Two-thirds of new fossil fuel infrastructure targets critical ecosystems, elevating health risks for millions

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Abstract

While the fossil fuel industry's role in driving climate change is well established, the elevated risks to fenceline communities and critical ecosystems remain underexplored at a global scale, limited to a handful of prior coarse assessments. Here we map over 18,000 operating fossil fuel facilities across 170 countries, and assess their placement in surrounding populations and ecosystems, relative to empirical data on known elevated risk zones. We find that ∼32% of facilities are located within critical ecosystems, including areas important to nature's contributions to people, key biodiversity areas, and critical irrecoverable carbon reserves, and that almost 463 million people, including over 120 million children, live within 1 km of these sites, placing them at heightened risk of health impacts. Looking forward, we assess 3,500 planned facilities and find that ∼69% are slated for, or are already under construction in, critical ecosystems, disproportionately in Asia's biodiversity hotspots, and where an additional 106 million people in then-to-be fenceline communities will live. Together, these findings build on earlier studies and establish higher spatial resolution global estimates of communities and ecosystems at elevated risk from fossil fuel infrastructure. They underscore the urgent need for stronger environmental and health impact assessments, community-engaged health monitoring, and accountability frameworks to prevent further entrenchment of unfolding climate, ecological, and environmental justice crises on the frontlines of the fossil fuel industry globally.

1 Introduction

Fossil fuels account for 79% of global greenhouse gas emissions—an estimated $14 trillion climate liability—and are responsible for one in five deaths worldwide through air pollution exposure (1; 2; 3; 4). Yet, while fossil fuel contributions to climate change are well-documented, the immediate environmental and health catastrophes borne by surrounding fenceline communities remain systematically under-examined. These local harms constitute ongoing public health emergencies. For instance, children living near refineries experience 50% higher asthma rates (5); communities near coal mines face toxic exposures linked to kidney failure and encephalopathy (6); and catastrophic accidents, such as the Texas City refinery explosion, have released thousands of pounds of carcinogens into nearby neighborhoods (7). These impacts are not isolated to one facility type. For example, oil shale processing in Estonia's Ida-Viru County drives elevated lung cancer rates (8), while routine spills along Trinidad's coast contaminate marine ecosystems with carcinogenic hydrocarbons, threatening food security and human health (9). These are just some of the stories of a larger and more widespread set of risks posed to people and ecosystems around the world, the scale of which has to date largely remained under-documented.

The harms posed to fenceline communities by the fossil fuel industry are not only environmental, but also legal and political. The recognition of the human right to a clean, healthy, and sustainable environment by the UN Human Rights Council (2021) and General Assembly (2022) (10; 11) followed by landmark advisory opinions (12; 13) underscores a global obligation to respect, protect, and fulfill the right under penalty of what "may constitute an internationally wrongful act which is attributable to that State" (13). Yet, implementation is grossly inadequate: fewer than 2% of countries have binding human rights and environmental due diligence laws (hereinafter "due diligence laws"), and violence against environmental defenders alone rose 150% between 2013-2023 (14). Weak protections are particularly devastating in ecologically critical areas, where disasters cascade across ecosystems and livelihoods. For example, the Deepwater Horizon spill contaminated an estimated 111,000 or km^2 of ocean (15), while recurrent oil spills in Nigeria have destroyed 45,000 hectares of mangroves and jeopardized the livelihoods of 150,000 fishers (16; 17). Indigenous peoples—who comprise less than 5% of the global population but steward 37% of Earth's remaining natural lands (18)—face especially acute risks: in Canada, half of all reserve-based Indigenous communities are at risk of pipeline spills, yet retain little control over decisions regarding extraction on their territories (19; 20).

Despite global calls for decarbonization, energy transitions are slow, uneven, and contested. Fossil fuel interests, disinformation campaigns, and deregulation continue to delay progress (21; 22; 23), and thousands of current and planned facilities will remain operational for decades. This reality emphasizes the need for systematic assessments of the ongoing risks that these facilities pose, and to identify not only which people and ecosystems are at risk today, but also those likely to be exposed in the near future through ongoing developments.

From an epidemiological perspective, a significant body of evidence documents the human health risks of living nearby facilities. This data exists across facility types (from extraction sites and mines, to pipelines, terminals, and plants), and documents a vast variety of evidence on distance-based elevated risks in cognitive defects (24), neuro developmental delays (25; 26; 27; 28), respiratory illnesses (29), sleep disturbance (30), pre-term birth and low birth weight (25; 26; 27; 28), congenital anomalies (25; 26; 27; 28), and cancer risks (29; 31; 32; 33) for populations living within the vicinity of facilities, mediated through exposure pathways such as polluted light, noise, soil, water, and air. That health risks are posed by this infrastructure is unequivocal, but the extent of adverse effects can vary depending on the pathway, with health impacts identified up to 10 km from the infrastructure itself in some cases. Consistently, across studies, extreme health risks have been documented for people living in close vicinity, with the highest risk for multiple facility types and health outcomes documented within 1 km (Table S1). A key question therefore, is how many people, children, or other demographic groups reside in these high risk zones globally? Fundamentally, another way to think about this, is "what is the estimated size of fenceline communities linked to the fossil fuel industry?" Because the length of pipelines globally are so extensive we assess these exposure numbers with, and without, pipelines.

From an ecological perspective, we currently have two sources of information on the potential risks fossil fuel facilities pose. The first are global, but spatially coarse (e.g. $\sim$50 km resolution), assessments of potential risks from current and future infrastructure or concessions to biodiversity and ecosystem services (34; 35; 36; 37; 38; 39). These studies provide important first order assessments but are limited in their ability to identify localized risks and siting at fine resolution within landscapes. The second is a body of literature assessing impacts of different kinds of fossil fuel facilities on species and communities through multiple pathways, e.g. through light, noise, and air pollution or through transport based disruptions. Direct documented impacts include degradation of marine mammal communication and behavior from noise pollution (40), increased mortality for whales from ship strikes (41), reduced habitat usage, foraging, and reproduction in birds and ungulates from onshore drilling (42), disruption of animal movement from pipelines (43), reduced freshwater biodiversity from mine leaching (44), foliar damage to plants and reduced growth from air pollution (45; 46), disruption of species interactions and predator-prey relationships from artificial light (47; 48), and more. The reported distances over which these ecosystem impacts occur vary depending on facility and species: from the 25 m immediate disturbance footprints of pipeline right of way allocations (43) up to 2 km for marine disruptions to marine mammals (40) and large scale environmental disasters such as explosions or spills which can stretch for $>$100 km (49). Because of these differences, we localize our sampling strategy using a facility type specific approach (see Methods). The key question here is, "how many of the current and planned fossil fuel facilities are sited in ecosystems that could be classed as critical?"

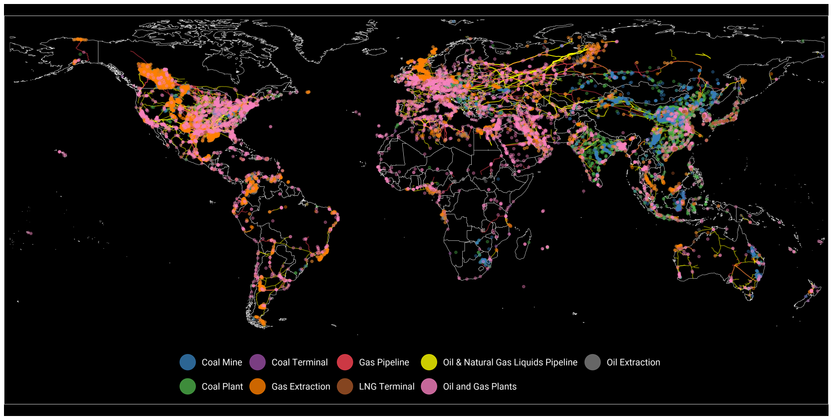
Here, we build on and extend infrastructure monitoring efforts, including the Global Energy Monitor (GEM) (50), to map approximately 18,000 unique fossil fuel facilities worldwide. We assess their siting across over 170 countries, and importantly, examine the ecological criticality of the landscapes in which they are located—not only for biodiversity conservation importance, but also in terms of zones of irrecoverable carbon storage and nature's contributions to people which includes area of global importance for fisheries and agriculture, freshwater quality and quantity regulation, and coastal and inland resilience alongside linked cultural values. We apply conservative estimates in our sampling strategy for siting, and only assess the most critical ecosystem components—those locations that fall in the 80th percentile globally of the outcomes we examine. We also perform sensitivity checks that relax our spatial sampling to encompass larger buffers around sites. We then quantify the human populations residing in high risk zones of this infrastructure, with special attention to children, Indigenous communities, residents in states with weak environmental regulation, and communities living near foreign-owned facilities where due diligence laws are lacking (laws that, if in place, should protect those communities by requiring businesses to respect human rights in their operations, subsidiaries, and value chains). Finally, we project future risks from more than 3,500 planned facilities, evaluating whether siting and impacts follow or diverge from past evidence. Taken together, our study establishes a global baseline of the location and size of fenceline communities associated with fossil fuel infrastructure, as evidence for scientists, advocates, and policymakers seeking to address the intertwined crises of energy, equity, and environmental justice.

2 Results

Disparity in fossil fuel production and consumption emissions

We consider more than 18,000 unique currently operating fossil fuel facility locations globally, which include coal mines, coal plants, coal terminals, oil and gas extraction sites, oil and gas plants, liquefied natural gas (LNG) terminals, and pipelines for both oil and gas (Fig 1a), of which oil and gas plants are the most numerous (Fig 1b). While exploring the emissions associated with sites is not the purpose of this study (such attribution is its own complex challenge) we use daily gridded CO_2 data for 2024 (51) to understand some of the spatial disparity in carbon emissions in terms of where fossil fuel extraction or processing occurs and where the highest consumption-based emissions patterns are (Fig S1). While this may seem obvious, the surrounding communities of these sites have the burden of high localized emissions compared to baselines (Fig 1c) although the consumption of these energy sources (for transport, residential heating, etc.) largely takes place elsewhere (Fig S1). These spatial differences are important and offer initial insight into locations around the world where communities experience localized pollution, in order for other communities, in disparate locations to benefit from meeting their energy needs. There are important differences by facility: coal plants, followed by coal terminals and oil and gas plants, are the largest source of CO_2 operating emissions (Fig 1c).

Disproportionate siting in critical ecosystems



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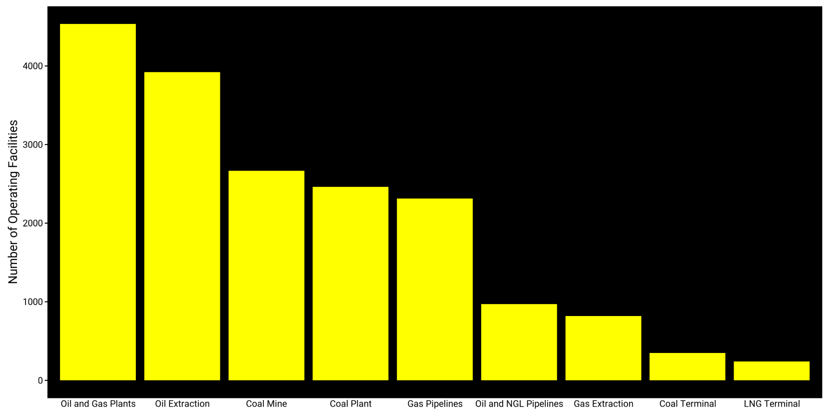

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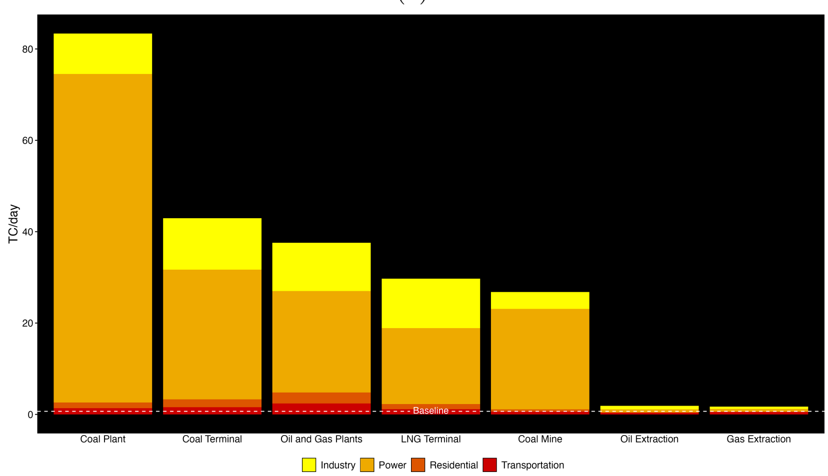

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Figure 1: Fossil fuel infrastructure is widespread globally and is associated with highly localized CO_2 emissions compared to background. (a) Locations and type of currently operating fossil fuel infrastructure; (b) The number of operating fossil fuel facilities by infrastructure type; (c) Estimated 2024 mean daily CO_2 emissions (tonnes/day) in the 10 km vicinity of each fossil fuel facility type (excluding pipelines) and emissions source compared to global average terrestrial emissions (baseline = 0.67 TC/day).

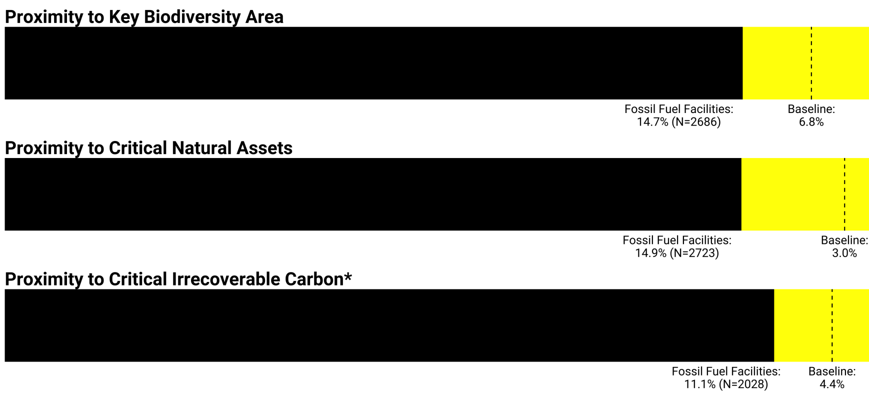
Of operating fossil fuel infrastructure, we find 14.7% to be within proximity to key biodiversity areas, compared to a baseline expectation (i.e. random global distribution given locations of KBAs) of 6.8% across terrestrial land and territorial seas (Fig 2a). Similarly, 14.9% of all fossil fuel infrastructure is in proximity to critical areas for nature's contributions to people (baseline: 3.0%) and 11.1% are in or nearby zones of critical irrecoverable terrestrial carbon (baseline: 4.4%) (Fig 2a). All of these represent indicators for critical ecosystems, defined here as those in which acute disasters or ongoing pollution would have disproportionate impacts on ecosystems and communities. Combined, we identify fossil fuel infrastructure disproportionately occurs in critical ecosystems with 32% of facilities sited in any of the critical ecosystem categories compared to a baseline of 11.9%, including high occurrence in critical biomes such as temperate and broadleaf forests in Eastern US and Central Europe and mangroves in Latin America (Fig 2b). The number of operations in critical ecosystems remains high when including protected areas as an alternative indicator, at 31% compared to a baseline of 18% (Figs S2, S3); although we do not include protected areas in our main results due to low coverage of biomes in the global south compared to the global north.

We also assessed facilities in proximity to critical ecosystems using a more conservative sampling strategy that ignores the footprints of facilities where no data are available. We found that even when using 1 km buffers around all facility types other than pipelines and oil and gas extraction sites, the infrastructure still disproportionately occurs in these critical ecosystems at double the rate of baseline values (Fig S4).

Millions live near fossil fuel infrastructure

We find overall ∼463 million people, of which ∼124 million are children, live within the 1 km high risk zone of fossil fuel infrastructure (Fig 3). Of this fenceline population, a subset of ∼310 million live in critical ecosystems and ∼107 million live in countries with weak environmental regulations, and therefore could be endangered due to environmental degradation or regulatory failures (Fig 3a). Thirty-one million live in proximity to an internationally owned facility which could further increase their risk because of the lack of protection and accountability measures in the absence of due diligence laws. And 14 million people live within 1 km of fossil fuel facilities on Indigenous land, risking already historically marginalized populations (Fig 3a).

While fenceline populations within 1 km have higher health risks due to their close proximity to these facilities, there are also documented health risks from exposure as far as 5 km (Table S2). Almost 2 billion people globally, or a quarter of the world's population, live within 5 km of fossil fuel infrastructure, which includes over 520 million children (Fig S5). As for all our estimates, this aggregate size of fenceline communities does not indicate the total number of people that will experience health impacts, but the size of the base population with elevated health risks. At the same time, it is important to note that negative health impacts for any one individual can have large and compounding



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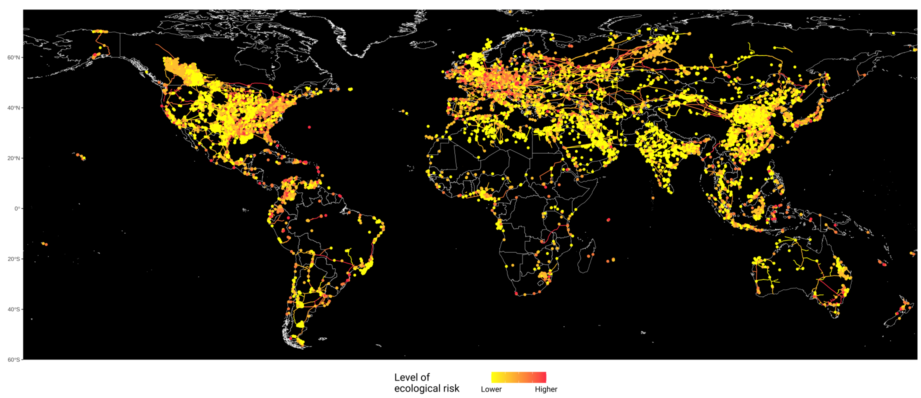

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Figure 2: Fossil fuel infrastructure is disproportionately sited in critical ecosystems, risking high priority areas for nature and people. (a) Fossil fuel infrastructure situated in critical coastal and terrestrial ecosystems compared to baselines (*indicates estimates calculated in terrestrial ecosystems only); (b) Fossil fuel infrastructure and the level of ecological risk based on critical ecosystem indicators.

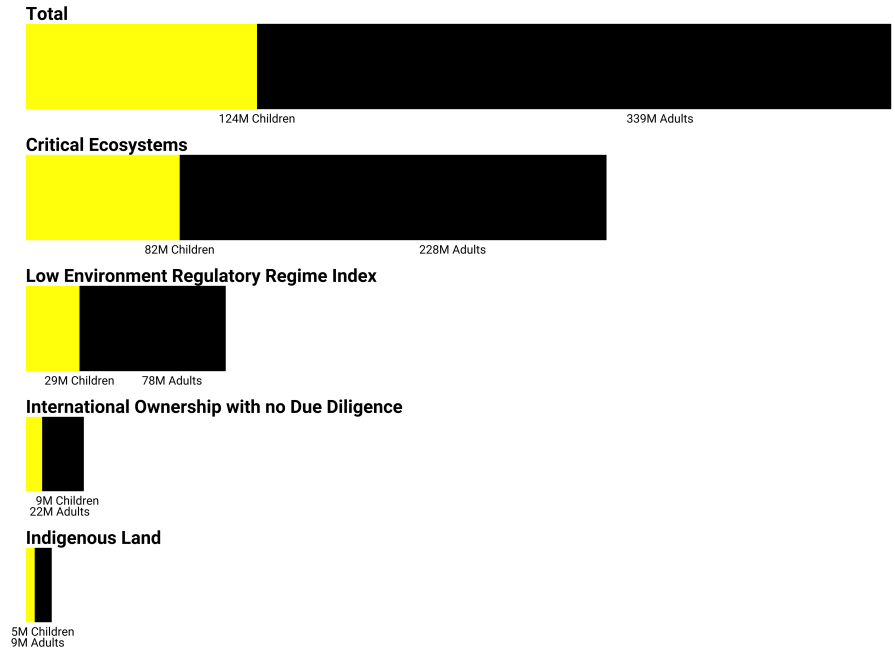
negative impacts on the wider community. The subsets of populations that live within 5 km and are situated in critical ecosystems, have weak environmental regulations, are in proximity to a internationally owned location, or are located on Indigenous land are also roughly 4x larger than for 1 km estimates (Fig S5).

Excluding pipelines, ~43 million people live within 1 km of fossil fuel facilities, 19 million of them are located in already critical ecosystems, 8 million in countries with weak environmental regulations, over 1 million near an internationally owned facility and another 1+ million on Indigenous land (Fig 3b, Table S2). This difference is roughly a factor of 10 from the total—in other words, most fenceline communities represent people living near pipelines. This adds complexity for public health programs aiming to assess absolute health impacts because while pipeline impacts on human health are documented and can be severe, exposure rates per km per year can vary based on whether oil or gas is being transported, the size and age of the pipeline, maintenance schedules, spillage, and leakage rates (52). Notably, at 5 km the differences between including and excluding pipelines is reduced, by a factor of 3-4 (Table S2).

As population datasets have biases depending on the underlying models and data sources (53; 54), we also consider an additional population dataset (LandScan Global) for estimating people exposed. This data attempts to estimate ambient population numbers (e.g. over a 24 hour period) rather than WorldPop, which estimates residence. Notably, we find that our total population estimates at 1 km with LandScan are within approximately 2% of our WorldPop-based numbers and overall within 4% for other subsets of exposed populations (situated in ecologically critical locations, foreign ownership, weak environmental regulation, or on Indigenous Land) (Table S3). It should be noted however that both of these datasets may underestimate rural populations (53).

Future expansion threatens additional communities

As of 2025, a further 3,507 fossil fuel facilities are either proposed, in development, or currently under construction in over 140 countries globally (Fig 4a). These facilities are predominately oil and gas plants (n=1,124), gas pipelines (n=801), and coal mines (n=630); striking examples include a large number of new coal mines and coal plants as well as gas pipelines in China and oil and gas plants in the United States (Fig S6). These planned facilities continue to endanger ecologically critical locations, with 59.4% anticipated to be in proximity to key biodiversity areas compared to a baseline of 6.8%, which is a prevalence 4x higher than currently operating facilities (14.7%) and suggests these environmental designations are not deterring development on these lands and that there is preferential siting in the world's most important areas for nature conservation (Fig 4b). Similar to operating facilities, 13.5% of planned facilities are in proximity to nature's contribution to people (baseline: 3.0%, operating facilities: 14.9%) and 15.0% are near areas of critical irrecoverable terrestrial carbon (baseline: 4.0%, operating facilities: 11.1%). Combining all these indicators, we elucidate that this planned infrastructure is even more disproportionately occur-



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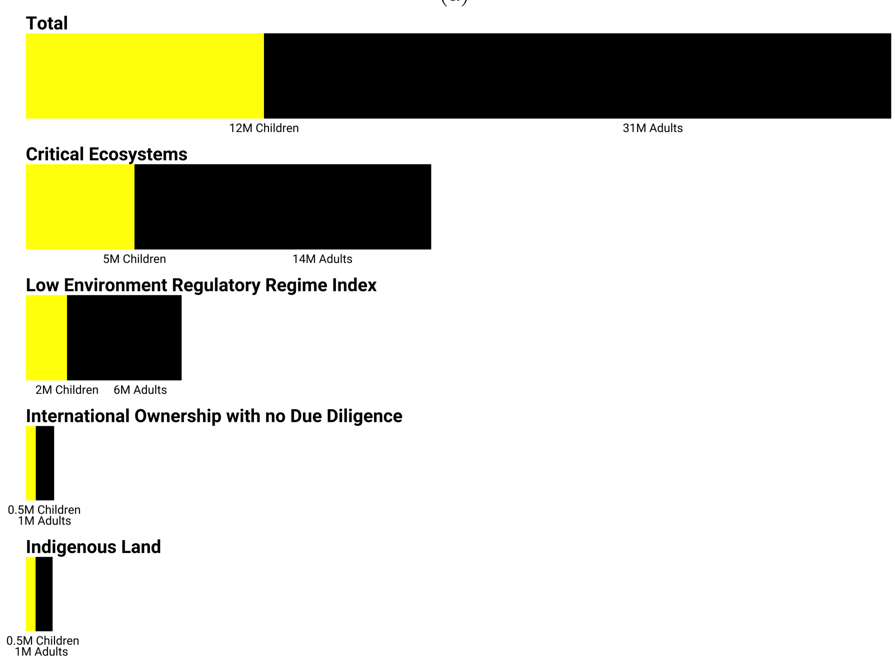
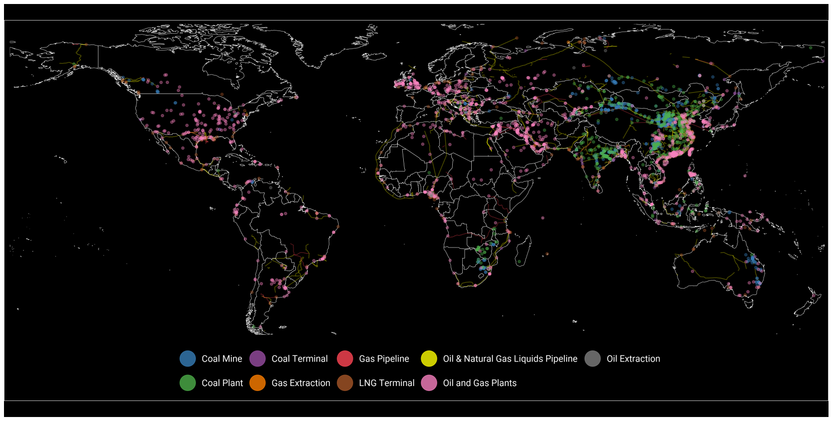


(b)

Figure 3: An estimated hundreds of millions of people, and over a hundred million children, live within 1 km of fossil fuel infrastructure globally. (a) The number of people living within 1 km of fossil fuel infrastructure, including pipelines. (b) The number of people living within 1 km of fossil fuel infrastructure, excluding pipelines.

ring in critical ecosystems, with 69% in any of the critical ecosystem indicators compared to a baseline of 11.9% (Fig S7).

The planned infrastructure also continues to expose millions more to potential risks and hazards: 106 million additional people will live within the high risk zone of 1 km of the proposed locations, more than 60% of whom already reside in critical ecosystems (Fig 4c). Of the people exposed, 7 million will be in countries with weak environmental regulations, 8 million in proximity to a location with foreign ownership, and 7 million on Indigenous land (Fig 4c). Looking further afield, 339 million additional people will be within 5 km proximity of planned facilities including over 100 million children. 217 million of these 5 km fenceline communities will be in existing critical ecosystems, 24 million in countries with lax environmental regulation, 21 million in proximity to a foreign-held facility, and 29 million located on Indigenous land (Fig S8).



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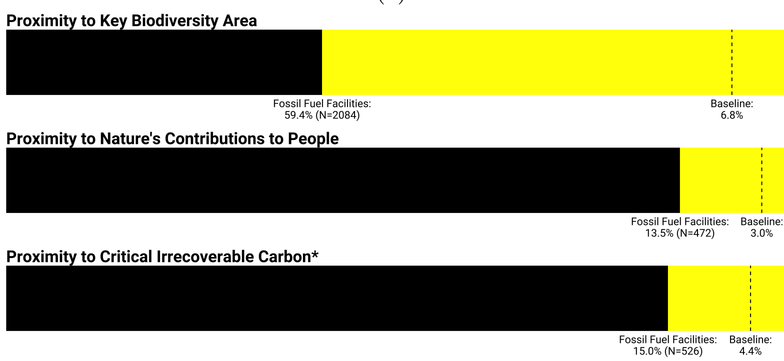

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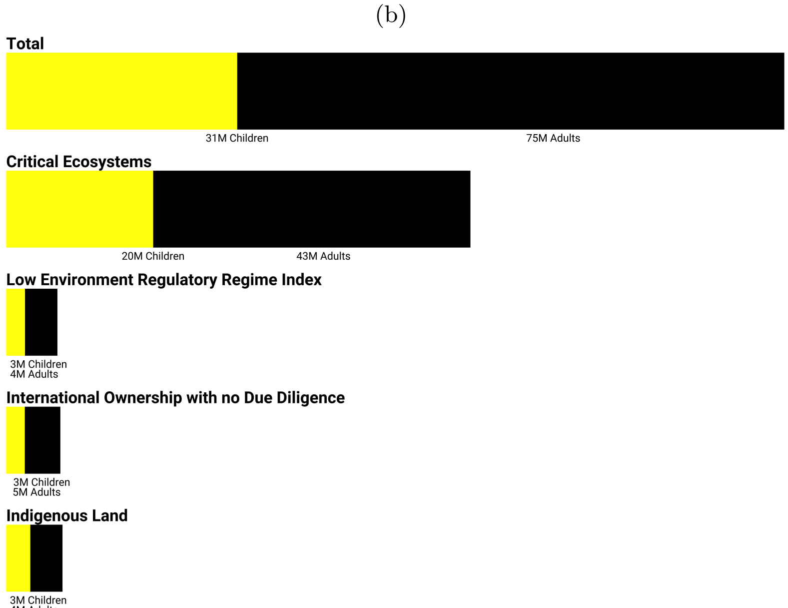

(c)

Figure 4: Planned fossil fuel infrastructure will continue to have an outsized impact on ecosystems and people. (a) Locations of planned fossil fuel infrastructure (b) Planned fossil fuel infrastructure situated in critical coastal and terrestrial ecosystems compared to baselines (*estimates calculated in terrestrial ecosystems only) (c) Number of additional people currently living within 1 km of planned fossil fuel infrastructure.

3 Discussion

Despite widespread calls for an energy transition, fossil fuels remain the dominant energy source worldwide. Our analysis demonstrates that the 18,000 unique facilities documented in the GEM database are not only globally extensive and diverse in type, but are also disproportionately sited in ecologically critical areas at more than triple the baseline expectations. This includes ecosystems already under severe strain, with facilities disproportionately situated in close proximity to key biodiversity areas, in regions critical to nature's contributions to people, and lands with high levels of irrecoverable carbon. This threatens to erode biodiversity, undermine ecological resilience, and accelerate ecosystem decline. Previous assessments of fossil fuel impacts on ecosystems have largely been conducted at much coarser scales, whether through uniform 50 km footprint assumptions (34; 38) or by mapping reserves and concession blocks that may never be developed (35; 36). Our study shows that when assessed at higher resolution the risks are widespread.

Equally important, this study establishes the first global estimates of the size of fenceline communities living in proximity to fossil fuel infrastructure. Building on decades of evidence linking exposure to increased risks of asthma, cancer, cardiovascular disease, and other chronic conditions, we quantify the number of people living in high risk zones. Prior work has assessed the global risk to ambient populations for limited infrastructure (e.g. refineries) and likely overexaggerated the number of people at risk (55). Our estimates provide a more detailed view and further disaggregate vulnerable populations, such as children, revealing the extent of people that are likely facing the highest risks. These risks are likely compounded where facilities overlap with ecologically critical areas, weak regulatory environments, foreign ownership structures, or Indigenous territories. When these communities are impacted they can face insurmountable barriers in accessing legal remedy, given both regulatory failures and the lack of accountability frameworks.

The trajectory of planned infrastructure raises even greater concern. The 3,500+ facilities currently proposed or under construction replicate and even intensify the inequities documented in existing infrastructure. We find that almost 60% of these projects are slated for, or are being constructed, near key biodiversity areas, with similarly disproportionate risks to nature's contributions to people. These projects will put at risk millions more people to the irreversible harms of fossil fuel operations. These findings underscore how new developments not only contravene international agreements and climate commitments but also deepen the burden on already-stressed ecosystems and fenceline populations.

Geographically, some of the planned expansion is concentrated in Asia's biodiversity hotspots, where the consequences for both people and nature could be devastating. China's 782 proposed coal facilities run directly counter to its net-zero pledges, while India's 156 planned coal plants, mines, and terminals undermine its commitment to derive half of installed electricity from non-fossil-fuel sources by 2030 (56; 57). These projects, alongside actions in other major world powers, including the United States' new "Unleashing American Energy" presidential order signal a dangerous backslide: rather than accelerating renewable energy investments, governments and corporations are choosing to lock in decades of reliance on the most greenhouse-gas-intensive and polluting fuel source. The cumulative result is not only billions of tonnes of additional CO_2 annually but also the expansion of toxic exposure, ecological destruction, and negative impacts on local communities. Impacts that are both predictable and preventable.

Moving forward, four critical actions are needed to address the global fossil fuel infrastructure crisis facing fenceline communities and critical ecosystems. First, comprehensive epidemiological research and associated public health systems must use our understanding of the number of people in fenceline communities to develop improved sampling programs to monitor, evaluate, and respond to what are likely millions of unreported and undocumented health impacts and needs globally. Second, researchers should support grassroots networks in fenceline communities with platforms for integrating these data into advocacy frameworks and legal action to realize environmental rights on the frontline of fossil fuel development. Third, equal efforts on both these fronts should be made but with respect to assessing and responding to ecosystem health—to ensure the health and rights of nature are equally documented at scale, and legal actions taken to ensure they are met. Fourth, in terms of planned and in construction developments, research-informed policy and continued pressure on government and industry are needed to push regulation on fossil fuel permitting processes beyond narrow project-level assessments to require evaluation criteria that incorporate climate commitment compatibility, renewable alternatives prioritization, and the rising and compounding costs to nature and ecosystems.

A just energy transition must center equity. This means not only phasing out fossil fuel infrastructure but also prioritizing the health, safety, and rights of the hundreds of millions living at the fenceline. It means integrating robust health and environmental impact assessments into decision-making, aligning national and global climate commitments with on-the-ground realities, and investing in renewable alternatives that reduce reliance on fossil fuels. Scientists, activists, and communities together have a vital role to play: exposing the hidden costs of fossil fuels, communicating risks with clarity, and demanding urgent, enforceable action.

Ultimately, dismantling fossil fuel dependence is not just a climate imperative—it is a moral one. The choice is stark: continue on a path of loss of ecosystem and human health, or build an energy future that prioritizes justice, resilience, and the flourishing of both people and planet.

4 Methods

Data Development

Global Energy Monitor Database

We use data from Global Energy Monitor (GEM), an organization that develops and analyzes data on energy infrastructure, resources, and ownership (50). We aggregated data from GEM on locations, capacity, throughput, operational status, and ownership levels for coal mines, coal plants, coal terminals, oil and gas extraction sites, oil and gas plants, liquefied natural gas (LNG) terminals, and oil and gas pipelines from their resource and ownership trackers, most recently updated between December 2024 and June 2025. Oil and gas wells are not included as part of the GEM facility databases. Fossil fuel infrastructure was also filtered to include only those that had unique location coordinates and had a status of operational for operating facility analysis or either proposed, announced, in development, or under construction for our planned facility analysis. Both terrestrial and offshore infrastructure located within a nation's exclusive economic zone (EEZ) was retained. A total of 18,273 unique operating fossil fuel facilities as well as 3,507 planned locations were included in the final dataset.

To help determine facility extents for developing ecological buffers, we also considered the oil and gas infrastructure from the Office of Fossil Energy's National Energy Technology Laboratory (NETL) which includes features on operating assets around the world (58). While this dataset did not have as many facility types and regular updates as the GEM, it did include shapefiles for undertaking sensitivity analysis of extents for some assets of interest.

CO_2 Emissions Data

Emissions data was obtained from the Global Gridded Daily CO_2 Emissions Dataset (GRACED) which has tracked daily power, industry, residential, and transportation CO_2 emissions since 2019 at a global resolution of $0.1°$ by $0.1°$ (51).

Ecological Data

All ecological data was spatially restricted to terrestrial and EEZ boundaries, excluding Antarctica, with terrestrial biomes defined using the RESOLVE Ecoregions dataset (59). Analyses focused on four key ecological dimensions: 1) Key Biodiversity Areas (KBAs): Spatial data provided by the KBA Partnership via BirdLife International (60) 2) Nature's Contributions to People (NCPs): Spatial raster data ($\sim$2 km resolution) representing top 20th percentile of global ecosystem service values across 12 NCP types (61) 3) Irrecoverable Carbon: Raster data ($\sim$300 m resolution) of high-density biomass and soil carbon stores that would not regenerate by 2050 if disturbed, considering only the top 20th percentile values (62) 4) World Database of Protected Areas (WDPAs): Developed by the United Nation Environment Programme (UNEP) and the International

Union for the Conservation of Nature (IUCN). Though included in supplementary analysis, WDPAs were excluded from main figures due to regional designation biases (63).

Population Data

Population exposure was assessed using the WorldPop 2020 gridded population dataset, which provides estimates at ∼1 km spatial resolution globally (64), including by age and gender for year 2020. For our analysis of population counts, children were defined as under 15 years of age. For sensitivity analysis, we also considered the 2020 population dataset from LandScan Global (65) which is an ambient population estimate at ∼1 km spatial resolution.

Regulation Data

The Environmental Regulatory Risk (ERR) Index was used to indicate country-level environmental regulation strength (66). Four countries (France, Germany, Netherlands, Norway) have due diligence laws and were omitted when considering locations that had international ownership.

To compile our due diligence law data, we employed a multi-step research process current as of May 1, 2025. Our primary data was compiled using the 2024 UN report "Business, planetary boundaries, and the right to a clean, healthy, and sustainable environment" (67) and Boyd and Keene 2022 Policy Brief No. 3, "Essential elements of effective and equitable human rights and environmental due diligence legislation" (68). To update our primary data, a search was conducted using the keywords "due diligence", "vigilance", "supply chain", "responsible business", and "responsible corporation" within FAOLEX (69), a legislative and policy worldwide database managed by the FAO and ECOLEX, a global environmental law repository jointly maintained by the IUCN, UNEP, and FAO (70), and HeinOnline which offers access to legal resources across the globe (71). The research also involved a targeted review of recent news developments through the webpages of the European Coalition for Corporate Justice and the Canadian Network on Corporate Accountability—two civil society networks dedicated to business accountability (72; 73). This was complemented by Google search using the same keywords to capture additional relevant materials. After identifying relevant due diligence laws, we consulted governmental gazettes to access official legislative versions.

Indigenous Lands Data

Indigenous lands spatial data was obtained from Garnett et al. 2018 (18) under a specific use agreement for this manuscript and research project.

Analytical Approach

Facility-Associated Emissions

Buffers for emissions estimates for spatial analysis of production vs. consumption comparisons were calculated at a standard 10 km around each facility, as airborne emissions are more dispersed compared to the effect of physical footprints on land-based impacts. Emissions baselines were calculated as the average emissions for the proportion of global terrestrial and EEZ surface area covered by the gridded emissions data. Fossil fuel infrastructure proximity was then assessed by calculating the proportion of infrastructure footprints intersecting this layer. Pipelines were excluded from emissions calculations due to the difficulty in identifying localized emissions, many being buried underground, emissions largely arising from spills, leakage, or compressions stations which would be challenging to observe at the current resolution of the data, and their density near population centers which could be conflated with consumption-based emissions.

Infrastructure Footprints and Ecological Risk

We assessed the probability of siting in critical ecosystems by developing a facility specific sampling strategy that accounted for the direct footprint of facilities plus moderate 'spillover' effects outside the facility boundaries. Such spillover effects include routine noise pollution, air pollution (including particulate matter and debris), light pollution, water pollution, and disturbance from traffic and transport in land, waterways, and sea, all of which can disrupt non-human species health, interactions, and movement as well as human activities which depend on nature in landscapes (25; 26; 27; 28; 29; 30; 31; 32; 33; 40; 41; 49; 42; 43; 44; 45; 46; 47; 48).

For our main analysis, we took a conservative approach that varied by facility type. For coal mines, existing spatial facility level footprint data exist and we simply use a 1 km buffer around those facility areas; for oil, gas, and coal plants spatial footprint data is not available, and so for these locations we use a 2 km radius from the plant centroid to account for the added spatial footprint of these plants globally (notably this choice was taken to account for even the world's largest coal, oil, and gas plants whose spatial footprints translate to $\sim$850 m, $\sim$500 m, $\sim$1.2 km, respectively; we relax this assumption in sensitivity analysis and reduce the radius to 1 km for plants, see Fig S4); for oil and gas extraction fields we considered 5 km around the centroid of the field, a choice validated against actual field boundaries data where it exists, showing a conservative approximation of prevalence in the risks for these extensive operations often highly interspersed in working lands (Fig S9); for pipelines, we consider a 25 m buffer around the width of the pipeline to represent local disturbance; and for LNG terminals, which generally have a smaller footprint, we consider a 1 km buffer. Notably, these buffers are simply to estimate siting issues in critical ecosystems, and are not intended to indicate the full extent of potential damage, for example from explosions, major spillage, pipeline breakage, or other ecological disasters, which we know to have much wider footprints that those ones we estimate here.

Ecological baselines are calculated as the proportion of global terrestrial and EEZ surface area covered by each ecological layer; that is, what percentage of global terrestrial and EEZ surfaces are in any of the ecological layers. Fossil fuel infrastructure proximity was then assessed by calculating the proportion of infrastructure footprints intersecting these layers. A normalized ecological risk index (0–3) is computed for each facility based on the number of overlapping ecological dimensions. Terrestrial sites are evaluated against three dimensions (KBA, NCP, irrecoverable carbon) while offshore sites are evaluated against two (KBA, NCP). For NCP and irrecoverable carbon we only assess those sites globally that fall in the 80th percentile of the distribution in order to represent the most critical ecosystems globally with respect to these indicators.

Fossil Fuel Infrastructure Ownership

Ownership of fossil fuel infrastructure is classified using a hierarchical approach, drawing on four levels of corporate ownership: Level 0 (official headquarters), Level 1 (Owner1), Level 2 (Owner2), and Level 3 (Owner3). Ownership type is based on aggregate shares. Facilities are designated as nationally owned if $\geq$50% of aggregate ownership is from companies headquartered in the host country or internationally owned if >50% of ownership is held by foreign entities. In cases where ownership data were missing at a given level the classification considers the next available level. For facilities spanning multiple countries, a conservative approach is used: if any of the countries listed matches the owner's headquarters, the infrastructure is classified as nationally owned. For population exposure analysis, foreign-owned facilities where the headquarters is not in France, Germany, Netherlands, or Norway are used in the analysis as other countries do not have any due diligence laws in place.

Fenceline Populations

To calculate the size of the fenceline communities around fossil fuel infrastructure buffer zones were created around facility centroids or lines (for pipelines) and resident population numbers extracted using zonal statistics. Two buffer distances were defined: 1 km to represent the highest risks and 5 km to capture lower but still elevated risks. These distances were based on the literature where studies assess health impacts for residential areas over various distances (Table S1). Additional analysis on population exposure also calculated people exposed at 1 and 5 km without the inclusion of pipelines, given their large extent and reduced risks at 5 km, as a sensitivity analysis (Table S2).

Subsets of the fenceline communities were estimated including 1) a total number of people within a facility's buffer, 2) the number within critical ecosystems, or all people within the buffer of a facility which also intersects an ecological risk layer, 3) those with a low environmental regulatory regime index (ERRI)—people in the facility buffer where the country has an ERRI below zero, 4) the number of people close to facilities that are international owned and without due diligence, counted as the number of people in the facility buffer where the facility is foreign-owned and the headquarter country does not have due diligence laws, and, finally, 5) those that are proximate to Indigenous lands—all people in the facility buffer which also intersects with the Indigenous lands layer.

To ensure there was no double counting of populations for current and future facilities, operating buffers were differenced from the buffers of the planned facilities. As a result all calculated populations for planned facilities are additional individuals at risk, on top of those already living nearby operating facilities.

As an additional sensitivity layer, we also assessed populations using the Landscan Global population layer, which is a population dataset with the same resolution as WorldPop but constructed through ambient population mapping (65). Estimating population has many challenges and global datasets have different levels of sophistication in terms of how they model populations from disaggregation of census counts to more complex approaches that utilize multiple auxiliary sources and dasymetric mapping. There are known challenges with population layers, including potential for under representation of rural populations (53) and how well they are fit for different use cases (54); however, LandScan and WorldPop have comparably high fidelity. To address the potential uncertainty between data products, we include an estimate of the percentage differences between WorldPop and Landscan exposed population estimates (Table S3).

5 Contributions

Project Ideation: GB, KF, LC, NO, SC, CO, ILG, VK, ZM

Analysis (Formal methodology): GB, KF, LC, NO, ZM

Analysis (Implementation): GB, KF, LC, NO

Results (Interpretation): GB, KF, LC, NO, ZM

Writing: GB, KF, LC, NO, ZM

Comments/review: GB, KF, LC, NO, SC, CO, ILG, VK, ZM

6 Data and Code Availability

The data sets and code used and created in this study are available at https://github.com/Better-Planet-Laboratory/amnesty.

7 References

References

[1] *IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland.* July 2023.

[2] C. W. Callahan and J. S. Mankin, "Carbon majors and the scientific case for climate liability," *Nature*, vol. 640, p. 893–901, Apr. 2025.

[3] D. O'Rourke and S. Connolly, "Just oil? the distribution of environmental and social impacts of oil production and consumption," *Annual Review of Environment and Resources*, vol. 28, p. 587–617, Nov. 2003.

[4] K. Vohra, A. Vodonos, J. Schwartz, E. A. Marais, M. P. Sulprizio, and L. J. Mickley, "Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from geos-chem," *Environmental Research*, vol. 195, p. 110754, 2021.

[5] F. A. Wichmann, A. Müller, L. E. Busi, N. Cianni, L. Massolo, U. Schlink, A. Porta, and P. D. Sly, "Increased asthma and respiratory symptoms in children exposed to petrochemical pollution," *Journal of Allergy and Clinical Immunology*, vol. 123, p. 632–638, Mar. 2009.

[6] S. Mondal, G. Singh, and M. K. Jain, "Spatio-temporal variation of air pollutants around the coal mining areas of Jharia Coalfield, India," *Environmental Monitoring and Assessment*, vol. 192, p. 405, May 2020.

[7] D. Holmstrom, F. Altamirano, J. Banks, G. Joseph, M. Kaszniak, C. Mackenzie, R. Shroff, H. Cohen, and S. Wallace, "Csb investigation of the explosions and fire at the bp texas city refinery on march 23, 2005," *Process Safety Progress*, vol. 25, p. 345–349, Sept. 2006.

[8] J. Idavain, K. Lang, J. Tomasova, A. Lang, and H. Orru, "Cancer Incidence Trends in the Oil Shale Industrial Region in Estonia," *International Journal of Environmental Research and Public Health*, vol. 17, p. 3833, June 2020.

[9] A. Balgobin and N. Ramroop Singh, "Source apportionment and seasonal cancer risk of polycyclic aromatic hydrocarbons of sediments in a multi-use coastal environment containing a Ramsar wetland, for a Caribbean island," *Science of The Total Environment*, vol. 664, pp. 474–486, May 2019.

[10] United Nations (Human Rights Council), *A/HRC/RES/48/13 Resolution adopted by the Human Rights Council on 8 October 2021.* Oct. 2021.

[11] United Nations (General Assembly), *A/RES/76/300 Resolution adopted by the General Assembly on 28 July 2022.* July 2022.

[12] *AO-32/25 Climate Emergency and Human Rights*. July 2025.

[13] *International Court of Justice AO on Obligation of States in respect of Climate Change*. July 2025.

[14] "Standing Firm: The land and environmental defenders on the frontlines of the climate crisis," tech. rep., Global Witness, 2023.

[15] NOAA Fisheries, "Deepwater horizon 10 years later: 10 questions," Apr 2020.

[16] J. O'Farrell, D. O'Fionnagáin, A. O. Babatunde, M. Geever, P. Codyre, P. C. Murphy, C. Spillane, and A. Golden, "Quantifying the Impact of Crude Oil Spills on the Mangrove Ecosystem in the Niger Delta Using AI and Earth Observation," *Remote Sensing*, vol. 17, p. 358, Jan 22 2025.

[17] P. S. zu Ermgassen, N. Mukherjee, T. A. Worthington, A. Acosta, A. R. d. Rocha Araujo, C. M. Beitl, G. A. Castellanos-Galindo, M. Cunha-Lignon, F. Dahdouh-Guebas, K. Diele, C. L. Parrett, P. G. Dwyer, J. R. Gair, A. F. Johnson, B. Kuguru, A. Savio Lobo, N. R. Loneragan, K. Longley-Wood, J. T. Mendonça, J.-O. Meynecke, R. N. Mandal, C. N. Munga, B. G. Reguero, P. Rönnbäck, J. Thorley, M. Wolff, and M. Spalding, "Reprint of : Fishers who rely on mangroves: Modelling and mapping the global intensity of mangrove-associated fisheries," *Estuarine, Coastal and Shelf Science*, vol. 248, p. 107159, 1 2021.

[18] S. T. Garnett, N. D. Burgess, J. E. Fa, Á. Fernández-Llamazares, Z. Molnár, C. J. Robinson, J. E. M. Watson, K. K. Zander, B. Austin, E. S. Brondizio, N. F. Collier, T. Duncan, E. Ellis, H. Geyle, M. V. Jackson, H. Jonas, P. Malmer, B. McGowan, A. Sivongxay, and I. Leiper, "A spatial overview of the global importance of Indigenous lands for conservation," *Nature Sustainability*, vol. 1, pp. 369–374, Jul 16 2018.

[19] M. A. Hurlbert and R. Datta, "When the environment is destroyed, you're destroyed: Achieving Indigenous led pipeline justice," *Energy Research amp; Social Science*, vol. 91, p. 102711, 9 2022.

[20] L. Wright and J. P. White, "Developing oil and gas resources on or near indigenous lands in canada: An overview of laws, treaties, regulations and agreements," *International Indigenous Policy Journal*, vol. 3, no. 2, pp. pp. 1–18, 2012.

[21] J. Farrell, "Network structure and influence of the climate change counter-movement," *Nat. Clim. Chang.*, vol. 6, pp. 370–374, Apr. 2016.

[22] J. Farrell, "Corporate funding and ideological polarization about climate change," *Proceedings of the National Academy of Sciences*, vol. 113, no. 1, pp. 92–97, 2016.

[23] S. Wolf, R. Bullard, J. J. Buonocore, N. Donley, T. Farrelly, J. Fleming, D. J. X. González, N. Oreskes, W. Ripple, R. Saha, and M. D. Willis, "Scientists' warning on fossil fuels," *Oxford Open Climate Change*, vol. 5, Jan. 2025.

[24] L. M. McKenzie, R. Z. Witter, L. S. Newman, and J. L. Adgate, "Human health risk assessment of air emissions from development of unconventional natural gas resources," *Sci. Total Environ.*, vol. 424, pp. 79–87, May 2012.

[25] R. D. Soares, M. Dos Santos, F. R. de Moura, A. L. Muccillo-Baisch, P. R. M. Baisch, M. C. F. Soares, and F. M. R. da Silva Júnior, “Gestational and neonatal outcomes in cities in the largest coal mining region in brazil,” *Int. J. Environ. Res. Public Health*, vol. 19, p. 12107, Sept. 2022.

[26] J. A. Casey, D. A. Savitz, S. G. Rasmussen, E. L. Ogburn, J. Pollak, D. G. Mercer, and B. S. Schwartz, “Unconventional natural gas development and birth outcomes in pennsylvania, USA,” *Epidemiology*, vol. 27, pp. 163–172, Mar. 2016.

[27] S. Ha, H. Hu, J. Roth, H. Kan, and X. Xu, “Associations between residential proximity to power plants and adverse birth outcomes,” *Am. J. Epidemiol.*, vol. 182, pp. 215–224, Aug. 2015.

[28] L. M. McKenzie, R. Guo, R. Z. Witter, D. A. Savitz, L. S. Newman, and J. L. Adgate, “Birth outcomes and maternal residential proximity to natural gas development in rural colorado,” *Environ. Health Perspect.*, vol. 122, pp. 412–417, Apr. 2014.

[29] H. Guo, S. H. Kota, K. Chen, S. K. Sahu, J. Hu, Q. Ying, Y. Wang, and H. Zhang, “Source contributions and potential reductions to health effects of particulate matter in india,” *Atmos. Chem. Phys.*, vol. 18, pp. 15219–15229, Oct. 2018.

[30] M. Lavoie, D. Risk, and D. Rainham, “Sociodemographic and population exposure to upstream oil and gas operations in canada,” *Int. J. Environ. Res. Public Health*, vol. 21, Dec. 2024.

[31] J. Cortes-Ramirez, S. Naish, P. D. Sly, and P. Jagals, “Mortality and morbidity in populations in the vicinity of coal mining: a systematic review,” *BMC Public Health*, vol. 18, Dec. 2018.

[32] A.-K. Hurtig and M. San Sebastián, “Geographical differences in cancer incidence in the amazon basin of ecuador in relation to residence near oil fields,” *Int. J. Epidemiol.*, vol. 31, pp. 1021–1027, Oct. 2002.

[33] D. Roy, G. Singh, and Y.-C. Seo, “Coal mine fire effects on carcinogenicity and non-carcinogenicity human health risks,” *Environ. Pollut.*, vol. 254, p. 113091, Nov. 2019.

[34] M. B. J. Harfoot, D. P. Tittensor, S. Knight, A. P. Arnell, S. Blyth, S. Brooks, S. H. M. Butchart, J. Hutton, M. I. Jones, V. Kapos, J. P. Scharlemann, and N. D. Burgess, “Present and future biodiversity risks from fossil fuel exploitation,” *Conservation Letters*, vol. 11, Apr. 2018.

[35] N. Butt, H. L. Beyer, J. R. Bennett, D. Biggs, R. Maggini, M. Mills, A. R. Renwick, L. M. Seabrook, and H. P. Possingham, “Conservation. biodiversity risks from fossil fuel extraction,” *Science*, vol. 342, pp. 425–426, Oct. 2013.

[36] H. S. Grantham, P. Tibaldeschi, P. Izquierdo, K. Mo, D. J. Patterson, H. Rainey, J. E. M. Watson, and K. R. Jones, "The emerging threat of extractives sector to intact forest landscapes," *Front. For. Glob. Chang.*, vol. 4, July 2021.

[37] B. W. Allred, W. K. Smith, D. Twidwell, J. H. Haggerty, S. W. Running, D. E. Naugle, and S. D. Fuhlendorf, "Sustainability. ecosystem services lost to oil and gas in north america," *Science*, vol. 348, pp. 401–402, Apr. 2015.

[38] L. J. Sonter, M. C. Dade, J. E. M. Watson, and R. K. Valenta, "Renewable energy production will exacerbate mining threats to biodiversity," *Nat. Commun.*, vol. 11, p. 4174, Sept. 2020.

[39] K. Kühne, N. Bartsch, R. D. Tate, J. Higson, and A. Habet, ""carbon bombs" - mapping key fossil fuel projects," *Energy Policy*, vol. 166, p. 112950, 2022.

[40] C. Erbe, S. A. Marley, R. P. Schoeman, J. N. Smith, L. E. Trigg, and C. B. Embling, "The effects of ship noise on marine mammals—a review," *Front. Mar. Sci.*, vol. 6, Oct. 2019.

[41] J. M. Van der Hoop, M. J. Moore, S. G. Barco, T. V. N. Cole, P.-Y. Daoust, A. G. Henry, D. F. McAlpine, W. A. McLellan, T. Wimmer, and A. R. Solow, "Assessment of management to mitigate anthropogenic effects on large whales," *Conserv. Biol.*, vol. 27, pp. 121–133, Feb. 2013.

[42] T. Rutherford, L. Maxwell, N. Kleist, E. Teige, R. Lehrter, M. Gilbert, D. Wood, A. Johnston, C. Mengelt, J. Tull, T. Haby, and S. Carter, "Effects of noise from oil and gas development on ungulates and small mammals—a science synthesis to inform national environmental policy act analyses," tech. rep., U.S. Geological Survey, 2023.

[43] M. L. Richardson, B. A. Wilson, D. A. S. Aiuto, J. E. Crosby, A. Alonso, F. Dallmeier, and G. K. Golinski, "A review of the impact of pipelines and power lines on biodiversity and strategies for mitigation," *Biodivers. Conserv.*, vol. 26, pp. 1801–1815, July 2017.

[44] R. G. Verb and M. L. Vis, "Periphyton assemblages as bioindicators of mine-drainage in unglaciated western allegheny plateau lotic systems," *Water Air Soil Pollut.*, vol. 161, pp. 227–265, Feb. 2005.

[45] T. M. Thompson, D. Shepherd, A. Stacy, M. G. Barna, and B. A. Schichtel, "Modeling to evaluate contribution of oil and gas emissions to air pollution," *J. Air Waste Manag. Assoc.*, vol. 67, pp. 445–461, Apr. 2017.

[46] R. Bobbink, K. Hicks, J. Galloway, T. Spranger, R. Alkemade, M. Ashmore, M. Bustamante, S. Cinderby, E. Davidson, F. Dentener, B. Emmett, J.-W. Erisman, M. Fenn, F. Gilliam, A. Nordin, L. Pardo, and W. De Vries, "Global assessment of nitrogen deposition effects on terrestrial plant diversity: a synthesis," *Ecol. Appl.*, vol. 20, pp. 30–59, Jan. 2010.

[47] K. J. Gaston, T. W. Davies, J. Bennie, and J. Hopkins, “Reducing the ecological consequences of night-time light pollution: options and developments,” *J. Appl. Ecol.*, vol. 49, pp. 1256–1266, Dec. 2012.

[48] R. Sordello, O. Ratel, F. Flamerie De Lachapelle, C. Leger, A. Dambry, and S. Vanpeene, “Evidence of the impact of noise pollution on biodiversity: a systematic map,” *Environ. Evid.*, vol. 9, Sept. 2020.

[49] B. R. Silliman, J. van de Koppel, M. W. McCoy, J. Diller, G. N. Kasozi, K. Earl, P. N. Adams, and A. R. Zimmerman, “Degradation and resilience in louisiana salt marshes after the BP-Deepwater horizon oil spill,” *Proc. Natl. Acad. Sci. U. S. A.*, vol. 109, pp. 11234–11239, July 2012.

[50] Global Energy Monitor, “Global energy trackers,” Jul 2025.

[51] X. Dou, Y. Wang, P. Ciais, F. Chevallier, S. J. Davis, M. Crippa, G. Janssens-Maenhout, D. Guizzardi, E. Solazzo, F. Yan, D. Huo, B. Zheng, B. Zhu, D. Cui, P. Ke, T. Sun, H. Wang, Q. Zhang, P. Gentine, Z. Deng, and Z. Liu, “Near-real-time global gridded daily CO2 emissions,” *The Innovation*, vol. 3, p. 100182, 1 2022.

[52] H. Wang and I. J. Duncan, “Likelihood, causes, and consequences of focused leakage and rupture of U.S. natural gas transmission pipelines,” *J. Loss Prev. Process Ind.*, vol. 30, pp. 177–187, July 2014.

[53] J. Láng-Ritter, M. Keskinen, and H. Tenkanen, “Global gridded population datasets systematically underrepresent rural population,” *Nat. Commun.*, vol. 16, p. 2170, Mar. 2025.

[54] S. Leyk, A. E. Gaughan, S. B. Adamo, A. de Sherbinin, D. Balk, S. Freire, A. Rose, F. R. Stevens, B. Blankespoor, C. Frye, J. Comenetz, A. Sorichetta, K. MacManus, L. Pistolesi, M. Levy, A. J. Tatem, and M. Pesaresi, “The spatial allocation of population: a review of large-scale gridded population data products and their fitness for use,” *Earth Syst. Sci. Data*, vol. 11, pp. 1385–1409, Sept. 2019.

[55] K. S. Dorman, Maxwell, “Fossil fuel atlas: Illustrating the threats of fossil fuel production — a rapid threat identification methodology and platform,” tech. rep., Stockholm Environment Institute, Global Energy Monitor, Institute for Governance Sustainable Development, 2022.

[56] Government of China, “Chinas’s achievement, new goals and new measures for nationally determined contributions (unofficial translation).” https://unfccc.int/sites/default/files/NDC/2022-06/China’s Accessed: 2025-8-26.

[57] Government of India, “India’s updated first nationally determined contribution under paris agreement.” https://unfccc.int/sites/default/files/NDC/2022-08/India Accessed: 2025-8-26.

[58] M. Sabbatino, "Global oil & gas features database," 2018.

[59] E. Dinerstein, D. Olson, A. Joshi, C. Vynne, N. D. Burgess, E. Wikramanayake, N. Hahn, S. Palminteri, P. Hedao, R. Noss, M. Hansen, H. Locke, E. C. Ellis, B. Jones, C. V. Barber, R. Hayes, C. Kormos, V. Martin, E. Crist, W. Sechrest, L. Price, J. E. M. Baillie, D. Weeden, K. Suckling, C. Davis, N. Sizer, R. Moore, D. Thau, T. Birch, P. Potapov, S. Turubanova, A. Tyukavina, N. de Souza, L. Pintea, J. C. Brito, O. A. Llewellyn, A. G. Miller, A. Patzelt, S. A. Ghazanfar, J. Timberlake, H. Klöser, Y. Shennan-Farpón, R. Kindt, J.-P. B. Lillesø, P. van Breugel, L. Graudal, M. Voge, K. F. Al-Shammari, and M. Saleem, "An ecoregion-based approach to protecting half the terrestrial realm," *BioScience*, vol. 67, p. 534–545, Apr. 2017.

[60] "Key biodiversity areas 2024," Sep 2024.

[61] R. Chaplin-Kramer, R. A. Neugarten, R. P. Sharp, P. M. Collins, S. Polasky, D. Hole, R. Schuster, M. Strimas-Mackey, M. Mulligan, C. Brandon, S. Diaz, E. Fluet-Chouinard, L. J. Gorenflo, J. A. Johnson, C. M. Kennedy, P. W. Keys, K. Longley-Wood, P. B. McIntyre, M. Noon, U. Pascual, C. Reidy Liermann, P. R. Roehrdanz, G. Schmidt-Traub, M. R. Shaw, M. Spalding, W. R. Turner, A. van Soesbergen, and R. A. Watson, "Mapping the planet's critical natural assets," *Nature Ecology amp; Evolution*, vol. 7, p. 51–61, Nov. 2022.

[62] M. L. Noon, A. Goldstein, J. C. Ledezma, P. R. Roehrdanz, S. C. Cook-Patton, S. A. Spawn-Lee, T. M. Wright, M. Gonzalez-Roglich, D. G. Hole, J. Rockström, and W. R. Turner, "Mapping the irrecoverable carbon in earth's ecosystems," *Nature Sustainability*, vol. 5, p. 37–46, Nov. 2021.

[63] "Protected planet-world protected areas," Feb 2025.

[64] "World pop 1 km 2020 population density," May 2025.

[65] V. Lebakula, J. Epting, J. Moehl, C. Stipek, D. Adams, A. Reith, J. Kaufman, J. Gonzales, B. Reynolds, S. Basford, A. Martin, W. Buck, A. Faxon, A. Cunningham, A. Roy, Z. Barbose, J. Massaro, S. Walters, C. Woody, A. Iman, A. Wilkins, E. Powell, and M. Urban, "LandScan silver edition," 2024.

[66] D. Etsy and M. E. Porter, *Ranking National Environmental Regulation and Performance: A Leading Indicator of Future Competitiveness?"*, p. 78–101. Oxford University Press, 2002.

[67] United Nations (Human Rights Council), *A/HRC/55/43 Business, planetary boundaries, and the right to a clean, healthy and sustainable environment.* Jan. 2024.

[68] S. Keene and D. R. Boyd, "Essential elements of effective and equitable human rights and environmental due diligence legislation," policy Brief No.3, UN OHCHR, 2022.

[69] Food and Agriculture Organization of the United Nations, "Faolex," May 2025.

[70] International Union for Conservation of Nature, United Nations Environment Programme and Food and Agriculture Organization of the United Nations, "Ecolex," May 2025.

[71] I. William S. Hein Co., "Heinonline," May 2025.

[72] European Coalition for Corporate Justice, "European coalition for corporate justice," May 2025.

[73] Canadian Network on Corporate Accountability, "Canadian network on corporate accountability," May 2025.

8 Supplementary Material

Table S1: Review of health impact studies, including location, distance, affected populations, and observed health impacts.

Study (Location)	**Distance**	**Population / Sample**	**Observed Health Impacts**	**Notes**	**Facility Type**
Casey et al., 2016 (USA, PA)	0–2 km	Pregnant women	Preterm birth, low birth weight, anomalies	Strongest effects <1 km	Gas Wells
McKenzie et al., 2012 (USA, CO & PA)	>1 km, <1 km	Residents near wells	VOCs, NOx, $PM_{2.5}$, asthma, bronchitis	Air quality declines with distance	Gas Wells
McKenzie et al., 2014 (USA, CO)	0–20 km	Pregnant women	Congenital defects, preterm birth	Higher prevalence near wells	Gas Wells
Osborn et al., 2011 (USA, PA)	0–1 km	Households w/ private wells	Methane migration, water contamination	Waterborne exposure	Gas Wells
Stacy et al., 2015 (USA, PA)	0–2 km	Pregnant women	Adverse perinatal outcomes	Distance-dependent risk	Gas Wells
Steinzor et al., 2013 (USA, Marcellus Shale)	0–3 km	Residents	Noise, light, stress, sleep disturbance	Indirect impacts	Gas Wells
Chen et al., 2021 (China)	0–50 km	Communities	Mortality, COPD, cardiovascular issues	Spillover >50 km	Coal Plants
Clemons et al., 2021 (USA, KY)	0–20 km	Children	Asthma hospital visits	Reduced after decommissioning	Coal Plants
Gasparotto & Martinello, 2021 (Global)	0–10 km	Residents	Respiratory, cardiovascular, heavy metals	Downwind effects extend 10–20 km	Coal Plants
Guo et al., 2018 (India)	0–50 km	Residents	$PM_{2.5}$, CEVD, IHD, COPD, cancer	Major contributor to premature mortality	Coal Plants

Study / Location	**Distance**	**Population / Sample**	**Observed Health Impacts**	**Notes**	**Facility Type**
Han et al., 2024 (South Korea)	2 km	General population near mines	Higher cancer incidence (all types)	Long-term $PM_{2.5}$ and coal dust exposure	Coal Plants
Henneman et al., 2023 (USA)	0–50 km	Residents near plants	Mortality risk ($PM_{2.5}$, SO_2)	460,000 attributable deaths	Coal Plants
Zhang et al., 2021 (USA)	<5 km	Children	Neurobehavioral problems	Airborne exposure, coal ash	Coal Plants
Graber et al., 2013 (USA)	<5 km	Coal miners	Bronchitis, asthma, reduced lung function	Particulate exposure focus	Coal Mines
Palmer et al., 2010 (Appalachia, USA)	1–10 km	Coal mining communities	Anxiety, depression, cardiovascular issues	Mountaintop removal; psychosocial stress	Coal Mines
Ramirez et al., 2018 (Global)	0–20 km	Communities near mines	Neoplasms, circulatory, respiratory, metabolic, congenital, cancer	Broad proximity risks	Coal Mines
Roy et al., 2019 (Jharkhand, India)	1–5 km	Villages near coal mines	Air pollution, cancer rates	Airborne exposure focus	Coal Mines
Soares et al., 2022 (Brazil)	1–10 km	Pregnant women	Low birth weight, preterm birth	$PM_{2.5}$ and toxic gases in pregnancy	Coal Mines
Dey et al., 2015 (India)	<5 sq km	Settlements near oil drilling	SO_2, NO_2, liver damage	Long-term abnormalities	Oil Fields
Hurtig & San Sebastian, 2002/2013 (Ecuador)	0–10 km	Local communities	Childhood leukemia, cancer	Higher incidence near oil fields	Oil Fields
Kponee et al., 2015 (Nigeria)	0–10 km	Local communities	Neurological, hematological effects	Benzene, hydrocarbons in water	Oil Fields

Study / Location	**Distance**	**Population / Sample**	**Observed Health Impacts**	**Notes**	**Facility Type**
Kudabayeva et al., 2014 (Kazakhstan)	0–10 km	School children	High thyroid volume (goitre)	More goitre proximal	Oil Fields
Di Ciaula, 2012 (Europe)	<3 km	Communities near plants	Air pollution, hospital admissions	Higher with PM_{10}	Oil & Gas Plants
Ha et al., 2015 (USA, FL)	0–10 km	Pregnant women	Preterm delivery, low birth weight	Increased risk near plants	Oil & Gas Plants
Liu et al., 2012 (USA, NY)	0–50 km	Residents	Hospitalization: asthma, ARI, COPD	Respiratory burden	Oil & Gas Plants
Solutions for Our Climate, 2021 (S. Korea)	0–100 km	Residents	COPD, diabetes, asthma, leukemia	Transboundary $PM_{2.5}$ impacts	Oil & Gas Plants
Davis et al., 2023 (USA)	0–2 km	Residents near corridors	Soil/water contamination, air risks	Chronic exposure possible	Pipelines
Emanuel et al., 2021 / Strube et al., 2021 (USA)	0–100 km	Counties with pipelines	Environmental justice disparities	Higher risk for vulnerable populations	Pipelines
Jonasson et al., 2019 (Canada)	0–5 km	Communities near terminus	Bioaccumulating toxins	Risks to food supply	Pipelines
Shi et al., 2014 (China)	0–1 km	Local populations	Heavy metal exposure, emissions	Impacts >50m ROW	Pipelines
Greenpeace, 2024 (USA)	0–100 km	Residents near terminal	Premature deaths, asthma, lost days	Air quality monitoring, strong correlation	LNG Terminals
Michanowicz et al., 2023 (Global)	<10 km	Communities near gas leaks	Headaches, nausea, respiratory complaints	Odorant exposure, acute unclear chronic	LNG Terminals
NFPA 59A, 2021 (USA/global)	0.5–2 km	General population	Fire/explosion risk	Regulatory guidance	LNG Terminals

Study / Location	Distance	Population / Sample	Observed Health Impacts	Notes	Facility Type
US DoE, 2016 (USA)	0–5 km	Surrounding communities	NOx, VOCs, odor, noise	Acute + chronic exposure pathways	LNG Terminals
Lavoie et al., 2024 (Canada, AB)	1–3 km	Communities near wells	Cardio-respiratory issues	9% of AB pop. within 1 km of wells	Conventional Oil & Gas Wells

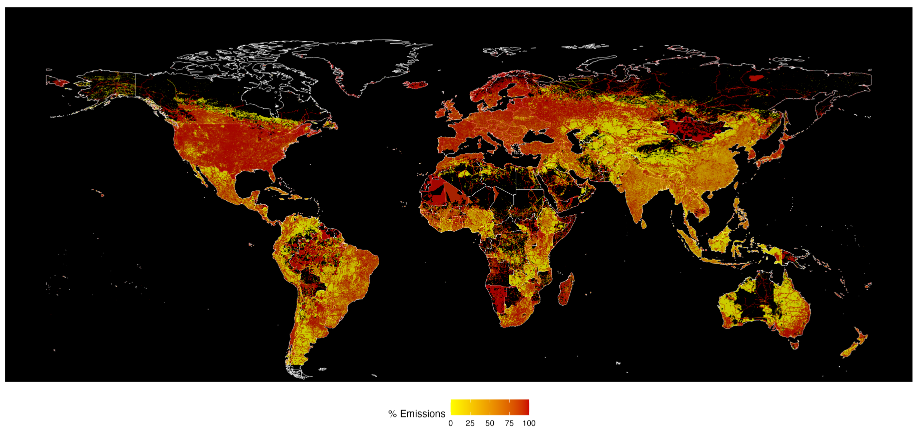

Figure S1: Consumption based emissions as a percentage of total 2024 CO_2 emissions.

Figure S2: Ecological risk prevalence of fossil fuel facilities near locations in the World Database of Protected Areas.

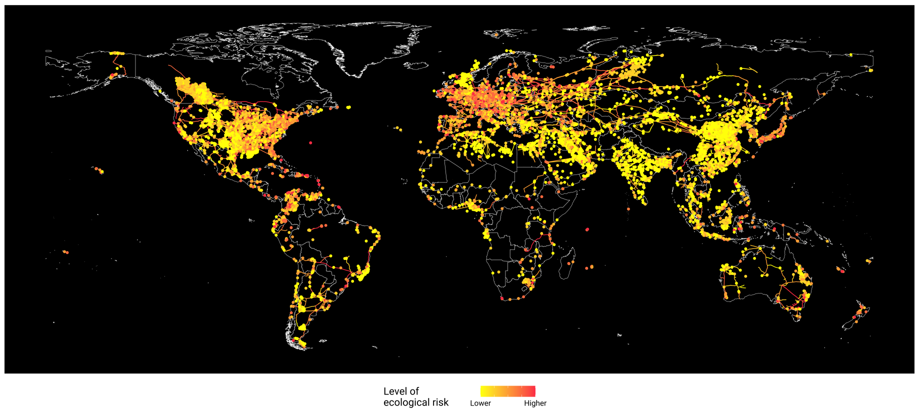

Figure S3: Risk map of fossil fuel facilities in ecologically sensitive areas (including World Database of Protected Areas).

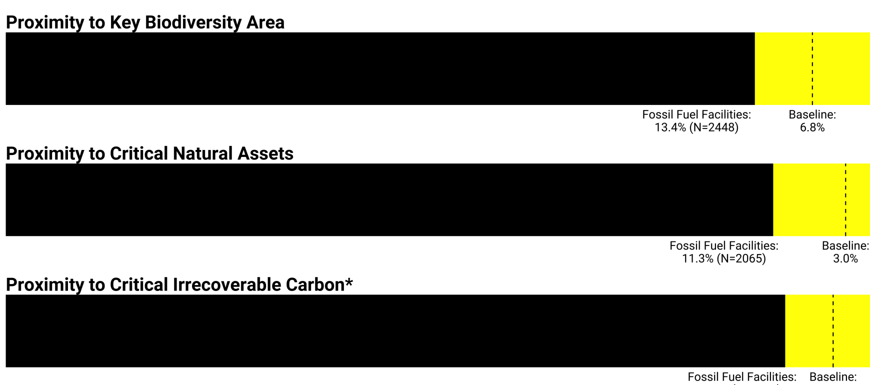

Figure S4: Ecological risk prevalence of fossil fuel facilities with 1 km footprint buffers for coal and oil and gas plants.

Table S2: Populations in proximity to fossil fuel infrastructure at different distances, including or excluding pipelines.

Type of Exposure	1 Km	1 Km No Pipelines	5 Km	5 Km No Pipelines
Total	462,794,372	42,229,033	1,947,553,808	621,547,837
Critical Ecosystems	310,500,206	19,783,405	1,368,728,496	308,852,375
Low Environment Regulatory Regime Index	106,887,136	7,600,357	468,093,799	139,546,272
International Ownership with No Due Diligence	31,018,846	1,386,160	156,635,531	26,727,910
Indigenous Land	13,884,394	1,306,433	66,182,091	18,183,870

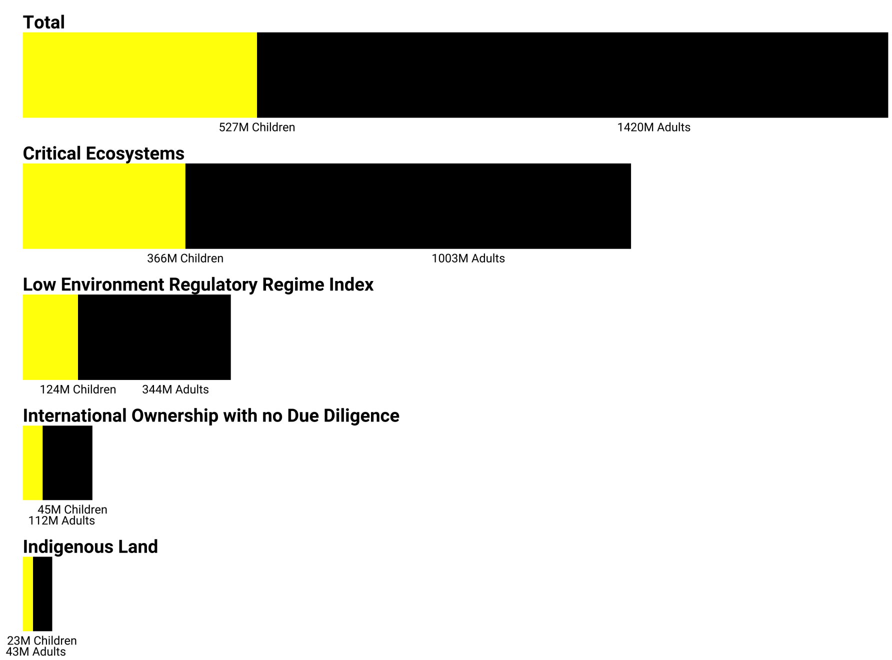

Figure S5: Number of people living within 5 km of fossil fuel infrastructure.

Table S3: Comparison of populations exposed at 1 km buffer including pipelines using WorldPop or LandScan population layers.

Type of Exposure	WorldPop	LandScan Global	Percent Difference
Total	462,794,372	452,910,802	2.16
Critical Ecosystems	310,500,206	309,088,807	0.46
Low Environment Regulatory Regime Index	106,887,136	104,297,980	2.45
International Ownership with No Due Diligence	31,018,846	29,978,095	3.41
Indigenous Land	13,884,394	13,299,079	3.56

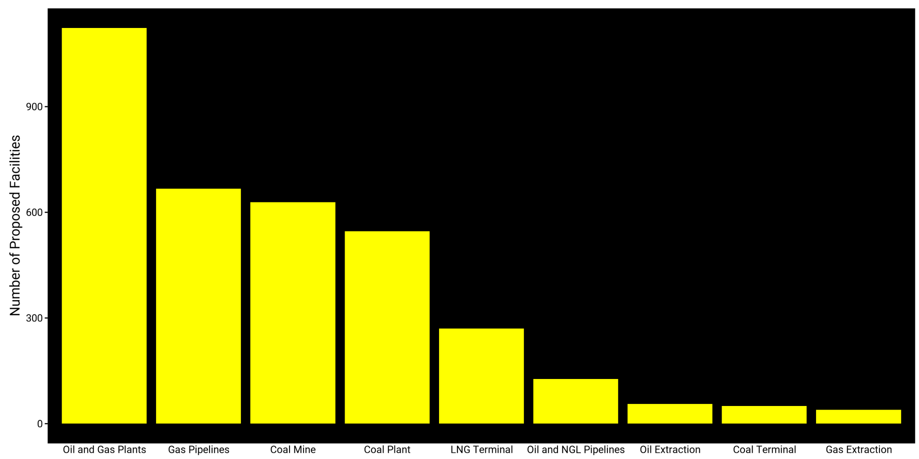

Figure S6: The number of planned fossil fuel facilities by infrastructure type.

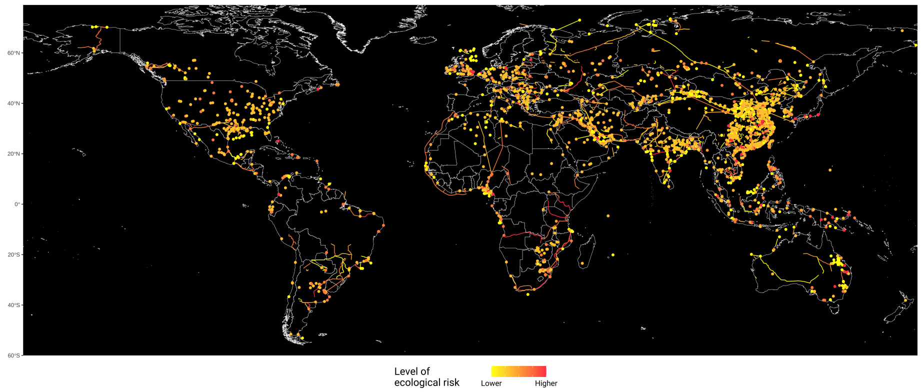

Figure S7: Fossil fuel infrastructure and the level of ecological risk of planned locations based on critical ecosystem indicators.

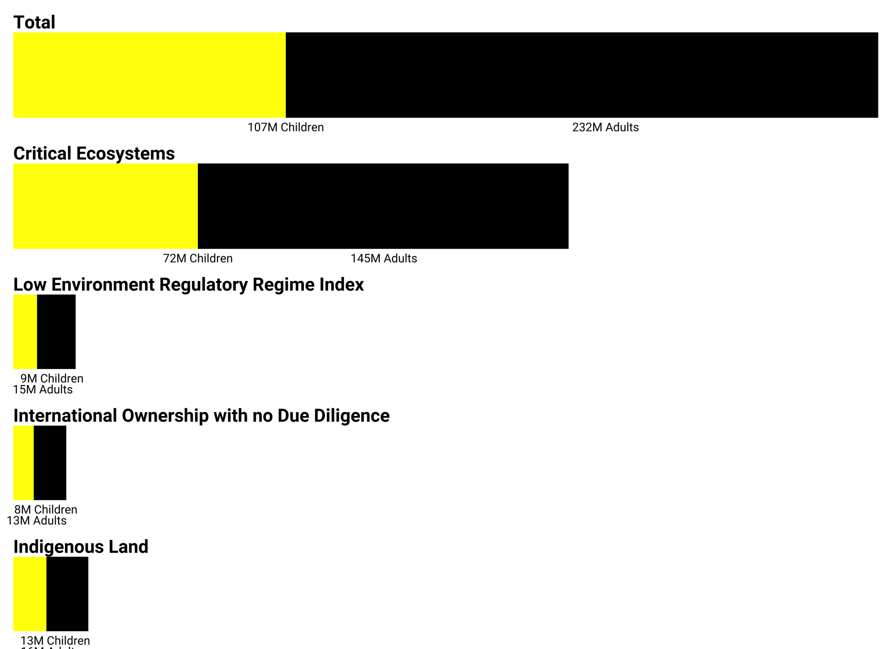

Figure S8: Number of additional people living within 5 km of planned fossil fuel infrastructure.

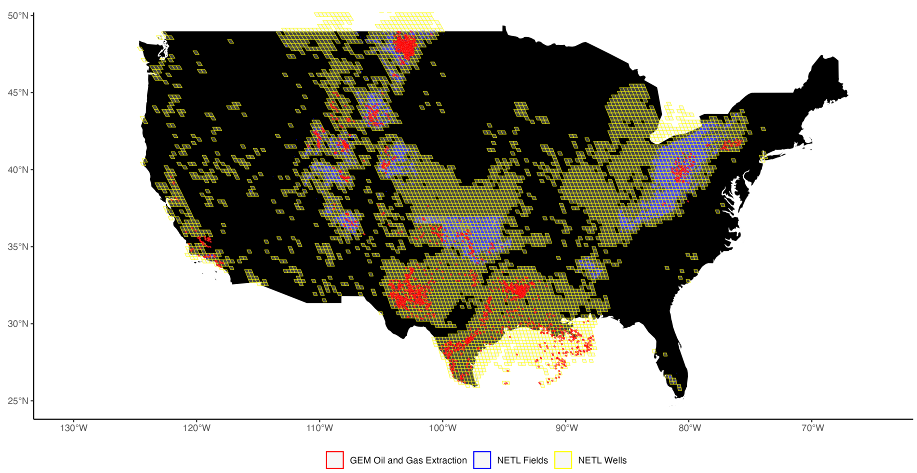

Figure S9: Comparison of Global Energy Monitor (GEM) oil and gas infrastructure 5 kilometer buffered extents with the Office of Fossil Energy's National Energy Technology Laboratory (NETL) oil and gas fields and wells extents for the United States of America.