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RESEARCH ARTICLE

Revoking coal mining permits: an economic and legal analysis

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ABSTRACT

Achieving mitigation targets under the Paris Agreement will depend on the early retirement of coal mines and plants over the next decade. In the absence of sufficiently stringent demand-side policies, supply-side injunctions provide a potential avenue to expedite the decline of coal. In many coal-producing jurisdictions, the law provides grounds to revoke coal mining permits. Recent plans to phase out coal use in Germany provide an interesting testing ground for this concept. We study the case of permits granted to RWE Power AG to continue operating Europe's largest opencast lignite mine, situated at the 12,000-year-old Hambach Forest in the state of North Rhine-Westphalia (NRW). We conduct two complementary assessments: (i) a legal analysis finding that German law provides several grounds for the revocation of coal mining permits, particularly when linked to quantifiable damages to local ecosystems and communities; and (ii) an economic analysis using natural capital accounting to quantify the environmental and societal costs associated with alternative scenarios of continued and halted mining activity. We find the net present value of gains from immediately halting operations at the Hambach lignite mine to be €98–208 billion over 34-years, equivalent to 13–30% of NRW's annual GDP. Health-related savings from avoided air pollution are 6.5 times greater than costs of replacing lost capacity with new renewable energy and battery storage infrastructure and two orders of magnitude greater than costs of compensating laid-off mining workers.

Key policy insights

- The revocation of coal mining permits could be a legally plausible and replicable means of expediting the decline of coal.
- Natural capital accounts highlight the third-party costs of coal mining, quantifying the often-ignored health-related damages from polluting activities.
- Legal criteria adopted by agencies when assessing coal mining permits should be modified to accurately reflect considerations of climate change, local ecology, human health, and national policy.
- Independent and externally reviewed natural capital assessments should be required as standard protocol for the issuance of fossil fuel exploitation permits.
- Debates about appropriate levels of compensation to coal companies for premature mine closures should factor in the implicit and explicit subsidies such companies have received in the past.

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1. Introduction

Climate mitigation scenarios limiting warming to below 1.5°–2°C require a global phaseout of CO₂ emissions from coal well before mid-century.¹ Relying solely on negative emissions technologies would be erroneous as such solutions remain unproven at scale (Fuss et al., 2014; Gasser, Guivarch, Tachiiri, Jones, & Ciais, 2015;

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Larkin, Kuriakose, Sharmina, & Anderson, 2018; SEI et al., 2019). Meeting the world's climate targets will therefore require many active coal mines and power plants to cease operations before their full economic potential is exhausted (IPCC, 2018; Jewell, Vinichenko, Nacke, & Cherp, 2019; Rogelj et al., 2016; Tong et al., 2019). Our analysis shows that the energy transition can produce net savings by reducing the health-related damages associated with mining and burning coal. It argues that agencies and courts can play a critical role in ensuring that the hidden costs of coal are brought to the forefront so that a just energy transition takes place. As Justice Louis Brandeis elucidated back in 1922,

[c]oal in place is land; and the right of the owner to use his land is not absolute. He may not so use it as to create a public nuisance; and uses, once harmless, may, owing to changed conditions, seriously threaten the public welfare.²

Coal's terminal decline is not a matter of *'if'* but *'at what speed'*. On the one hand, there are signs that coal's diminution has entered a self-reinforcing stage. In China, the internal rate of return for coal power in most provinces is expected to be very low or even negative by 2020 (Zhao et al., 2017). In the European Union (EU), 79% of coal-fired power generation is now cash-flow negative, with this figure projected to reach nearly 100% by 2030 (Carbon Tracker Initiative, 2019). In the United States, several of the nation's largest coal producers have filed for bankruptcy, dozens of planned coal plants have been cancelled, and hundreds of existing plants have closed ahead of schedule, despite the Trump administration's best efforts to resuscitate the ailing industry (Global Energy Monitor, 2019; Mendelevitch, Hauenstein, & Holz, 2019).

On the other hand, forecasts of coal's terminal decline should be tempered by a healthy dose of realism about the inertia generated by long-lived capital stock, supply-side policy loopholes and the political influence of incumbent mining interests. Conventional climate policies such as low-carbon technology support, performance standards, and demand-side decarbonization incentives such as carbon pricing have failed to prevent persistent growth in global annual CO₂ emissions, which reached a record high of 37 Gt in 2019, driven largely by unabated coal use (Friedlingstein et al., 2019). Coal still generates 40% of global annual CO₂ emissions, with only minor fluctuations in the share since 1980. Given current policy shortcomings and mounting costs of near-term mitigation delays, a growing body of research has evaluated the merits of complementing conventional demand-side mitigation policies with various supply-side measures that directly restrict fossil fuel production (e.g. Collier & Venables, 2014; Erickson, Lazarus, & Piggot, 2018; Green & Denniss, 2018; Lazarus, Erickson, & Tempest, 2015; Sinn, 2012).

The supply-side challenge is best understood as a problem of 'carbon overcapacity' (Johnsson, Kjärstad, & Rootzén, 2019). The world possesses approximately 1,000 gigatonnes (Gt) of known, economically viable coal reserves, but 1.5°–2°C mitigation scenarios entail leaving around 80% of these reserves in the ground (McGlade & Ekins, 2015). In the electricity sector alone, existing and planned fossil fuel plants are already slated to generate enough global cumulative CO₂ emissions up to 2060–2070 to breach the sector's carbon budget, assuming these plants remain operational over their typical economic lifespan (Edenhofer, Steckel, Jakob, & Bertram, 2018; Pfeiffer, Hepburn, Vogt-Schilb, & Caldecott, 2018).

In this paper, we consider the economic rationale and legal grounds for a largely overlooked climate policy option in coal-producing jurisdictions: the revocation of active coal mining permits. We begin by describing the historical context and policy concerns motivating our analysis (Section 2). We then evaluate the prospects for permit revocation in the context of Germany's ongoing coal phase out, focusing on the high-profile case of lignite mining permits granted previously to RWE Power AG at the Hambach Forest in North Rhine-Westphalia (NRW) (Section 3). Our assessment contains two complementary parts: (i) a legal analysis finding that German law provides several plausible grounds for revoking coal mining permits, particularly when they are linked to quantifiable damages to human health and local ecology that outweigh the (public or private) interest in continued mining (Section 4); and (ii) an economic analysis based on natural capital accounting which estimates that the net present value (NPV) of gains from halting mining operations at Hambach is approximately €98–208 billion, primarily due to avoided air pollution costs over a 34-year period (Section 5). Health-related savings from reduced air pollution exceed the market value of lignite and the cost of compensating mining workers by at least an order of magnitude. The 34-year period signifies the remaining operational lifespan of the Hambach mine if all known reserves of lignite were excavated at the present rate. After noting several caveats about transferring lessons from the Hambach case to other jurisdictions with heterogeneous permitting

laws and procedures (Section 6), we conclude with recommendations for reforming the criteria used by agencies for permit approval and revocation (Section 7).

2. Supply-Side climate policy loopholes and the rise of litigation

Two chief considerations motivate our analysis of revoking coal mining permits: near-term CO₂ mitigation delays created by the neglect of restrictive supply-side climate policies (see section 2.1); and administrative loopholes created by anachronistic laws guiding the issuance of fossil fuel production permits, which have encouraged the proliferation of climate-related litigation (see section 2.2).

2.1. *The neglect of restrictive supply-side climate policies*

Recent scholarship has highlighted the paucity of supply-side climate policies that directly restrict fossil fuel production (Erickson et al., 2018; Green & Denniss, 2018; Lazarus et al., 2015; Sinn, 2012). The relative focus of governments has been to adopt policies that target fossil fuel consumption (e.g. carbon pricing), promote uptake of low-carbon technologies (e.g. public RD&D expenditure), and establish performance standards for emissions-intensive products and facilities (e.g. scrubbers, sorbent injection, and selective catalytic reduction at fossil fuel power plants). Such policies have proliferated alongside the continued permitting, subsidization, and expansion of upstream fossil fuel production. Current climate pledges imply that by 2030 world coal production will still exceed levels consistent with 1.5–2°C by ~150–280%, or ~5.2–6.4 billion tonnes (SEI et al., 2019).

The neglect of restrictive supply-side climate measures has generated regulatory loopholes, policy inconsistencies, market uncertainty, and avoidable emissions (Green & Denniss, 2018; Lazarus et al., 2015; Sinn, 2012). The aggregate performance of California's stringent demand-side climate policies, for example, has been partly muted by the simultaneous issuance of over 20,000 new permits authorizing additional domestic oil and gas production (Oil Change International, 2018). Ceasing the issuance of all new oil drilling permits could reduce California's CO₂ emissions by an estimated 6–19 million tonnes (Mt) annually (Erickson et al., 2018). Similarly, in Norway, approved expansions of offshore oil production have lowered the net mitigation impact of climate policies by an estimated 30–40% (Fæhn, Hagem, Lindholt, Mæland, & Rosendahl, 2017). In Canada, if supply-side measures were adopted to halt any further expansion of oil sands production, 50–150 Mt of CO₂ emissions could be avoided annually up to 2030, in addition to the CO₂ abatement resulting from current policy plans (Erickson, 2018).

These cases highlight why a strategic climate policy mix that includes restrictive supply-side measures could help expedite decarbonization (Sterner et al., 2019). Fossil fuel producing jurisdictions in particular may benefit from restrictive supply-side policies, which could mitigate carbon leakage, reduce short-term mitigation burdens in other sectors (e.g. road transport), and work synergistically with other more conventional policy instruments (Collier & Venables, 2014; Erickson et al., 2018; Green & Denniss, 2018).

2.2. *Lax fossil fuel permitting and the rise of climate litigation*

In a 'first-best' policy scenario, it would be optimal for governments to refrain from issuing fossil fuel production permits that would later need to be modified or revoked to comply with their own greenhouse gas (GHG) abatement targets. But for both historical and institutional reasons, lax fossil fuel permitting persists unabated.

The statutes and norms guiding fossil fuel permitting decisions are inherited, in most cases, from the heyday of carbon-intensive industrialism during the late 19th to mid 20th centuries, predating concerns about anthropogenic climate change (McHarg, Barton, Bradbrook, & Godden, 2010). Globally, most fossil fuel is situated on public lands owned or regulated by governments (Rønne, 2010). Private and state-owned enterprises seeking to commercially exploit these reserves must first obtain authorization in the form of leases, permits, or production-sharing agreements (McHarg et al., 2010; Weaver & Asmus, 2006). The history of fossil fuel development is replete with examples of state-sponsored land grants, production subsidies, and agency capture, sometimes involving the forcible transfer of land rights from households, indigenous groups, and farmers to companies for 'public use' (Meidinger, 1980; Squillace, 2012). Under the Nazi regime, for example, the German government

legally designated domestic lignite supply with ‘strategic military status’, enabling the eviction and destruction of entire villages for the purpose of coal excavation, with several hundred coal-related community evictions having occurred up to the present (Brock & Dunlap, 2018; Michel, 2005). As Wood (2014) documents, the proliferation of pollution-related disputes in North America and Europe during the second half of the twentieth century birthed a burgeoning regulatory state, whose discretion over fossil fuel permitting often led to generic, rubber stamped approval of new mining and drilling projects, so long as they met minimal ecological standards. The evidentiary base used to inform permitting decisions shifted from claims about *absolute levels* of environmental harm caused, to demonstrations that maximum *rates* of pollution were not breached.

Plaintiffs are increasingly responding with litigation seeking compensatory or injunctive relief (Fisher, Scotford, & Barritt, 2017; Ganguly, Setzer, & Heyvaert, 2018; Hein, 2018; Squillace, 2012; Wood, 2014). Non-Governmental Organizations (NGOs) and other actors have challenged numerous fossil fuel mining and power plant permitting decisions cross-jurisdictionally, including at least 175 US cases and 140 non-US cases (Sabin Center for Climate Change Law, 2018). Such cases are disrupting the conventions of tort and administrative law, challenging courts to confront uncertainties surrounding causation, attribution, and responsibility that environmental statutes and the administrative state have largely sidestepped until recently (Fisher et al., 2017; Ganguly et al., 2018; Kysar, 2011).

3. Germany’s Hambach lignite mine as a pilot case

Germany’s energy transition (*Energiewende*) is now at a critical juncture, as its next steps will largely determine the speed of coal’s decline in Europe as a whole. Following Japan’s Fukushima nuclear power plant disaster, Germany’s decision to phase-out nuclear power by the end of 2022 helped to prolong its reliance on coal-fired power generation. The tension between climate action and the easy exploitation of domestic fossil fuel reserves is no better typified than in the case of the Hambach opencast lignite mine.

There are several critical facts surrounding Germany’s Hambach opencast lignite mine that make it an ideal case study to explore the potential of permit revocation:

- (1) **High stakes and opportunity to set a precedent:** Germany has the largest fleet of fossil fuel related assets at risk of stranding in the EU (valued at around €12 billion according to Carbon Tracker Initiative (2017), see Figure 1). Within Germany, RWE is the most exposed entity and Hambach has been the scene for clashes between climate activists and corporate interests. If Germany can successfully navigate the transition – given the entrenched interests and the stakes involved – it could serve as a blueprint for other countries.
- (2) **Few plausible alternatives for lignite:** Germany is the world’s largest lignite producer, and lignite mines are *sui generis* candidates for permit revocation. Studies by Öko-Institut (2018) and DIW Berlin et al. (2019) show that the ‘implicit CO₂ cost’ of switching from lignite plants to combined cycle gas turbine (CCGT) plants can be well over €40/tCO₂. This means that the projected carbon price under the EU ETS up to 2030 (€22-35/tCO₂) is unlikely to trigger lignite plant closures, unlike its relative efficacy for hard coal. Furthermore, since lignite has high water content, low energy density, and high transport costs relative to hard coal, it is used almost exclusively at power plants in its country of origin, with less than 2% of the lignite produced each year traded across borders (BGR, 2018; IEA, 2018). Since lignite also has the highest specific CO₂ emission factor among energy fuel options, this means that all substitutes will almost invariably result in fewer CO₂ emissions per unit of energy generated. This bolsters the case for using restrictive supply-side measures in the case of lignite, relative to hard coal, oil, and natural gas products for which supply restrictions would be partly (sometimes wholly) counteracted by concomitant increases in fuel production in other jurisdictions (Sinn, 2012).
- (3) **Positive feedback effects:** Early termination of Hambach mining operations could significantly expedite power sector decarbonization domestically (Commission on Growth, Structural Change and Employment, 2019), helping Germany to stay consistent with its own GHG reduction targets and potentially sending a signal to markets that policymakers are serious about the post-carbon transition and its implications for coal. Farmer et al. (2019) introduce the concept of ‘sensitive intervention points’, which highlights how the most successful climate interventions tap into positive feedback dynamics and amplification effects.

Figure 1. Value of Potential Stranded Coal Assets Among EU Countries and Electric Utilities.

Note: Data on stranded coal asset values is derived from Carbon Tracker Initiative (2017). The size of the circles corresponds to the relative size of operating coal capacity (in GW) for each country and utility company.

We hypothesize that the revocation of coal mining permits at Hambach could send shockwaves across European energy markets, compelling investors, insurance companies, electric utilities and other stakeholders to take stock of a new type of regulatory risk. It would also set a legal precedent which could open up new avenues of climate litigation and establish new standards for the issuance of fossil fuel permits (see section 7).

4. Legal basis for revoking mining permits in Germany

Recognizing that current policies will breach the national GHG reduction target for 2020, the German government established the multi-stakeholder Commission on Growth, Structural Change and Employment (also known as the 'Coal Commission'), tasked with determining a date by which coal should be phased out (Wehrmann, 2018). The Commission's final report recommended that all coal-fired power generation should be terminated by 2038. With the federal government now under pressure to implement the Commission's coal phaseout recommendations, it is timely to consider the basis for revoking coal excavation rights under German law. However, before that, we will consider the legal context of the Hambach case.

4.1. Legal context of the Hambach case

The state government's approval of RWE's plans to expand Hambach operations through to 2020 and 2030 provoked two separate lawsuits initiated by BUND, the German conservation organization.

In November and December 2017, the Cologne Administrative Court dismissed both cases and ruled to allow continued deforestation, paving the way for the expansion of Hambach operations. However, the Münster Higher Administrative Court subsequently granted BUND's motions for an appeal. As of 10 October, 2018, the higher court ruled to temporarily prohibit any further deforestation within the scope of RWE's current operating plan but allowed for adjacent mining operations to continue until it had fully dealt with the evidence. The decision to temporarily halt further deforestation elicited a severe setback to RWE's share price (RWE, 2018). RWE anticipates that Hambach lignite production will be cut by 10–15 Mt annually up to 2021, resulting in a €100–200 million curtailment in earnings (RWE, 2018).

More recently, the Administrative Court of Cologne ruled that, contrary to BUND's argument, protections for fauna and flora under the 1992 Habitats Directive under EU law were not applicable to the remaining 5 km² of the Hambach Forest (VG Köln 12 March 2019 14 K 3037/18). BUND lodged an appeal against this judgment with the Higher Administrative Court in Münster.

Whether and when the remainder of the Hambach Forest may be cleared for further coal extraction will be decided by both the Cologne and Münster courts in principal proceedings, with a final ruling handed down potentially in 2020 (RWE, 2018). As we show in the following section, the legal grounds for denying/revoking mining permits are potentially much broader and more widely applicable than the legal rules invoked by BUND. Specifically, we argue that a strong case for cessation of mining activities can be made on the grounds of the immense human cost that is incurred due to air pollution from lignite.

4.2. Two potential legal avenues for revoking coal mining permits in Germany

Under German law, the right to mine lignite is contingent upon public law permits granted by administrative authorities. There are two possible legal avenues for parties wishing to halt further lignite mining operations:

- (1) **the administrative law route**, through which entities with a legitimate interest in the matter (e.g. those living in the vicinity of the Hambach mine or environmental NGOs) may participate in the administrative decision-making process and challenge the permit before the German courts; or
- (2) **the private law route**, through which persons whose property has been adversely affected by climate change may sue emitters of GHG emissions for damages (under Art. 4(1) of EU Regulation No. 1215/2007 and EC regulation No. 864/2007), or seek a court order prohibiting the emitter from operating the source of emissions (under § 1004 of the German Civil Code, *Bürgerliches Gesetzbuch* (BGB)).

We do not investigate the private law route, since a lawsuit based on tort law cannot, in the Hambach case, lead to a court order prohibiting mining operations. If the mining operator does not emit more than what the law and applicable permits allow it to emit, such an injunction is precluded (Brückner, 2017). We therefore focus on the administrative law route. This was the strategy pursued by BUND in its pending lawsuit.

4.3. Legal grounds for rejecting (or revoking) the mining permit

Under German law, lignite under the land's surface is *terra nullius* – i.e. owned by nobody (§ 3(2) and (3) of the Federal Mining Act/BBergG). Private companies need to request that the state confer upon them the right – embodied in a mining permit – to excavate the lignite. Before they may excavate lignite at a *commercial scale*, the state must approve an operation plan (§§ 8, 9, and 50 *et seq* of BBergG), which sets out the amount of lignite to be excavated, security measures, and preparations for restoration, in a consecutive procedure.

The Federal Mining Act (*Bundesberggesetz*/BBergG) governs the issuance of mining permits, the approval of operation plans, and the applicable administrative procedures. Mining authorities of the German federated states (*Länder*) are authorized to grant permits and approve operation plans. They are accountable to a state ministry, which is, in turn, accountable to the respective state's legislature. When a mining authority receives an application for a mining permit or an operation plan requiring approval, it *must*, in principle, grant the

mining permit or approve the operation plan, respectively. The mining authority may only reject the application on one of the grounds of rejection enumerated in the Federal Mining Act (§§ 12, 13 and 55 of BBergG).

The mining authority can later *revoke* an existing mining permit on its own initiative. Subject to one additional requirement, the grounds for a revocation are the same as the grounds of rejection. A revocation requires that the factual situation has changed and the new circumstances would have required the mining authority to deny the permit (§ 18(1) of BBergG).

The essential question is whether the abatement of GHG emissions qualifies as one of the grounds on which a mining permit or operation plan may be rejected. There are two grounds in the Act that are conceivably applicable:

- (1) the mining authority may deny the permit or reject the operation plan if coal mining at the location in question conflicts with a public interest that outweighs the (private or public) interest in coal production (§§ 12 (1), 11 No. 10 of BBergG; § 48(2) of BBergG; Federal Administrative Court, Judgment of 29 June 2006, *NVwZ* 2006, 1173); or
- (2) the operation plan must be rejected if the mining is deemed harmful to society (§ 55(1) No. 9 of BBergG);

The original interpretation of the first ground of rejection does not seem to allow the mining authority to deny the mining permit on the basis of climate mitigation but does allow rejection on the grounds of *local* damages. The first ground requires a balancing of the interest in lignite mining against the public interests adversely affected by it (Federal Administrative Court, Judgment of 29 June 2006, *NVwZ* 2006, 1173–1175). Parliamentary history indicates that the ‘public interest’ must have a connection with the specific location where the applicant wishes to extract the lignite. As examples of public interests, the explanatory memorandum mentions environmental protection, the preservation of the landscape, spatial planning, infrastructure, and water protection (Deutscher Bundestag, Drucksache 8/1315, p. 87). The authority could thus, for instance, deny the permit due to the *local* damages caused by the depletion of natural capital, such as deforestation and losses to ecosystem services. But the particular status of GHG emissions abatement is unclear. It seems highly unlikely that the legislature had the purpose of climate mitigation in mind when it drafted this ground of rejection. In any case, the climate damage attributable to Hambach is not strictly local, since the CO₂ emitted from deforestation, lignite mining, and combustion diffuses across Earth’s atmosphere.

The prevailing interpretation of the second ground of rejection is also rather narrow. According to this interpretation, lignite mining should be deemed harmful to society only if it is so dangerous as to directly threaten the ‘public good’ (Federal Administrative Court, Judgment of 4 July 1986, *NJW* 1987, 1713, 1714). Since climate change is arguably an indirect consequence of the mining operations and the overall contribution of Hambach mining operations to climate change is fairly limited, this ground of rejection may not apply under the prevailing interpretation. It would apply, however, if there were evidence of a dangerous rise in local air pollution due to the mining operations.

Even the prevailing narrow interpretation of both grounds offer some scope for authorities to halt Hambach mining operations. A case would have to be made that the ecological and societal damages resulting from mining at Hambach (e.g. increased particulate matter, hospital visits, losses to ecosystem services) are substantial, *locally concentrated*, and outweigh the social and economic utility of lignite.

There are, moreover, persuasive reasons for a more progressive interpretation that takes into account the adverse consequences of GHG emissions. The Mining Act was adopted in 1980, at a time when climate change was not yet a significant cause for global public concern. But today, approximately 71% of the German public deems climate change a major threat, more than any other single issue (Pew Research Center, 2019). Moreover, the political context has also changed significantly as national plans to phase out coal have been formulated (Commission on Growth, Structural Change and Employment, 2019). A more progressive interpretation would also seem appropriate from a constitutional perspective. The German Basic Law (*Grundgesetz*; GG), which guides the interpretation of statutes, protects the right to life and commands that the state protect the environment (Art. 2(2) and 20a of GG, respectively). Such a case may be made, for example, by directly linking GHG emissions to droughts and natural disasters, or by establishing a link between particulate air pollution from lignite mining at Hambach to respiratory illness and premature deaths.

Following this progressive interpretation, the increasing adverse effects of GHG emissions could constitute a change in the factual situation that provides a ground for the competent authority to revoke the mining permit. It is important to bear in mind, however, that a sudden and immediate revocation of the permit may trigger a compensation claim for disproportionate state action, since RWE has already invested resources into mine expansion at Hambach (Cf. BVerfG 15 September 2011, *NVwZ* 2012, 429, 430). Furthermore, institutionally, the mining authorities neither have leeway in balancing the involved interests nor discretion in dictating the appropriate level of compensation (Federal Administrative Court, Judgment of 29 June 2006, *NVwZ* 2006, 1173, 1175). Settlement of a compensation claim would likely depend on subsequent adjudication in court.

In the absence of an agency revoking the mining permit, environmental NGOs and other parties have the right to file an action for annulment, provided they can show that their rights have been infringed by the permit (§§ 1, 2 of the Environmental Law Remedies Act; § 42(2) of the Administrative Court Procedure Code, *Verwaltungsgerichtsordnung*, VwGO). For example, BUND could still put forward the argument sketched above in its appeal against the RWE operation plan (§ 128 VwGO). It is then for the courts to rule on whether the grounds of rejection apply. With the final ruling pending, an injunction – such as the one recently awarded by the Higher Administrative Court of Münster at the request of BUND – could halt preparatory works for mine expansion and prevent further deforestation at Hambach (OVG Münster 5 October 2018, 11 B 1129/18). As in the case of agency-initiated revocation of the permit, an injunction would entail a change in the prevailing interpretation of the law. The courts tend to be reluctant to deviate from the legislature's intention due to the separation of powers. But with pressure mounting on the federal government to finalize a credible coal phaseout strategy, the courts have an evident basis for seeking guidance from the legislature.

A historical complication would arise if RWE's mining permit had been granted before the current Mining Act came into force on 1 January 1982. The current Mining Act would uphold such a permit, but *not* allow for revoking it (§§ 149, 151, in particular (2) No. 2, 154 BBergG). However, the mining authority could instead *expropriate* the permit (§ 160 BBergG). The compensation for this expropriation could be very limited since the permit's market value is greatly diminished by the planned coal phase out (§ 85 BBergG). An alternative avenue for halting mining activities, which would also require the initiative of the state, could be to amend NRW's state lignite plan (*Braunkohleplan*), which regulates substantive revisions to the status of operation plans at coal mines (§ 29(3) of the State Planning Act (*Landesplanungsgesetz*)). The lignite committee – consisting of representatives of municipalities, districts, economic stakeholders, and the environmental protection authority – may amend the state lignite plan if the core assumptions on which it was established no longer apply (§ 30 of the Act). The recent decision of the NRW government to reduce the size of the *Garzweiler II* mining area and preserve the town of Holzweiler, which was originally included in that mining area and would otherwise have to be moved, demonstrates that overriding national objectives, such as energy system transformation and emissions abatement, may justify such a change (*Leitentscheidung der Landesregierung* of 5 July 2016, pp. 12 *et seq.*)³

5. Hidden ecological costs of the Hambach mine

5.1. Context

Hambach Forest is a biodiverse, 12,000-year-old oak-hornbeam woodland that has existed since the end of the last glacial period (Donahue, 2018). However, it is situated above an estimated 2.5 billion tonnes of lignite (Imboden & Moczek, 2015). Since mining commenced in 1978, Hambach Forest has been felled and downsized from its original 55 km² to just 5 km², creating the largest opencast mine in Europe that stretches over an approved area of 85 km² (Imboden & Moczek, 2015; Schmitz, 2006). RWE excavates around 40 Mt of lignite annually from Hambach forest, which is then distributed by rail to local electricity and processing plants (RWE, 2018).⁴

The expansion of the Hambach opencast mine has dramatically disfigured the regional landscape (see Figure 2). Studies of pre- and post-mining landscapes in Germany document the metastasizing effects of despoiled arable land, disturbed water regimes, degenerated soil, and decomposed vegetation (Larondelle &

Figure 2. The Growth of Hambach Mine has transformed the natural landscape. Source: Alex Kraus, Bloomberg.

Haase, 2012). Hambach's pre-mining landscape had an exceptionally biodiverse ecosystem providing a host of ecosystem services, which today is highly threatened.

Forests are fecund sources of natural capital. The ecosystem services they provide – from carbon sequestration and topsoil formation to recreation and air and water purification – are usually not priced by the market (Costanza et al., 1997; Foley et al., 2005). The de facto value of nature in decision-making processes is frequently assumed to be zero, leading to its destruction. This is misleading since the services that nature provides would be costly to substitute – and substitution is rarely perfect (Cohen, Hepburn, & Teytelboym, 2019). Natural capital accounting provides a means of translating the 'hidden' value of nature into the language of financial and economic systems so that decision-makers do not assume that nature's absence from a balance sheet implies that its economic value is null. Natural capital accounting is increasingly recognized as a powerful tool to holistically measure the benefits of nature that accrue to the economy and society (Helm, 2015).

In what follows, we use natural capital accounting to bolster the evidentiary basis for revoking coal-mining permits in the Hambach Forest.

The natural asset under consideration is the Hambach Forest, and we estimate the monetary value of a small sample of the ecosystem services it provides. This is carried out for indicative purposes, in order to determine how their value, in addition to concomitant environmental damages and societal costs, changes across alternative scenarios of continued vs. halted mining activity.

Natural capital accounts are computed for three plausible scenarios:

- (1) **Scenario 1 (baseline):** RWE continues to mine lignite until the end of its latest approved operating plan in 2030, complying with the Coal Commission's recommended 2038 phaseout deadline and reducing the size of the Hambach Forest to roughly 1 km².
- (2) **Scenario 2 (high emissions pathway):** RWE continues to excavate 40 Mt of lignite annually until mid-century (i.e. 2053), at which point all known reserves are exhausted and the size of the Hambach Forest is reduced to zero.
- (3) **Scenario 3 (climate action):** The Hambach Forest is preserved at its current size of approximately 5 km², and all mining activity ceases immediately.

Scenario 1 represents the expected baseline trajectory given the current state of politics and policy in Germany. RWE is allowed to mine until 2030 but still complies with the Commission's coal phaseout deadline. Scenario 2 is the worst-case ecologically and represents RWE's preference, entailing near-total deforestation and mining up to full capacity. Scenario 3 represents maximal climate action, where agency-led revocation of the

mining permit (or an injunction handed down by the court) blocks further mining activity at Hambach and preserves the extant forest. Across the three scenarios, we assume that prices, population and other variables are the same. All flows are discounted at a constant rate of 3.5% over a 34-year time period (2019–2053), which is the maximum projected lifespan of the Hambach mine assuming an average annual excavation rate of 40 Mt lignite.

While there is a wide range of ecosystem services, environmental damages and societal costs that could be quantified in relation to these three scenarios, our analysis selects a sample for indicative purposes. Specifically, we quantify the monetary damages from lost carbon sequestration, pollination services, and recreation due to deforestation, as well as the health-related air pollution costs from increased PM_{2.5} emissions due to the combustion of lignite. We also estimate the social cost of increased CO₂ emissions from the mining of lignite, which refers to damages associated with future climate change (see Supplementary Material for further description). The societal costs that are quantified include the cost of compensating workers laid-off due to early mine closure, RWE's foregone revenues based on their own calculations, and the cost of replacing the electricity generated by lignite with electricity from renewable energy plus battery storage.

The direction of bias we adopt is to, if at all, overestimate the societal transition costs of moving away from coal and conservatively estimate the value of ecosystem services and environmental damages from continued mining and combustion. Despite adopting this approach, we still find evidence supporting the conclusion that it is in society's best interests to pursue the climate action scenario. Statements have been made claiming that halting lignite excavation to preserve the Hambach Forest would make it one of Germany's most expensive woodlands (see news coverage in Wehrmann, 2019). Our analysis suggests that failing to halt lignite excavation at Hambach would make the opencast mine one of Germany's most expensive healthcare crises.

A description of the methodology underpinning the calculations is provided in Appendix A. In short, we rely on the TEEB Valuation database (Van der Ploeg & de Groot, 2010) to attain monetary values for ecosystem services. Monetary values were chosen on the basis of those that are most applicable to Hambach's properties in terms of the location and type of natural asset, filtering for methodological quality.

5.2. Results of natural capital assessment

The results of the natural capital assessment are presented in Table 1. Relative to the baseline scenario, the high-emissions pathway scenario implies €110 billion in extra costs by 2053. In contrast, the climate action scenario implies savings of €98 billion. The largest line item is air pollution, generating costs that are several orders of magnitude larger than the cost of compensating laid-off workers or RWE's lost revenue due to immediate mine closure. Air pollution costs also exceed the value of foregone income from lignite sales and the cost of switching from lignite-fired electricity to renewable power, even with battery storage.

One may observe that the value of many of the ecosystem services (e.g. carbon sequestration, pollination and recreation) appears relatively small in monetary terms. Several factors account for this artefact of our analysis.

First, the physical size of the remaining forest is small when compared to its original size, which was an order of magnitude larger. It is also small when compared to the vastness of the lignite reserves underground, given that Hambach is among the world's largest lignite deposits (Wynn & Coghe, 2018).

Second, and most importantly, our accounts quantify the 'use value' of ecosystem services at the Hambach Forest and do not attempt to measure the 'existence-' or 'bequest value'. Hambach Forest is home to several rare species that are protected by EU law (listed in Annex IV of the Fauna Flora Habitats Directive). Due to the special nature of these species, Hambach should ordinarily be considered a protected zone that is safeguarded from disturbance. The discrepancy between EU law and the actions of RWE on these grounds has already provided the basis for a temporary cessation of lignite excavation in the area (Deutsche Welle, 2019).

RWE has plans to spend €4 million to re-create a green corridor to accommodate migratory species that rely on the Hambach Forest (Brock & Dunlap, 2018). While this is a positive move, it should not be considered a justification for continued mining. Ecologists have highlighted that new forests take time to equal the rich biodiversity and purpose of the ancient woodland (Imboden & Moczek, 2015). A unique 12,000-year-old ecosystem cannot be recreated within the multi-decadal timespan and purview relevant to current society. The preservation of this natural asset bequeaths untold value to future generations that this analysis has not attempted

Table 1. Natural capital accounts under three scenarios at the Hambach mine.

	Scenario 1	Scenario 2	Scenario 3
	Deforestation asnd mining up to 2038 (Baseline)	Deforestation and mining up to 2053 (High emissions)	Current forest with no mining (Climate action)
All values are shown in million Euros (2019)			
Carbon sequestration*	€0.5	€0.0	€3.0
Pollination*	€1.0	€0.0	€5.0
Recreation*	€0.0	€0.0	€0.1
Revenue from lignite sales	€5,700	€12,000	€0.0
Air pollution costs from lignite mining	–€110,000	–€240,000	€0.0
Increased cost of electricity by switching from lignite to solar PV with battery	–€19,000	€0.0	–€37,000
Social cost of carbon	–€12,000	–€26,000	€0.0
Lost revenues to RWE from immediate closure of Hambach mine [‡]	N/A	N/A	–€5,000
Compensation to laid-off workers from immediate closure of mine	N/A	N/A	–€300
Sum total	–€140,000	–€250,000	–€42,000

Note: All values are shown in million euros (2019), NPV over a 34-year period, at a constant discount rate of 3.5%. €30/tCO₂ is used for the social cost of carbon estimate. The list of benefits and damages is not exhaustive but intended to illustrate relative magnitudes. Ecosystem services with a star (*) accrue in perpetuity; hence, while the NPVs are relatively small, it should be remembered that these services last beyond the lifetime of lignite production. Estimates of ecosystem services are lower bounds. Estimate of market value of lignite is an upper bound. [‡]Figure from RWE AG statement.

to quantify in monetary terms. But the value to society is apparent from scenes of citizen-occupied encampments and large-scale standoffs with police and bulldozers in the hopes of protecting the forest. Out of the three scenarios assessed, the climate action scenario preserves the little that is left of a natural asset of arguably unquantifiable heritage value.

A further consideration is that the local air pollution costs in Table 1 are high enough to independently drive the conclusion that immediate revocation of the mining permits is likely to be in the best interests of society. Air pollution attributable to burning the lignite mined at Hambach will result in increased particulate matter (PM_{2.5}), which is known to cause respiratory illnesses and, increase hospital visits, healthcare costs, and incidence of premature deaths. Some epidemiological studies have already linked the Hambach mine to premature deaths. Hamilton, Brahmbhatt, and Liu (2017) estimate that in Germany the health-related benefits of avoided PM_{2.5} per tonne of abated emissions amount to €230–330/tCO₂e. Using this value, we find that air pollution damages are significantly larger than (i) the market value of lignite;⁵ (ii) the cost of switching from lignite-based electricity to renewable power with storage; and (iii) other societal transition costs such as compensating laid-off workers and lost revenues to RWE. It is also worth noting that in RWE's own financial disclosures, the lignite business (which is clubbed with nuclear) barely breaks even and is among the least profitable of its operations (see RWE financial statements).

Air pollution generated by the Hambach mine is a diffuse but substantial cost imposed on local communities. It is 'hidden' because of the difficulties in attributing hospital visits and respiratory illness to lignite combusted from Hambach. However, through quantification exercises such as the one herein and in Fearnough et al., one can begin to appreciate how the healthcare costs of continued mining operations compare against the scenario of immediate mine closure.

However, it can be argued that the benefits of lignite are not limited to its market value but also include its role in creating jobs and supporting the regional economy. To this end, it is worth recalling that the expansion of the Hambach mine itself displaced local communities and that in Germany as a whole, and in North-Rhine Westphalia specifically, renewable energy generates more jobs than coal (see Figure 3).

Nevertheless, one can still question how economically viable it will be to compensate laid-off workers if the mine closes. RWE AG released a statement indicating that 3,000 workers would be laid-off due to the immediate closure of the Hambach mine (Wehrmann, 2019). Assuming these workers are compensated €100,000 each, the

Figure 3. Number of Employees in Germany's Lignite and Renewable Energy Industries.

Note: Data on lignite industry employment is obtained from Statistik der Kohlenwirtschaft (2019). From 2002 onward, employment numbers include not only mining workers but also employees at lignite power plants. Data on nationwide employment in renewable energy industries is from O'Sullivan, Edler, and Lehr (2019), available only from 2000 onward. It includes workers in solar (PV and thermal), wind (onshore and offshore), hydro, biogas, biomass, combined heat and power (CHP), geothermal, and heat pump industries.

total cost of compensation will amount to €300 million. The €100,000 figure is equivalent to the total cumulative value of ~15 years of unemployment benefits for each laid-off worker, assuming an average monthly payment of €6,700, which is the maximum gross (pre-tax) wage paid to unemployed beneficiaries in West Germany in 2019 (European Commission, 2019). Our compensation estimate appears credible, and perhaps conservative, given that two-thirds of German lignite workers are age 45 or older and ~63% will retire by 2030 regardless of any mine closures (DIW Berlin et al., 2019). Paying out this compensation package is ~800 times cheaper than incurring the healthcare costs of continued lignite excavation and combustion (see Table 1). Furthermore, with Germany's trade surplus consistently above 7% of GDP, it could be argued that any additional federal investment above €300 million to help diversify the coal-dependent local economy surrounding Hambach should be a matter of due course, even in the absence of premature mine closure.

Another important consideration is how the gap in power generation created by halting lignite excavation can be met through other energy sources. In Table 1, we calculate the increased cost of electricity if lignite were hypothetically substituted by renewable energy plus energy storage (to address intermittency problems). This would imply an extra cost of €37 billion. However, this is an upper bound because not all of lignite has to be substituted by solar PV *plus* battery storage. If lignite were substituted with only solar PV, there would be cost-savings since the levelized cost of electricity from solar PV in Germany is lower than that of lignite (Kost, Shammugam, Jülch, Nguyen, & Schlegl, 2018). Moreover, demand-side solutions, importing more electricity from neighbouring countries, and switching to natural gas can be potentially cheaper and less emissions-intensive options (since lignite is the most carbon-intensive of energy fuel options, virtually any fuel substitute is preferred from an environmental perspective). It is illustrative that the investment in new, green energy infrastructure in the form of solar PV plus batteries would pay itself back in less than four years through the savings realized on the healthcare front from avoided PM2.5 pollution.

We also consider the global benefits of GHG emissions abatement resulting from early closure of the Hambach mine, even though these benefits are unlikely to factor into the legal case for permit revocation. We use an illustrative input value of €30/tCO₂ for the 'social cost of carbon' (SCC), which approximates the losses to economic output – destruction of physical assets, loss of productivity, etc. – that accrue from the increased risk of extreme weather events, higher temperatures, and other climate impacts (Ricke, Drouet, Caldeira, & Tavoni, 2018). The SCC is strictly distinct from the healthcare costs captured by the estimates of air pollution damage (e.g. PM2.5 emissions). We find that the global (SCC) damage from the Hambach mine is greater than the market value of lignite. Our choice of €30/tCO₂ is arguably conservative, since the expert elicitation in Pindyck (2019) suggests that the global average SCC could be around €70-90/tCO₂ or higher.

Finally, we run a sensitivity check on our results to see how they align with government estimates. In its latest methodological report, the Federal Environment Agency (2019) recommends a rate of €180/tCO₂e to capture the total (upstream and downstream) GHG and air pollution costs associated with lignite mining and combustion. Applying this rate results in total cumulative ecological costs of negative €153 billion (NPV over 34 years),

which falls within our range of estimated damages (€140–250 billion) for the baseline and high emissions scenarios in Table 1, lending some level of external validation to our findings.

Based on these results, we conclude that the environmental and societal costs of continued mining at Hambach, whether until 2030 or 2038, constitute substantial harm that outweigh the benefits. The human cost of prolonged operations suffices to make the case independently for immediate mine closure. Healthcare savings from avoided air pollution are 6.5 times larger than the cost of building new green energy infrastructure (which includes high-tech grid balancing technologies); at minimum, 48 times larger than the value of RWE's lost revenues; and 800 times greater than the cost of compensating laid-off workers. On aggregate, the climate action scenario can realize savings of €98 billion relative to a situation in which mining persists until 2030 (baseline), and savings of €208 billion relative to the case in which mining ends in 2053. In other words, early closure of Hambach mine would result in savings worth 13–30% of NRW's annual GDP.⁶ The natural capital assessment thus bolsters the legal case for an agency-initiated permit revocation or courtroom injunction compelling the early closure of the Hambach mine.

6. Applications in other fossil-fuel-producing jurisdictions

Our analysis of the legal and economic grounds for permit revocation is specific to the case of German lignite, and the Hambach opencast mine in particular. In principle, the case for permit revocation at Hambach may serve as a model, or reference point, for other jurisdictions exploring alternative measures to keep fossil fuels in the ground. Two important caveats apply, however.

First, the unique economic and geochemical properties of lignite make it a particularly compelling candidate for immediate mine closure, as we describe in Section 3. This does not preclude valid extensions of our argument to cases involving other categories of fossil fuels, but it does highlight that the merits of permit revocation relative to other policy options will vary depending on the characteristics of the targeted fuel supply. Second, the statutory criteria informing agency decisions to accept, deny or revoke fossil fuel permits are nationally and sub-nationally specific. Relevant laws, administrative procedures, and legal precedents vary considerably across jurisdictions. We thus caution that the particulars of our legal argument (e.g. the emphasis on air pollution damages) may not necessarily apply to other jurisdictions with heterogeneous permitting laws and grounds for revocation.

There are, nevertheless, strong indications that permit revocation is legally plausible in a considerable number of coal-producing jurisdictions. In the case of EU Member States, Directive 2008/1/EC of the European Parliament and Council establishes standard requirements for national and subnational permitting programmes. These include provisions related not only to permit approval and denial, but also amendment and revocation; indeed, similar to the regulatory discretion provided under German law, EU Member States may revise the status of active permits when relevant conditions on the ground have changed or additional evidence has come to light. In the US and Canada, statutes in major coal-producing states/provinces such as Wyoming and Alberta specify grounds for the cancellation or expropriation of mining leases, subject to compensation.⁷ In countries such as China and India with large state-owned coal companies, it is not uncommon for natural resource ministries to cancel or revoke mining permits on grounds of their poor economic outlook. Further investigation of the permissible grounds for permit revocation across heterogeneous legal regimes represents an important area for future research.

7. Conclusions and policy implications

Our analysis provides several policy-relevant and actionable lessons. First, under German law, ministers, environmental NGOs, and citizens retain lawful avenues to challenge past fossil fuel permitting decisions. It is possible that under changed circumstances, wherein climate change mitigation is now widely deemed a public good to be pursued expeditiously, active lignite extraction permits, such as those at Hambach, may be revoked. Furthermore, under German law, the case for permit revocation is greatly strengthened when reference is made to the localized co-benefits of avoided mining and deforestation, especially community-level savings from avoided air pollution.

Second, natural capital accounting can be a powerful tool employed to bolster the evidentiary base supporting restrictive supply-side climate policies. In our natural capital assessment, we find that revoking lignite mining permits previously granted to RWE could avoid 1.4 billion tonnes of CO₂ emissions, up to €240 billion in health-related costs from air pollution, and about €26 billion in social costs of carbon (in NPV over a 34-year period). Total cumulative ecological damages in the worst-case scenario amount to nearly one-third of NRW's 2017 GDP.

We also consider some of the broader implications of our research in terms of changing the dynamics of fossil fuel permitting. We believe that the first instance of revoking fossil fuel extraction rights, on grounds such as those enumerated in our analysis, could trigger significant changes in how the legal profession views its role in tackling climate change, securing public interest and internalizing third-party costs such as those of air pollution. In the language of Farmer et al. (2019), revoking permits at Hambach and other similarly emission-intensive mines could potentially be a 'sensitive intervention point' in climate mitigation efforts. We consider three key implications:

Firstly, if a mining permit can be *revoked* on grounds of localized air pollution and healthcare costs, as well as damages from depleted natural capital, then a permit application may also be *denied* in the first place for similar reasons. Our findings not only relate to revoking permits for active mines but also have implications for the approval rate of future fossil fuel projects.

Secondly, permitting authorities could consider requiring independent and externally reviewed natural capital assessments as standard protocol for the lawful issuance of fossil fuel permits, thereby encouraging applicants to be more accountable to the 'hidden' ecological and societal costs (or externalities) of their operations. The UK's Natural Capital Committee has already constructed guidance on how such evaluations could be undertaken, which may serve as a starting point for interested parties (Office for National Statistics and Department for Environment, Food, and Rural Affairs, 2017).

Thirdly, permitting agencies should consider explicitly modifying the criteria for permit approval and revocation to accurately reflect considerations of climate change, local ecology, human health and national policy (such as GHG emission reduction commitments). All plausible third-party costs that are ordinarily hidden from companies' balance sheets and borne by society should be enumerated, quantified and verified. This may entail a change in norms for permitting authorities (Wood, 2014). Environmental protection under Germany's Federal Mining Act was originally conceived as a largely local and provincial concern, and therefore exceptions to the norm of granting mining permits required evidence of profound impacts to local communities and ecosystem services that outweigh the benefits of lignite mining. However, today, climate change and other environmental problems are of paramount national and international concern. The burden of proof should be reversed such that the focus is on why, in a particular case, the benefits of fossil fuel combustion override climate, ecological and human health priorities.

In Germany, which has been the world's largest producer of lignite since the late nineteenth century, a combination of climate-related lawsuits and recommendations of the Coal Commission have challenged the notion that past administrative decisions are irrevocable. The end of coal in Germany is nearing, but establishing a target date for the phase-out is just a first step in the potential for restrictive supply-side climate policies to contribute to a greener and more inclusive energy transition. The German government must henceforth confront a number of competing concerns as they determine the policies through which domestic coal use is to be terminated. One thing, however, is clear: continued lignite production represents among the costliest and most myopic options to secure Germany's energy supply. As our analysis shows, investment in new, green energy infrastructure will pay itself back in less than four years through the savings realized on the healthcare front from avoided PM_{2.5} damages associated with the combustion of Hambach's lignite.

Our case study of the Hambach mine may serve as a model, or frame of reference, for other jurisdictions, NGOs, and citizen groups currently exploring measures to keep fossil fuels in the ground. Natural capital accounts quantifying the hidden costs of air pollution, CO₂ emissions, and disruptions to ecosystem services can and should be used to bolster the evidentiary base for restrictive supply-side climate policies, whether by parliaments, ministries, or courts. If it is ultimately preserved on climate and air pollution grounds, the Hambach Forest could be a harbinger of other successful efforts to align coal-producing regions with commitments under the Paris Agreement.

Notes

1. For example, in IPCC (2018) model scenarios with 'high overshoot' prior to stabilizing global mean temperature rise at 1.5°C, coal's share of global primary energy supply declines to around 4% by mid-century, with most of the remaining coal-fired plants retrofitted with carbon capture and storage (CCS) technologies.
2. Justice Louis Brandeis, dissenting opinion in *Pennsylvania Coal Company v. Mahon*, 260 US 393 (1922).
3. Note that the *Garzweiler II* decision will only have implications for the mining company from 2030 onward.
4. Since 2018, annual lignite production at Hambach has partly diminished as a consequence of BUND's legal action.
5. The market value of lignite in Table 1 is also an upper bound because excavation costs have not been factored in.
6. NRW's GDP in 2017 was €690 billion.
7. See Section 1-26-504(a) of the 2017 Wyoming Statutes; Sections 32 and 33 of the Wyoming Constitution; Section 8(1)(b) and (c) of the Alberta Mines and Minerals Act; and Section 8.1(1) of the Alberta Coal Conservation Act.

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References

- BGR (Federal Institute for Geosciences and Natural Resources). (2018). *BGR energy study: Data and developments concerning German and global energy supplies*. Hannover, Germany: Federal Institute for Geosciences and Natural Resources.
- Brock, A., & Dunlap, A. (2018). Normalising corporate counterinsurgency: Engineering consent, managing resistance and greening destruction around the Hambach coal mine and beyond. *Political Geography*, 62, 33–47.
- Brückner, B. (2017). *Münchener Kommentar zum Bürgerlichen Gesetzbuch: BGB, Band 7: Sachenrecht §§ 854-1296, WEG, ErbbauRG* (7th edition). Munich: C.H. Beck.
- Carbon Tracker Initiative. (2017). *Lignite of the living dead: Below 2°C scenario and strategy analysis for EU coal power investors*. London, UK: Author.
- Carbon Tracker Initiative. (2019). *Apocalypse now*. London, UK: Author. Retrieved from <https://www.carbontracker.org/reports/apocalypse-now/>
- Cohen, F., Hepburn, C., & Teytelboym, A. (2019). Is natural capital really substitutable? *Annual Review of Environment and Resources*, 44, 425–448.
- Collier, P., & Venables, A. J. (2014). Closing coal: Economic and moral incentives. *Oxford Review of Economic Policy*, 30(3), 492–512.
- Commission on Growth, Structural Change and Employment. (2019). Final report. Berlin: Federal ministry for economic affairs and energy (BMWi).
- Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., ... Raskin, R. G. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387(6630), 253–260.
- Deutsche Welle. (2019). *German court orders suspension of Hambach Forest clearance* [online]. Berlin: Author.
- DIW Berlin (German Institute for Economic Research), Wuppertal Institute for Climate, Environment and Energy, and Ecologic Institute. (2019). Phasing out coal in the German Energy Sector: Interdependencies, challenges, and potential solutions. Retrieved from https://www.ecologic.eu/sites/files/publication/2019/3537-kohlereader_englisch-final.pdf
- Donahue, M. (2018, April 15). Ancient forest home of squatter communities is doomed by coal. [Online] *National Geographic*. Retrieved from <https://news.nationalgeographic.com/2018/04/hambach-forest-germany-logging-coal-conservation-science/>
- Edenhofer, O., Steckel, J. C., Jakob, M., & Bertram, C. (2018). Reports of coal's terminal decline may be exaggerated. *Environmental Research Letters*, 13(2), 1–9.
- Erickson, P. (2018). *Confronting carbon lock-in: Canada's oil sands* (Discussion brief), Stockholm Environment Institute, Seattle, WA.
- Erickson, P., Lazarus, M., & Piggot, G. (2018). Limiting fossil fuel production as the next big step in climate policy. *Nature Climate Change*, 8, 1037–1043.

- European Commission. (2019). *Your social security rights in Germany*. Directorate-General for Employment, Social Affairs and Inclusion, Directorate C, Unit C.2. Brussels: European Commission. Retrieved from <https://ec.europa.eu/social/BlobServlet?docId=13751&langId=en>
- Farmer, J. D., Hepburn, C., Ives, M. C., Hale, T., Wetzter, T., Mealy, P., ... Way, R. (2019). Sensitive intervention points in the post-carbon transition. *Science*, 364(6436), 132–134.
- Federal Environment Agency (Umweltbundesamt). (2019). Methodological Convention 3.0 for the Determination of Environmental Costs: Cost Rates. February 2019.
- Fæhn, T., Hagem, C., Lindholt, L., Mæland, S., & Rosendahl, K. E. (2017). Climate policies in a fossil fuel producing country – demand versus supply side policies. *The Energy Journal*, 38(1), 77–102.
- Fisher, E., Scotford, E., & Barritt, E. (2017). The legally disruptive nature of climate change. *The Modern Law Review*, 80(2), 173–201.
- Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., ... Helkowski, J. H. (2005). Global consequences of land use. *Science*, 309(5734), 570–574.
- Friedlingstein, P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Hauck, J., Peters, G. P., ... Zaehle, S. (2019). Global carbon budget 2019. *Earth System Scientific Data*, 11, 1783–1838.
- Fuss, S., Canadell, J. G., Peters, G. P., Tavoni, M., Andrew, R. M., Ciais, P., ... Le Quéré, C. (2014). Betting on negative emissions. *Nature Climate Change*, 4(10), 850–853.
- Ganguly, G., Setzer, J., & Heyvaert, V. (2018). If at first you don't succeed: Suing corporations for climate change. *Oxford Journal of Legal Studies*, 38(4), 1–28.
- Gasser, T., Guivarch, C., Tachiiri, K., Jones, C. D., & Ciais, P. (2015). Negative emissions physically needed to keep global warming below 2°C. *Nature Communications*, 6, 1–7.
- Global Energy Monitor. (2019). Global Coal Plant Tracker. *Summary statistics*. Retrieved from <https://endcoal.org/global-coal-plant-tracker/>
- Green, F., & Denniss, R. (2018). Cutting with both arms of the scissors: The economic and political case for restrictive supply-side climate policies. *Climatic Change*, 150, 1–15.
- Hamilton, K., Brahmabhatt, M., & Liu, J. (2017). Multiple benefits from climate change mitigation: assessing the evidence. Policy report, Grantham Research Institute on Climate Change and the Environment.
- Hein, J. F. (2018). Federal lands and fossil fuels: Maximizing social welfare in federal energy leasing. *Harvard Environmental Law Review*, 42, 1.
- Helm, D. (2015). *Natural capital: Valuing the planet*. New Haven, CT: Yale University Press.
- Imboden, C., & Moczek, N. (2015). Risks and opportunities in the biodiversity management and related stakeholder involvement of the RWE Hambach Lignite Mine. *International Union for Conservation of Nature and Natural Resources*.
- Intergovernmental Panel on Climate Change (IPCC). (2018). *Global warming of 1.5°C: An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Paris, France: IPCC.
- International Energy Agency (IEA). (2018). *Coal Information 2018*. Paris, France: IEA.
- Jewell, J., Vinichenko, V., Nacke, L., & Cherp, A. (2019). Prospects for powering past coal. *Nature Climate Change*, 9(8), 592–597.
- Johnsson, F., Kjärstad, J., & Rootzén, J. (2019). The threat to climate change mitigation posed by the abundance of fossil fuels. *Climate Policy*, 19(2), 258–274.
- Öko-Institut. (2018). *Dem Ziel verpflichtet CO₂: Mindestpreise im Instrumentenmix einer Kohle-Ausstiegstrategie für Deutschland*. Berlin: WWF Deutschland. Retrieved from https://mobil.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/WWF_Studie_Kohleausstieg_CO2_Mindestpreise.pdf
- Kost, C., Shammugam, S., Jülch, V., Nguyen, H., & Schlegl, T. (2018). *Levelized cost of electricity renewable energy technologies*. Fraunhofer Institute for Solar Energy Systems ISE.
- Kysar, D. A. (2011). What climate change can do about tort law. *Environmental Law*, 41(1), 1–71.
- Larkin, A., Kuriakose, J., Sharmina, M., & Anderson, K. (2018). What if negative emission technologies fail at scale? Implications of the Paris Agreement for big emitting nations. *Climate Policy*, 18(6), 690–714.
- Larondelle, N., & Haase, D. (2012). Valuing post-mining landscapes using an ecosystem services approach—An example from Germany. *Ecological Indicators*, 18, 567–574.
- Lazarus, M., Erickson, P., & Tempest, K. (2015). Supply-side climate policy: the road less taken. Stockholm Environment Institute, Working Paper, SEI-WP-2015-13 (October), pp. 1–24.
- McGlade, C., & Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature*, 517(7533), 187–190.
- McHarg, A., Barton, B., Bradbrook, A., & Godden, L., eds. (2010). *Property and the law in energy and natural resources*. Oxford, UK: Oxford University Press.
- Meidinger, E. E. (1980). The public uses of eminent domain: History and policy. *Environmental Law*, 11(1), 1–66.
- Mendelevitch, R., Hauenstein, C., & Holz, F. (2019). The death spiral of coal in the US: Will changes in US policy turn the tide? *Climate Policy*, 19(10), 1310–1324.
- Michel, J. H. (2005). Status and impacts of the German lignite industry. Swedish NGO Secretariat of Acid Rain.
- Office for National Statistics and Department for Environment, Food, and Rural Affairs. (2017). *Principles of natural capital accounting: A background paper for those wanting to understand the concepts and methodology underlying the UK natural capital accounts being developed by ONS and Defra*. London, UK: Office for National Statistics.
- Oil Change International. (2018). *The sky's limit California: Why the Paris climate goals demand that California lead in a managed decline of oil extraction*. Washington, DC: Author.

- O'Sullivan, M., Edler, D., & Lehr, U. (2019). *Ökonomische Indikatoren der Energiebereitstellung: Methode, Abgrenzung und Ergebnisse für den Zeitraum 2000-2017*. Berlin: Deutsches Institut für Wirtschaftsforschung (DIW). Retrieved from <https://www.econstor.eu/bitstream/10419/201574/1/1669556603.pdf>
- Pew Research Center. (2019, February 10). Climate Change Still Seen as the Top Global Threat, but Cyberattacks a Rising Concern.
- Pfeiffer, A., Hepburn, C., Vogt-Schilb, A., & Caldecott, B. (2018). Committed emissions from existing and planned power plants and asset stranding required to meet the Paris Agreement. *Environmental Research Letters*, 13(5), 054019.
- Pindyck, R. S. (2019). The social cost of carbon revisited. *Journal of Environmental Economics and Management*, 94, 140–160.
- Ricke, K., Drouet, L., Caldeira, K., & Tavoni, M. (2018). Country-level social cost of carbon. *Nature Climate Change*, 8(10), 895–900.
- Rogelj, J., Schaeffer, M., Friedlingstein, P., Gillett, N. P., Van Vuuren, D. P., Riahi, K., ... Knutti, R. (2016). Differences between carbon budget estimates unraveled. *Nature Climate Change*, 6(3), 245–252.
- Rønne, A. (2010). Public and private rights to natural resources and differences in their protection. In A. McHarg, B. Barton, A. Bradbrook, & L. Godden (Eds.), *Property and the law in energy and natural resources* (pp. 60–79). Oxford, UK: Oxford University Press.
- RWE. (2018). Powering Into the Future: Annual Report 2018.
- Sabin Center for Climate Change Law. (2018). *Climate change litigation databases*. New York: Author.
- Schmitz, R. (2006). Provision of resources for the city by the Hambach opencast mine. International Association for Engineering Geology and the Environment (IAEG), Paper number 791.
- SEI, IISD, ODI, Climate Analytics, CICERO, and UNEP. (2019). The production gap: The discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C. Retrieved from <http://productiongap.org/>
- Sinn, H. W. (2012). *The green paradox: A supply-side approach to global warming*. Cambridge, MA: MIT Press.
- Squillace, M. (2012). The tragic story of the federal coal leasing program. *Natural Resources & Environment*, 27, 29.
- Statistik der Kohlenwirtschaft. (2019). Lignite at a glance. Retrieved from <https://kohlenstatistik.de/daten-fakten/>
- Sterner, T., Barbier, E. B., Bateman, I., van den Bijgaart, I., Crépin, A. S., Edenhofer, O., ... Lange, A. (2019). Policy design for the Anthropocene. *Nature Sustainability*, 2, 14–21.
- Tong, D., Zhang, Q., Zheng, Y., Caldeira, K., Shearer, C., Hong, C., ... Davis, S. J. (2019). Committed emissions from existing energy infrastructure jeopardize 1.5° C climate target. *Nature*, 572, 373–377.
- Van der Ploeg, S., & de Groot, R. S. (2010). *The TEEB valuation database—a searchable database of 1310 estimates of monetary values of ecosystem services*. Wageningen, Netherlands: Foundation for Sustainable Development.
- Weaver, J. L., & Asmus, D. F. (2006). Unitizing oil and gas fields around the world: A comparative analysis of national laws and private contracts. *Houston Journal of International Law*, 28, 3.
- Wehrmann, B. (2018, July 24). Germany's coal exit commission. *Clean Energy Wire*, Berlin.
- Wehrmann, B. (2019). Saving Hambach Forest would make it "Germany's most expensive woodland" - RWE CEO [online]. *Clean Energy Wire*. Retrieved from <https://www.cleanenergywire.org/news/saving-hambach-forest-would-make-it-germanys-most-expensive-woodland-rwe-ceo>
- Wood, M. C. (2014). *Nature's trust: Environmental law for a new ecological age*. Cambridge, UK: Cambridge University Press.
- Wynn, G., & Coghe, P. (2018). Lignite Retreat: RWE's Short-Term Pain, Long-Term Gain. *The Institute for Energy Economics and Financial Analysis*.
- Zhao, C., Zhang, W., Wang, Y., Liu, Q., Guo, J., Xiong, M., & Yuan, J. (2017). The economics of coal power generation in China. *Energy Policy*, 105, 1–9.