highlighting practical use and functionality was not always the main objective. This is proven by their use of non-functioning exhibit turbines as well as construction manuals, which lacked essential information needed to build a functioning wind turbine.[50] Nevertheless, these organizers used the physical appearance even of non-working wind turbines to actively promote alternative energy. Materiality was used purposefully to create public awareness of the discourse.

Another common practice were so-called excursions. Popular excursion destinations included do-it-yourself installations and Danish projects such as the Tvind. As Ruth Oldenziel and Mikael Hård have noted, the Danish Tvind, the first large wind turbine in Europe to be in operation since 1977, “became a pilgrimage site for the alternative energy movement.” “Like the American kitchen, the giant windmill became an icon for both an ideology and a technology.”[51] In these specific spaces, the practices outlined visualized imaginaries of new energy futures. According to the owners of DIY wind turbines, the number of visitors ranked in the hundreds and thousands, and the regional daily press tended to regularly report on new wind turbines in the area.[52] In 1987, engineers Ulrich

[49]Crome (1987, pp. 6, 9).

[50]An example is the construction manual of the Arbeitsgemeinschaft Sanfte Energie (1979).

[51]Oldenziel & Hård (2013, Introduction). With an output of 2,000 kW, a height of 63 m, and a rotor diameter of 54 m, Tvind was for several years the largest well-functioning wind turbine in Europe.

[52]Stampa & Bredow (1987, p. 22); “Energie vom Eumel” (1983); “Kukate” wird schon sehnsüchtig erwartet (1986); Crome (n.d.); Crome (1987, pp. 80–84, 195); Hallenga (2008, pp. 5, 7–10, 28–31).

FIGURE 2 Self-made KUKATE wind turbine. From *Windenergie Praxis: Windkraftanlagen in handwerklicher Fertigung* by H. Crome, 1987, Staufen, Germany: Ökobuch Verlag (Cover). With many thanks to Horst Crome

Stampa and Wolfgang Bredow published a book about 16 DIY wind turbines in the region around Bremen alone.[53] The authors not only described these turbines but also provided information about specialist literature, turbine manufacturers, and wind energy associations. It is difficult to quantify how many DIY plants were constructed and operated between 1970 and 1990. Statistical data about small and DIY wind turbines has only been available in Germany since 2006.[54] The source material suggests that several hundred such turbines were in use. Stampa and Bredow mention 400 to 500 DIY wind turbines in Germany in the second half of the 1980s.[55]

The presentation of wind turbines made an alternative energy path literally visible: in the landscape, in cities, schools, and neighborhoods (Figure 1 & 2).

2.1.3 | Low-tech concepts

The third aspect was the development of simple but functional low-tech wind plant concepts, which were often distributed via construction manuals. Concerned engineers and experts like Horst Crome developed plant concepts from easily obtainable materials designed to be built in poorly supplied areas. His wind plant concepts were installed in Germany, but also exported to Nicaragua, the Czech Republic, India, North Korea, the Greek islands, Haiti, and Papua New Guinea, among others. They sometimes took on the role of a development aid project or became the destination for an educational trip.[56] Other concepts addressed German users who wanted to generate their own energy. The construction manuals for these concepts conveyed technical knowledge while at the same time bringing political messages about environmental protection, the risks of nuclear energy, alternative energy paths, peace initiatives, and development aid to a wider audience. In West Germany, more than 40 construction manuals for wind turbines were published in the period under review, some of them in large editions.[57] They can even be seen as a

[53]Stampa & Bredow (1987).
[54]Jüttemann (2016).
[55]Stampa & Bredow (1987, p. 82); Crome (1987, p. 13); Ohlhorst (2009, p. 99).
[56]Crome (n.d.).
[57]Hesse (2016, p. 127).

materialized form of contemporary discourse. Christian Kuhtz, an anti-nuclear activist from Kiel, wrote in one of his four construction manuals that "a wind turbine could be a visual symbol for environmental protection."[58] The quotation illustrates the intentional linking of material and discursive practices to make a new and ecological energy future more tangible to a broader audience: to neighbors, to other activists, to a local, regional and supra-regional public. The materiality of wind energy technology was conceived as a specific expression of environmental awareness. Even construction materials played an important role in environmental wind tinkering. Detailed explanations conveyed knowledge about ecological and available materials, suitable artifacts, and tools for the construction of an environmentally friendly wind turbine. Bicycle components, generators, dynamos, scrap steel towers, tubes, and pipes were recycled. The use of scrap, natural, and recycled materials drove home the environmental objectives. Low-tech concepts formed a practice that linked energy generation to environmental policy and activism, developmental aid, manageability, and materials.

Over time, environmental wind tinkerers founded their own organizations, some of which also received state funding.[59] In addition, several local and regional associations existed that addressed economic interests. In 1974, the regional association for wind energy research and application was founded, which merged with the Bundesverband Windenergie e.V. in 1996.[60] These associations became knowledge hubs for the scientific and economic development of wind energy in Germany. However, at the same time, they contained two antagonistic factions: the idealistic advocates of wind energy, and the drivers of a new industrial energy sector.

These interwoven patterns of action, which came together to form the practices of environmental wind tinkering, moved visibility concerns out from experts to a broader audience. They led to the public perception of wind energy as an environmentally friendly technology, "an alternative energy source with a benign image," as Pasqualetti, Gipe, and Righter noted.[61] DIY turbine tinkering, excursions, exhibitions, construction manuals, and scrap yards became practices and spaces in which the interaction between material and discursive practices created visibility in condensed forms. In the practices of environmental wind tinkering, materiality and discursivity complemented each other. They were linked to political symbolism by interweaving knowledge about energy technologies with social demands and materiality. Knowledge was expanded upon, consolidated, and distributed, and wind energy and other renewables received a new environmentally friendly image. This increased attention made it possible to learn more about wind energy without being an expert or a traditional user. As we shall see, the German Federal Ministry of Research and Technology and the energy industry followed up on this development and used it to pursue their own interests.

2.2 | Visualization of failure

In contrast to the wind tinkerers' small- and medium-size wind plants, the state-funded research plant GROWIAN was designed to contain the world's largest wind turbine to date. Initially, it was supposed to act as a research and test facility and provide scientific data, though it was intended to remain in operation long beyond the initial project phase.[62] Its rotor was 100.4 m in diameter with a hub height of 100 m. The nacelle, the size of a detached house, weighed 340 tons, while the rotor blades, which were manufactured in hybrid construction from fiber composite and steel, each weighed 23 tons (Figure 3).[63] As Figure 3 illustrates, this impressive materiality alone created

[58]The construction manuals were published from 1976 onwards: Kuhtz (1981, p. 1).

[59]To name a few, the Energie- und Umweltzentrum am Deister e.V., the Interdisziplinäre Projektgruppe für angepasste Technologie at the Technical University of Berlin, the Arbeitsgruppe Angepasste Technologie Kassel, the Forschungsinstitut Sanfte Technologie, and the Gruppe Windwerk were established in Germany between 1975 and 1985.

[60]Between 1985 and 1990, several associations were founded: in 1985 the Interessenverband Windkraft Binnenland (IWB) and the Fördergesellschaft Windenergie e.V. (FGW); in 1988, the Institut für Solare Energieversorgungstechnik e.V. (ISET); and in 1990, das Deutsche Wind-Energie-Institut (DEWI). Until 1996, companies in the newly emerging sector also organized themselves into associations. Ohlhorst (2009, pp. 144–146).

[61]Pasqualetti, Gipe, & Righter (2002, p. 4).

[62]Wirtschaftsminister Dr. Jürgen Westphal besichtigte Growian (1982, Sept. 2), *Dithmarsche Landeszeitung*, Dept. B4, No. 3445, KANF.

[63]Große Windenergieanlage Bau- und Betriebsgesellschaft mbH (1984, p. 3).

FIGURE 3 GROWIAN's impressive size shaped the countryside in Kaiser-Wilhelm-Koog near Marne on the North Sea coast. From "4. Oktober 1983—Windkraftanlage Growian geht in Betrieb," *WDR*, 2013 (https://www1.wdr.de/stichtag/stichtag7866.html)

enormous visibility, a visibility that the project participants explicitly desired and connected to discourses, as I demonstrate in the following examination.

In 1974, the GROWIAN project was launched by a program study commissioned by the Research Ministry, *Energy Sources for Tomorrow*. The study announced at its completion in 1976 that "theoretically wind energy could cover 75 % of electricity consumption in Germany."[64] RWE, HEW, Schleswag, and the mechanical engineering company MAN were then entrusted with GROWIAN's implementation.[65] In January 1980, they founded the Große Windenergieanlage Bau- und Betriebsgesellschaft mbH (GROWIAN GmbH).[66] An energy research project management team at Jülich Research Institute supervised the scientific program at the wind turbine site.[67] The objective was to examine the possibilities of wind power generation within the existing large-scale German energy system. This goal demonstrated the difference between this project and the environmental wind tinkerers' intentions: in opposition to the highly centralized and powerful energy industry, they desired wind power as a means of decentralized and local supply of renewable energies. Since the 1970s, the prevailing paradigm, which linked economic growth and prosperity to increasing energy consumption, has been supplemented by new paradigms of self-sufficiency, sustainability, and ecology. Sociologist Rüdiger Mautz speaks of the "incubation period of an alternative energy discourse," in which so-called power-limited primary energies such as wind energy slowly found their way into energy research programs.[68] Nevertheless, West German energy policy continued to concentrate mainly on nuclear and fossil energy research. The wind tinkerers accused the government of missing the boat on wind energy use.[69] The German government, in turn, proposed a decentralized wind energy supply only for isolated applications in rural areas and developing countries. In addition, the government's explicit goal was to establish an export market for wind energy plants. Wind power use in West Germany itself was only conceivable within the electrical grid, if at

[64]Heymann (1995, pp. 362–633).
[65]About MAN and RWE, see, for example, Bär, Banken, & Flemming (2009); Thieme & Schweer(1998).
[66]Pulczynski (1991).
[67]Große Windenergieanlage Bau- und Betriebsgesellschaft mbH (1984, p. 14).
[68]Mautz, Byzio, & Rosenbaum (2008, p. 18).
[69]"Wie Don Quijote gegen Mühlenflügel" (1986).

all. However, since the chances of this being done by the energy industry were considered low during the period under review, the total budget for wind energy use was correspondingly small. In 1979, only 4.4% of the government's energy research funding was spent on renewable energies. In contrast, the USA invested 16.5%, France 7.6%, and Sweden 30.4%.[70] Moreover, most of the money spent on renewable energies was initially used to finance solar technologies, as the Research Ministry expected better and, above all, faster results. Only a small percentage went into the development of wind energy technologies.[71] During the 1980s, the largest share of these funds was granted to the GROWIAN project.

GROWIAN's two-bladed test plant was first commissioned in October 1983, decommissioned in 1987, and disassembled in 1988. Amazingly, operating hours during the 3-year test period amounted to only 418.8 total working hours.[72] GROWIAN was shut down for repairs for the rest of the time. In the end, the project, initiated and largely financed by the Research Ministry, cost DM 90 million. But how are these key data connected to the production of visibilities?

On September 2, 1982, the *Dithmarsche Landeszeitung* reported on an official trip by Jürgen Westphal, Schleswig-Holstein's Minister of Economic Affairs, who was accompanied by members of the State Energy Advisory Council.[73] The tour's purpose was to visit the pillars of the northernmost West German state's energy supply and to demonstrate its independence from oil-producing countries by showing the viability energy alternatives. In addition to the natural gas town of Marne, the district heating plants in Glückstadt, and the Brokdorf nuclear power plant, the trip's agenda included the GROWIAN construction site in Kaiser-Wilhelm-Koog, which had popular appeal.[74] The visits to Brokdorf and Kaiser-Wilhelm-Koog especially had an impact beyond Schleswig-Holstein's borders and attracted journalists from the then-capital of Bonn. The politically motivated tour of Germany's so-called wind state connected the physical appearance of the energy facilities with a discursive visibility that is characteristic of dealings with GROWIAN. Materiality itself thus became the medium for discourse.

The GROWIAN project participants could be divided into three groups: The Federal Ministry of Research and Technology, the private companies tasked with its implementation (energy utilities and MAN), and the Jülich Research Institute, which took up research topics other than nuclear energy in the 1980s.[75] Two objectives can be distinguished: the plant was to become a prototype for large-scale commercial wind energy use, but it also represented a test facility for broader research purposes.[76]

The main political actor, the Research Ministry, which was the supervising body of the state-owned Jülich Research Institute, felt obligated to react to the oil price crisis and the growing strength of environmental movements.[77] However, GROWIAN's low budget points to a half-hearted approach. Research funding in the field of wind energy technology was predominantly a strategy for examining new ways of generating electricity, and above all, it was designed to send a signal to society: "GROWIAN rises impressively in the extensive coastal landscape in Kaiser-Wilhelm-Koog near Marne as a widely visible sign that new technologies are being used here to tap an old, abundant source of energy."[78] The visibility created by the GROWIAN GmbH was meant to highlight two main topics: the functionality of wind energy within a large-scale energy system and the development of new technologies. Discourses on technological progress, innovation, and a reliable energy future were linked to the physical presence of the world's largest wind turbine and presented to a national and international audience. This is evidenced by, among others, the Research Ministry's considerable efforts to scale up the wind turbine's size by a factor of 30, by

[70]Heymann (1995, p. 344); Ohlhorst (2009, p. 94).
[71]Bundesministerium für Wirtschaft und Energie (2017, pp. 17, 38, 40–42, 73).
[72]Pulczynski (1991, p. 57).
[73]Der Erpressung durch Ölstaaten wirkungsvoll begegnet (1982, Sept. 2), *Dithmarsche Landeszeitung*, Dept. B4, No 3445, KANF.
[74]Der Erpressung durch Ölstaaten wirkungsvoll begegnet (1982, Sept. 2), *Dithmarsche Landeszeitung*, Dept. B4, No 3445, KANF.
[75]See Knie & Lengwiler (2007); Ohlhorst (2009, pp. 95–97).
[76]Mitschel (1983, p. 2).
[77]During the project period, the Ministry was represented by four consecutive Federal Ministers for Research and Technology, all of whom had quite different priorities: Hans Hermann Matthöfer until 1978, Volker Hauff until 1980, Andreas von Bülow until 1982, and Heinz Riesenhuber from 1982 to 1993.
[78]Große Windenergieanlage Bau- und Betriebsgesellschaft mbH (1984, p. 2).

extrapolating from 300 kW turbines to a 1,000–3,000 kW turbine. The wind energy expert, Ulrich Hütter, and Erich Hau, a leading engineer at MAN, recommended scaling up more gradually by using the experience gained from working with the solid W 34 turbine.[79] With its impressive materiality, GROWIAN was intended to convince environmental activists that the German government was operating with a sustainable energy supply from renewable energies. Furthermore, GROWIAN was to become a masterpiece of German engineering aiming to equally succeed in the international wind energy sector.[80] Above all, this show of strength was directed at the US, as Germany's main competitor in the large-scale wind industry. Whereas Denmark pushed mainly small- and mid-scale projects, the US also focused on large-scale wind power plants.[81] There had been discussions about how to confront a newly emerging energy crisis even before the oil price crisis hit. One outcome of these was the U.S. Federal Wind Energy Program of 1973, which included research on large-scale wind plant concepts from 100 to 7,000 kW. At the end of the 1980s, the program was terminated without ever being able to develop a market-ready large-scale wind turbine. The reasons were similar to those GROWIAN faced—a thorough underestimation of technological challenges.[82] Nevertheless, the German magazine *Bild der Wissenschaft* wrote in 1986 that "GROWIAN was planned with the intention of setting up a large-scale wind energy plant in one single step."[83]

Similar to the environmental wind tinkering, material practices were accompanied by the generation and distribution of knowledge. Between 1980 and 1988, GROWIAN GmbH published various brochures and 20 issues of *GROWIAN Information*. The operating company maintained an information kiosk and a GROWIAN sales shop at the Kaiser-Wilhelm-Koog premises. In its publications, the operating company provided data about the individual GROWIAN project steps. In contrast to the environmental wind tinkerers, the operators justified the investments with political and economic, but not ecological, arguments. They argued that it was necessary to develop new technologies to become "more independent of conventional energy sources."[84] In doing so, they tried to avoid having the public develop too great expectations, and they pointed out that it was still largely uncertain as to what role wind energy use could play in the future.[85]

Thus, the policies that led to the construction of the GROWIAN plant made use of the symbolic attributions of the environmental wind tinkerers to show that social concerns were being taken seriously. GROWIAN's size corresponded with the contemporary belief in Germany that new forms of power plants should be able to replace the old fossil and nuclear power plants within the given centralized system. Integration into the large-scale grid was the only conceivable way to make wind energy viable.[86] Accordingly, the state never questioned the power concentration in the monopolistic energy industry.

Due to the goal of integrating wind energy use into the centralized energy system, energy suppliers should have been involved in the project from the very beginning. However, at first, they were not interested in wind energy, as their capital and expertise was tied up in coal and nuclear energy.[87] In a tough process of negotiation, HEW, Schleswag, and RWE were finally won over. However, these companies only contributed a small amount to the costs and risks. The minutes of a GROWIAN meeting held at the Federal Ministry of Research and Technology in Bonn in 1979 provide information about the reasons why the energy supplier RWE to eventually participated in the project. Assuming the project would fail, the company nonetheless wanted to appear open to social concerns and new, environmentally friendly technologies.[88] RWE board member Günther Klätte and former Research Minister Hans Hermann Matthöfer were confident that GROWIAN

[79]Pulczynski (1991, p. 18).
[80]"Wie Don Quijote gegen Mühlenflügel" (1986).
[81]Ohlhorst (2009, pp. 87–89).
[82]Heymann (1995, pp. 346–355).
[83]Quoted in Dittmann (2019, p. 55).
[84]Große Windenergieanlage Bau- und Betriebsgesellschaft mbH (1984, p. 1).
[85]Große Windenergieanlage Bau- und Betriebsgesellschaft mbH (1984, p. 1).
[86]Electricity generation from wind energy is often considered decentralized compared to conventional power plants. Smaller wind farms often supply power to nearby consumers. In contrast, offshore onshore wind farms with megawatt capacities, which are linked to large-scale transmission grids (such as Südlink), point to the integration of wind power into the logic of the existing centralized energy system and thus to structural continuity.
[87]Dittmann (2019, p. 52).
[88]Heymann (1995, pp. 372–373); "Wie Don Quijote gegen Mühlenflügel" (1986).

would fail, and they consequently made more precise statements to the press at the time: GROWIAN's failure would show that wind energy did not work within the large electrical system. The facility was supposed to serve as an educational tool for anti-nuclear activists. Its failure would prove that renewable energies could not replace nuclear energy. On December 9, 1981, 20 members of the German parliament and the parliamentary group of the opposition party CDU/CSU sent a request to the federal government. According to them, the public suspected that project participants wanted to prove that wind energy use was not marketable. Thus, the members of parliament called on the federal government to take a stance on this accusation.[89] Unsurprisingly, the federal government denied it.[90] Though GROWIAN's failure was probably not initially intentional, it was subsequently accepted that its failure could be used to help stabilize the existing energy system. Insufficient funding, over-scaling, and project officials spreading the narrative of possible failure generated a visibility that led to the public perception outlined above.

At the same time as GROWIAN, the Research Ministry supported other wind energy projects in which significantly smaller turbines were tested. One example is the test field on the North Frisian island of Pellworm, 100 km north of the GROWIAN site. In 1979, a restricted invitation to tender was used to find suppliers of various technical concepts meant to be tested under North Sea coastal conditions. The aim was to help smaller wind turbine manufacturers mature their technical concepts by generating measurements and operating experience.[91] With approximately 10 kW, the Pellworm turbines generated an electrical output 300 times smaller than GROWIAN. But this effort had a different goal. At the Pellworm test field, the objective was to immediately test simple, operational, and maintenance-free systems for underserved areas in industrialized countries, but above all for their export to developing countries.[92] Integration into the German energy system was not the intended use. The focus of the Pellworm test field was on the development of a new branch of industry and technology in Germany, rather than on a possible transformation of the German energy system. Scientific support was provided by the University of Hannover and the GKSS-Forschungszentrum Geesthacht GmbH (Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt mbH), institutions comparable to those participating in GROWIAN project.[93] However, after only 4 years, this Ministry of Research project was abandoned as well, again due to very limited research funding and immature concepts. Thus, governmental and industrial development of wind energy remained largely symbolic.[94]

The Ministry of Research and the energy supplier intentionally used GROWIAN's failure to stress the inadequacy of renewables within the existing energy system. The negative spin they put on wind energy was meant to make it invisible again. Ironically, despite the publicly fostered narrative of the early government-funded wind energy projects' failures, they also contributed to a more comprehensive visibility for wind energy use. GROWIAN's site represented an impressive materiality connected to a site of knowledge and information capture. Nevertheless, the narrative of failure prevailed in the contemporary national press.[95] However, the material and discursive practices of the government and the operating companies contributed to establishing a new visibility for wind energy use beyond the narrative of failure. For a short time, the public failure benefited the big players in the German energy industry and supported the preservation of existing power structures. But the first commercial wind park, Windenergiepark Westküste, was put into operation at the GROWIAN site in 1988, only a few months after GROWIAN's disassembly.

HEW and Schleswag, two of the energy suppliers in northern Germany in 1987, were involved in building Windenergiepark Westküste and its medium-size plants. Interestingly, the government of Schleswig-Holstein did not participate in the GROWIAN project, but rather launched more than 40 smaller wind energy projects. A spokesperson of the Federal Ministry of Research in Bonn said that these medium-size projects were used to find the Volkswagen Beetle out of all the installations.[96] With this analogy, he referred to the characteristics attributed to the VW Beetle:

[89]Deutscher Bundestag 9. Wahlperiode (1981).
[90]Deutscher Bundestag 9. Wahlperiode (1982).
[91]GKSS-Forschungszentrum Geesthacht GmbH (1980), Versuchsfeld Pellworm für Windkraftanlagen, pp. 3, 8, Dept. Z 800, KANF.
[92]GKSS-Forschungszentrum Geesthacht GmbH (1980), Versuchsfeld Pellworm für Windkraftanlagen, p. 6, Dept. Z 800, KANF.
[93]Bundesministerium für Wirtschaft und Energie (2017, p. 64).
[94]Heymann (1995, pp. 390–392).
[95]See Bauer (2014); Fraunholz & Hänseroth (2012).
[96]Dickes Lob aus Bonn für die Windmühlen aus Husum (1988, Mar. 3), *Nordfriesland-Tageblatt*, Dept. B4, no. 3465, KANF.

low maintenance, reliability, and mass producible. These characteristics were to be the guiding principles for medium-size wind turbines. Thus, in Schleswig-Holstein politicians were looking for a reliable, low-cost, medium-size wind turbine that would be affordable for many customers and could be mass produced. In contrast to GROWIAN, its funding policy was aimed at practical application. In doing so, the actors did not only pursue local economic value. They also built on the knowledge of regional, small- to medium-size machine factories that had manufactured wind turbines since the end of the 19th century.[97] The fact that the state of Schleswig-Holstein carried out several successful wind energy projects of this size simultaneously underlines the GROWIAN project's symbolic objectives.

3 | PRACTICES OF VISIBILITY – A CONCLUSION

The importance of an energy resource within a specific socio-technological culture affects its visibility, and vice versa. Between 1973 and 1991, various actors with different goals and strategies occupied the field of wind energy use in Germany. Newly formed visibilities of wind energy spawned new possibilities for energy use and revealed the power structures and economic interests of the centralized fossil-nuclear energy industry and the government.

The visibility in the context of environmental movements was established by farmers, environmental activists, concerned engineers, and teachers. These groups wanted to draw attention to power concentrations in the energy industry, to suggest a new energy future, and, within a risk discourse, to reveal dangers, especially those relevant to nuclear energy use. The goal was to protect the environment and resources and to search for alternative energy and economic opportunities. In DIY constructions, construction manuals, public information events, informative exhibitions, activities in vocational schools, educational trips, and initiatives for developing countries, material visibility was combined with discourses as well as old and new knowledge. These practices became a fundamental part of the reinterpretation of wind energy as a human and environmentally friendly technology that is, despite all conflicts and protests, still effective today.[98] The environmental wind tinkerers demonstrated different possibilities of using energy to a broader public. The GROWIAN project strengthened a similar visibility, albeit with different goals in mind. The key players here were the Ministry of Research, RWE, Schleswag and HEW, the German engineering company MAN, and the Jülich Research Institute. Despite the activities of the environmental wind tinkerers, public discourses, and governmental diversification strategies, wind energy was not an alternative taken seriously by politics and industry as part of the centralized German energy system until the first electricity feed-in law was passed in 1991.[99] Sociologist Dörte Ohlhorst explained this, stating that the energy supply companies hardly generated any savings by operating decentralized units. Capital costs continued to be incurred and were tied up in large power plants and electricity grids.[100] Large energy suppliers, such as RWE, therefore closed their doors to renewable energy sources for economic reasons, but political projects at the federal level—and GROWIAN is an impressive example of this—were also oriented more towards symbolic appeal than towards serious implementation. But what was made visible with GROWIAN? With this large-scale project, both the state and the energy industry were able to show that they were taking up contemporary social discourses and environmental debates. The project was intended to demonstrate that politics and industry were active in matters of environmental protection. A detailed look, however, shows that more was at stake. Politicians such as the various Federal Ministers for Research, as well as the monopolistic energy industry, upheld the centralized energy supply system. They repeatedly stated that GROWIAN was about showing environmentalists and opponents of nuclear power that wind energy use is not feasible within a centralized electricity system. In doing so, they

[97] One example is the Köster machine factory and iron foundry in Heide/Holstein, founded in 1861, which manufactured wind turbines until the first half of the 20th century and then invested again in the construction of wind turbines and components acquired under license in the 1980s. Köster (1986); Hütter (1954).

[98] Since the late 1990s, protests against the use of wind energy, expressed through a number of local citizens' initiatives, have increased. See Hoeft, Messinger-Zimmer, & Zilles (2017).

[99] The Electricity Feed Act regulated for the first time the obligation of electricity companies to purchase and pay for electricity from renewable energies. See Reiche & Bechberger (2004); Grau, Huo, & Neuhoff (2012).

[100] Ohlhorst (2009, p. 99).

nonetheless drew great attention to the topic and made wind energy impressively visible again. "Green politicians" spoke of wind energy use as an "ecological fig leaf" for the energy industry.[101]

The new visibilities are thus an expression of political and socio-technological discourses and the sovereign right of everybody to interpret the future design of the German energy system. All actors used the materiality of the plants and linked them to their own interests. In addition to its internal effect on German society, GROWIAN also had an external effect. In the US, research into large wind turbines was performed in the late 1970s and 1980s. The large scale of GROWIAN was supposed to be an example of the superiority of German engineering. At the same time, however, GROWIAN was depicted as a failure in Germany! Ironically, this contradictory portrayal upends the visualization of failure; however, historical sources do not address this paradoxical situation.

The examined visualization strategies fashioned wind energy use as a symbol for an ecologically sustainable and responsible energy system. Both case studies show that the establishment of visibilities goes hand in hand with the generation, storage, and distribution of knowledge in expert circles, as well as in the broader public. The practices generated a new, ecologically minded mode of visibility of wind energy, paving the way for social acceptance. As this analysis shows, practices of visualization are an articulation of politics and economic power, as well as practices of materiality, education, opposition, protest, and resistance. The concept of visibility poses questions on historical developments that in retrospect seem to have been taken for granted. It helps to answer the question of why something is visible or invisible, and of what intentions, actors, and practices are involved. Thus, the concept of visibility is aimed at an analysis of transition, but at the same time reveals practices of intentional perpetuation of power structures.

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ORCID

Nicole Hesse https://orcid.org/0000-0002-1598-188X

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