Climate Change Transition and Physical Risks of Industrial Companies in Australia, Canada, the European Union and the United States

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ABSTRACT

We present a methodology to develop the integrated climate change transition and physical risk assessment of industrial plants in Europe, Northern America and Australia. There is an increasingly important need for effective large scale climate change risk assessment solutions with more governments aligning their company reporting regulations with the Task Force on Climate-related Financial Disclosures recommendations. In this paper we measure key aspects of climate change risks of industrial firms on the globe and vice-versa. The study provides valuable insights into climate risk exposure for companies, investors, and consumers, offering a pioneering approach by integrating data from major international registers. We analyse data from 70,000 plants, which report to fragmented Pollutant Release and Transfer Registers and Greenhouse Gas Reporting Programs. For our assessment, transition risks are measured in terms of reported greenhouse gas emissions, while physical risks calculated for all company plant locations in terms of historical cooling energy needs, flood exposure and photovoltaic power potential. We show that climate change transition and physical risks are not correlated, therefore there are no winners and losers of climate change in general. The research contributes to the evolving landscape of climate risk management and highlights the need for standardized methodologies in the face of impending regulatory changes.

Introduction

Albeit climate-related financial disclosure is becoming a universal norm with more governments around the world adopting the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD), not all companies are preparing strategies, selecting key performance indicators and setting targets to contribute to reaching the global objective of minimizing global warming to 1.5°C by 2050. Firms' TCFD/climate risk disclosures are prone to become a 'ceremonial' practice with cheap talk, green wash or cherry-picking and reporting of primarily non-material climate risk information.[1],[2]

The methodology developed by the present study gives corporate level insight on the potential corporate strategies towards managing these risks and can give insight for policy makers how to internalise the diverse interest of corporate stakeholders.

Hence, in this paper we discuss the relevance and opportunities of developing a standardized methodology for assessing climate change transition together with physical risks in an integrated framework for a sufficiently large company population.

In Europe the reporting of climate change risks is going to be not only a norm, but a legal obligation from the 2024 financial year, with first reports to be published in 2025. The Corporate Sustainability Reporting Directive (CSRD) will require from 50,000 companies to disclose information on environmental and social impacts, including all large companies and all listed companies (except listed micro-enterprises).

In this paper we discuss the exposure of industrial companies to the two major categories of climate risks: (i) transition risks and (ii) physical risks.[3] Transition risks associate with the extent and speed at which an organization adapts to climate change, e.g. reduces greenhouse gas emissions and manages its transition to renewable energy. Physical risks stem from the physical impacts of climate change, including extreme weather events, such as heat waves and floods.

Physical risks can directly damage assets or indirectly harm production by causing supply chain disruption. Hence, physical risks may have financial implications for organizations. Rising temperature at work also increases the likelihood of heat-related illnesses and limit workers' productivity, especially due to workers' low risk perception of heat stress[4],[5].

Transition risks impact on firms indirectly by influencing investors' and clients' attitudes towards asset classes with different climate risk profile. Firms with the lowest climate transition risk exposures are found to perform better financially.[6].

The energy used to power people's lives and livelihoods and to fuel global trade and industry produces about three-quarters of global greenhouse gas (GHG) emissions. A well-managed retirement of energy generation plants with the largest global

Figure 1. Location of industrial company sites in the sample

warming potential and a massive scale-up in clean energy are essential to achieving the Sustainable Development Goals and the targets of the Paris Agreement.[7] In particular, the transition from fossil fuels to renewable power for heating and cooling is a cornerstone of the sustainable energy transition.

Companies will need to transition an increasing share of their energy generation to low emission alternatives such as solar to meet emission-reduction goals.[3] Furthermore, protective measures against flood risks for example can help reduce the extent of inundated areas as an effective adaptation strategy leading to substantially lower negative impact for firms.[8]

The significant novelty of this study is that it allows to understand and measure climate change risk exposure before reporting obligations become effective for a substantial number of companies, their investors and consumers.

To the best of our knowledge, this is the first study that integrates information from the major Pollutant Release and Transfer Registers covering more than 30 countries (AU, CA, EU27 + UK, IS, RS, NO, CH, US) on the company facility level (Table 2). Furthermore, we integrate further data from repositories on point-source greenhouse gas emissions.

About 10,000 foreign companies are expected to be required to report according to the EU CSRD rules, mostly from the Unites States (31%), Canada (13%), United Kingdom (11%), Japan (8%) and Australia (6%)[9]. All these countries are covered in this study except Japan. Companies subject to the CSRD will have to report according to European Sustainability Reporting Standards (ESRS).

The IEA points out that the private sector have to play a central role in the unprecedented levels of climate related investments. Beyond government incentives and regulations it is important to give a corporate level analysis how the losses and the gains investing in climate mitigation are distributed amongst the companies. Climate and environmental services are often regarded as public goods leading to over-exploitation or under-investments. If the gains are not borne by the potential financing companies it gives a rise to “free riding” strategies.

We show that climate change transition and physical risks are not correlated, therefore there are no winners and losers of climate change in general. The research contributes to the evolving landscape of climate risk management and highlights the need for standardized methodologies in the face of impending regulatory changes.

Results

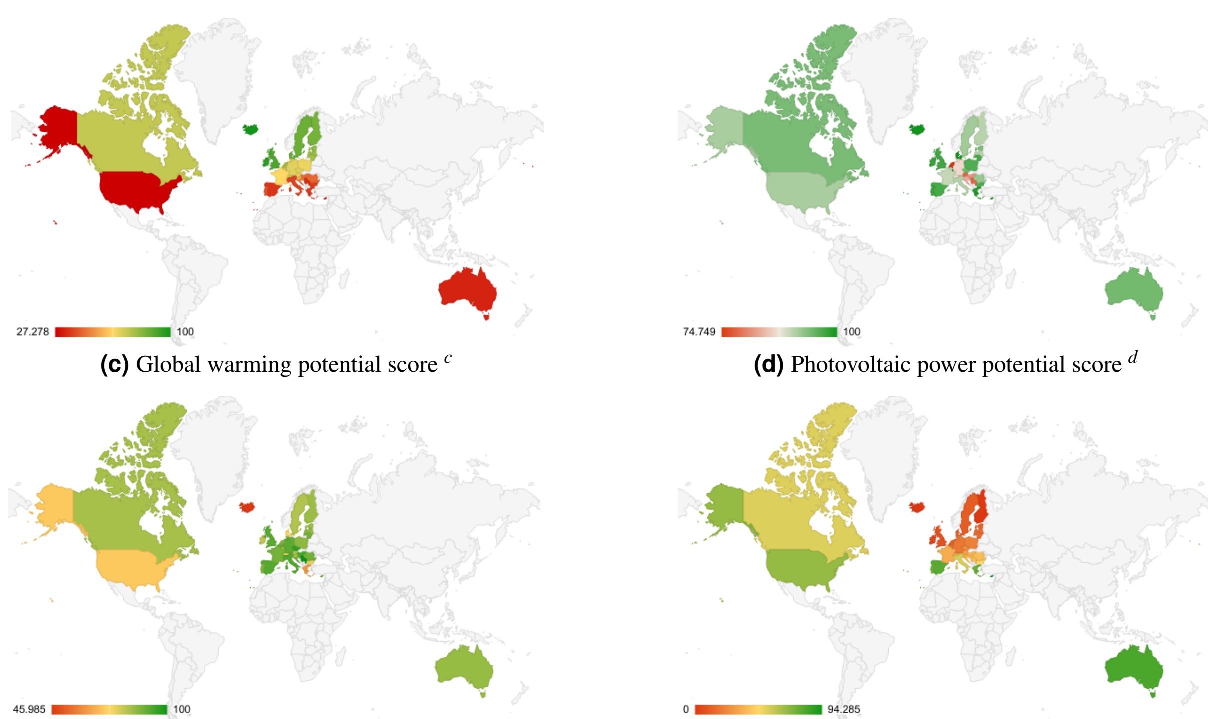
Climate change can impact on companies via several channels. The seriousness of consequences can be underestimated, if only the climate change transition risks from GHG emissions are calculated. The consequences from physical risks, for example from material damages to company properties, machinery or labour force, the related production, financial or reputational losses can be vast and are dependent on the location of company facilities.

Therefore, we calculated risks both in terms of global warming impact potentials and physical risks and opportunities (flood risk, heat risk and photovoltaic potential) of large industrial companies in Europe, in Northern America and Australia. Impact potentials are measured in terms of carbon dioxide equivalents (CO2eq) for the global warming potentials, flood risk in terms of the depth of historical water discharge (meter), heat risk in terms of cooling degree days (CDD) and renewable energy potentials at plants in terms of solar photovoltaic power potential (kWh/kWp).

Different climate change risk indicators cannot be directly compared, as they are measured on different scales and in different units. Hence, we also converted original values into normalized scores.

Figure 2 presents a geographic map of the investigated climate risks by country as average normalized scores. Green colour and higher score mean lower climate change risk, while yellow and red colour and lower score values mean higher risks.

Figure 2. Climate change transition risks and physical risks by country. Normalized values (0 - highest risk/lowest potential, 100 - lowest risk/highest potential, arithmetic mean of all reporting entities in the given country)



(a) CDD score [a]

(b) Flood score [b]

(c) Global warming potential score [c]

(d) Photovoltaic power potential score [d]

Notes:
[a] Heat risk scores are normalized (CDD) - Cooling Degree Days values.
[b] Flood risk scores are normalized flood risk values in meter (m).
[c] PV potential scores are normalized photovoltaic power potential values in kilowatthour/kilowattpeak (kWh/kWp).
[d] Global warming potential scores are normalized reported and calculated CO2 equivalents in tonnes.
The visualized score values for each country in the sample are the arithmetic mean for the reporting companies in the given country.
More detailed company plant level maps are presented in the Appendix.

Heat risk is estimated to be higher for firms in the US, in the Mediterranean countries of Europe and in Australia, while lower for firms located in Canada and Northern European countries (UK, Sweden, Norway). In the US the plants most exposed to heat risks are located in the South and Southern States, while in Europe in Spain and Italy.

On the continental level industrial firm locations in Central Europe have been most vulnerable to flood events in the past. More detailed visualisation on the plant level data reveals that there are several plants in Eastern States of the US which are exposed to higher level of flood risks. (See the detailed maps in the Appendix).

On average, the largest average global warming potential was calculated for industrial plants in Iceland, the United States, Denmark and Greece. Detailed maps in the Annex shows that CO2 emissions of industrial plants are concentrated in Central Europe, in the UK and Eastern America.

The photovoltaic potential is the highest in Australia and Spain, while the lowest in Northern Europe.

Correlation

Here we documented that there are differences in the exposure to different climate change risks at the country level. It is, however, an important issue of climate risk management, whether and to what extent different climate risks are interlinked and associated at the company plant level. Table 1 presents the correlations of indicator pairs by sample countries.

We found that correlations are in most cases low, in some cases indicator pairs are independent. This implies that there are no clear losers of climate change, some companies will be exposed more to heat risks, others to flood risks. The only exemption is presumably the relationship of heat risks and photovoltaic potential, for which the correlation is mostly positive and many cases above 0.3, which is a value that can be considered as a threshold for non-negligible correlation.

In Hungary (0.82), Spain (.61), Luxembourg (.58), Portugal (.52), Australia (.52), Czech Republic (.51), France (.51) were the calculated correlation ratios between the heat risk and photovoltaic potential at the company location the highest. Although, electricity can be transmitted, if the most productive geographical regions for solar energy generation are far away from the place of use, network infrastructure cost and transmission losses may increase costs of adaptation to climate change physical risks. Power loss and costs of renewable energy deployment can increase as a function of the power generated and the transmission distance.

Table 1. Pairwise correlation of plant level climate change indicators by countries

	countryCode	n	CDD_PV[a]	CDD_FL[b]	GHG_CDD[c]	GHG_FL[d]	GHG_PV[e]
1	LT	98	-0.80	0.10	0.00	0.09	-0.08
2	CY	62	-0.52		-0.42		0.21
3	BE	880	-0.50	0.06	-0.02	-0.01	-0.06
4	LV	60	-0.44	-0.33	0.04	-0.06	-0.07
5	EE	107	-0.37	0.20	0.17	-0.06	-0.05
6	GR	108	-0.32	0.00	-0.12	-0.04	-0.10
7	IE	466	-0.03	0.04	0.02	0.07	0.05
8	FI	646	-0.02	0.11	0.00	0.10	-0.02
9	HR	123	-0.00	0.07	0.01	-0.02	0.03
10	AT	357	0.06	0.00	0.06	-0.01	0.01
11	RS	174	0.10	0.11			
12	CA	7153	0.13	-0.00	-0.02	0.01	-0.01
13	NL	948	0.15	0.06	-0.07	-0.06	0.13
14	CH	235	0.16	0.16	-0.11	0.03	0.09
15	BG	195	0.20	0.09	0.11	-0.02	0.06
16	DK	282	0.25		-0.03		-0.10
17	PL	1488	0.31	0.03	0.03	-0.01	-0.01
18	DE	5421	0.37	0.11	0.06	0.01	-0.02
19	IT	4068	0.39	0.05	0.03	-0.01	0.08
20	GB	5381	0.40	0.09	-0.00	-0.00	-0.03
21	US	23215	0.41	-0.03	0.04	0.03	0.02
22	SE	604	0.45	-0.01	-0.16	-0.01	-0.14
23	SI	147	0.48	-0.13	-0.07	-0.02	-0.04
24	RO	745	0.48	0.07	0.03	-0.01	0.04
25	FR	3190	0.51	0.05	-0.00	-0.01	0.07
26	CZ	2681	0.51	0.04	0.02	-0.00	-0.07
27	AU	4519	0.52	0.02	0.10	-0.02	-0.14
28	PT	625	0.58	0.07	-0.09	0.12	0.12
29	LU	35	0.58		0.37		0.23
30	ES	4187	0.61	0.08	-0.06	0.01	-0.05
31	HU	821	0.82	0.05	-0.10	-0.01	-0.06
32	IS	19					
33	MT	18					0.07

Notes:
Normalized values were used to calculate correlation ratios.
[a]CDD_PV: Cooling Degree Days vs. Photovoltaic Power Potential
[b]CDD_FL: Cooling Degree Days vs. Flood Risk
[c]GHG_CDD: Global Warming Potential vs. Cooling Degree Days
[d]GHG_FL: Global Warming Potential vs. Flood Risk
[e]GHG_PV: Global Warming Potential vs. Photovoltaic Power Potential

Data & Methods

Our methodology and empirical analysis are based on two types of data sources: (i) on siloed plant level pollution registers, (ii) on historical data from Geographic Information Systems on physical risks and opportunities (heat risk, photovoltaic power potential and flood risk). We relate these information sources to calculate different types of climate risk measures at the company plant level.

Data

Our company location and global warming potential data is retrieved from Pollutant Release and Transfer Registers and greenhouse gas reporting repositories in more than 30 countries (Australia, Canada, European Union (EU) Member States and further EU neighbouring countries reporting to the European Pollutant Release and Transfer Register, United States) (Table 2). These registers contain annually aggregated emission data by company plants. We used the 2019 observations for our analysis due to delays in reporting.

The Protocol on Pollutant Release and Transfer Registers (PRTRs) was agreed on by international parties to register environmental footprints across regions and times. PRTRs are increasingly used as a fundamental data source for corporate environmental footprint research,[10],[11],[12],[13].

The European Industrial Reporting dataset of the European Environment Agency (EEA) contains the location and administrative data for the largest industrial complexes in Europe, releases of regulated substances to all media reported under the European Pollutant Release and Transfer Register (E-PRTR) and as well as more detailed data on energy input and emissions for large combustion plants (reported under the Industrial Emissions Directive Art.72). The E-PRTR reporting covers 91 key pollutants including greenhouse gases.

The US Environmental Protection Agency (EPA)'s PRTR repository is called Toxic Release Inventory (TRI). The EPA collects information on greenhouse gases separately from other pollutants. Large emitters report these under the Greenhouse Gas Reporting Program (GHGRP). The EPA aggregates the GHGRP information and publishes data via the Facility Level Information on Greenhouse Gases Tool (FLIGHT). To merge the TRI and FLIGHT databases for our analysis we used the Facility Registry Service Id (FRSID) of EPA, which was available in both the TRI and FLIGHT datasets.

Table 2. Company location and greenhouse gas data sources of the study by institution, reporting program and country

Institution	Reporting program, database	Country
European Environment Agency	EU Pollutant Release and Transfer Register	European Union
Environmental Protection Agency	Toxic Release Inventory	Unites States
Environmental Protection Agency	Greenhouse Gas Reporting Program	Unites States
Australian Government	National Pollutant Inventory	Australia
Government of Canada	Greenhouse Gas Reporting Program	Canada, United States
Clean Energy Regulator	National Greenhouse and Energy Reporting	Australia
Australian Government	National Pollutant Release Inventory	Australia

Abbreviations of institutions, programs and databases
European Environment Agency (EEA)
Environmental Protection Agency (EPA)
Toxic Release Inventory (TRI)
Facility Level Information on Greenhouse Gases Tool (FLIGHT)
National Pollutant Inventory (NPI)
Clean Energy Regulator (CER)
National Greenhouse and Energy Reporting (NGER)
Greenhouse Gas Reporting Program (GHGRP) - There are two separated programs with identical program names for Canada and the United States.
National Pollutant Release Inventory (NPRI)

The National Pollutant Inventory (NPI) is the Australian PRTR tracking pollution, and ensuring transparency and public access to information. Under the Australian National Greenhouse and Energy Reporting (NGER) Scheme, corporations that meet certain thresholds must also report to the Clean Energy Regulator (CER) their emissions, energy production and energy consumption each financial year. For our research the 'facilityid' field has been used to merge the Australian NPI and NGER datasets.

The National Pollutant Release Inventory (NPRI) is Canada's public inventory of pollutant releases, disposals and transfers. It tracks over 300 pollutants from over 7,000 facilities across Canada. The Canadian Greenhouse Gas Reporting Program (GHGRP) collects information on greenhouse gas (GHG) emissions annually from facilities across Canada. It is a mandatory program for those who meet the requirements. Furthermore, facilities that emit 10 kilotonnes or more of GHGs, in carbon dioxide (CO2) equivalent (eq.) units, per year must report their emissions to Environment and Climate Change Canada. The

’NPRIID’ has been used to merge the Canadian NPRI and GHGRP databases. The ’NPRIID’ is a unique National Pollutant Release Inventory identifier.

Our final database covered almost 70,000 plant locations in the reporting countries. The coordinates of plants (latitude, longitude) were used to collect information on climate change physical risks. By using the exact coordinates our analysis can provide more accurate climate risk assessment than studies using addresses of firm headquarters which do not identify locations precisely.[8]

Table 3. Coordinate level climate risk information sources

Physical risks and opportunities	Data source	Resolution
Heat risk	Global Land Data Acquisation System	25 km
Flood risk	Joint Research, Centre	1 km
Photovoltaic power potential	The World Bank Group	1 km

The source of the company plant heat risk information was based on geographic sampling the historical information systems of the globe. Our input cooling degree days map was originally computed using meteorological parameters from the Global Land Data Assimilation System (GLDAS) ver. 2 (@ 0.25 degree global gridded resolution).[14] The cooling degree dataset covers 49 years over the period 1970-2018.

The source of flood risk data was the Joint Research Center’s long-term dataset of river discharges in the Global Flood Awareness System (GloFAS).[15] Flood risk values indicate water depth (in m) from river discharges. All flood-prone areas are then merged by the Joint Research Centre to create continental flood hazard maps for different return periods at 30” resolution (approximately 1 km at the Equator).

The World Bank Group’s Global Solar Atlas was used to sample photovoltaic power potential at company plants, more precisely the average daily total photovoltaic power potential (PVOUT) in kWh/kWp 1 kWp free-standing PV system at optimum tilt at the company locations. The clear-sky irradiance calculated is coupled with the cloud index to retrieve the all-sky irradiance values. The resolution of solar resource data is 30 arcsec (nominally 1 km).

Methods

In this study global warming impact potentials (GWP) in carbon dioxide equivalents (CO2eq) of direct point-source pollutant releases are analyzed. In some of the countries in our sample, the GWP information is calculated and provided by the authorities (CA, US and AU).

$$GlobalWarmingPotential(GWP) = \sum_i E_i \times GWP_i \tag{1}$$

For the EU+ countries the European Environment Agency (EEA) publishes releases by pollutant in the European Pollutant Release and Transfer Register (E-PRTR), which can be used to calculate impact potentials. Here, the GWP has been calculated as recommended by the Intergovernmental Panel on Climate Change (IPCC). The emissions in kilograms of substances (i) in the E-PRTR have been multiplied by their global warming potential value factors, and aggregated across all substances (Equation 1). Six air pollutants are classified in the E/PRTR as GHGs, similarly to the Kyoto Protocol, i.e. Carbon dioxide (CO2), Methane (CH4), Hydro-fluorocarbons (HFCs), Nitrous oxide (N2O), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6).

Geographic sampling was applied to collect climate change physical risk values from multiple layers at specified company plant location sampling points from the thematic maps detailed in the previous subsection on data.

Normalized values of the four climate change physical risk indicators values (Table 4) were calculated as percentile ranks so as to lessen the problem of outliers[16]. To generate sector agnostic scores the normalized values were calculated in relation to all peers regardless of the industry.

Discussion

There are obstacles to the geographic sampling and overlaying method we proposed here to calculate climate change physical risks. One obstacle of our approach is that not all companies are covered by the registers we used. Another obstacle to precise calculations is that PRTR databases do not register emissions below reporting thresholds. Reliability of data could be affected by the errors of facility location reporting.

The resolution of the geographic information systems we used for our assessment is also limited. This can increase the uncertainty of geographic sampling, calculations and limit precise judgements in some cases. The resolution of the historical flood information was approximately 1 km. In flood risk management few hundred meters can make significant difference in terms of flood vulnerability, since elevation, dams or other built and natural barriers can create conditions that the flood risk significantly varies within a 1 km X 1 km geographic cell.

We draw attention of the readers that some industries are not covered by our analysis, because PRTRs and greenhouse repositories cover usually point-source emissions, but not diffuse emissions from for example agricultural activities or transportation.[17]

The usability of our methodology could be further enhanced by using real-time or projected information on climate change risks. Integration of additional indicators like the estimations of other risks like extreme weather events or further categories of renewable energy (tidal, geothermic, wind, etc.) could lower the uncertainty of our estimations.

The precision of our methodology at the company level for environmental assessment or rating is hindered by the well-known problems of company registers. For example, reporting on company ownership or business activity is not mandatory, hence aggregation of climate risk is not always possible at the final parent company level. Consequently, requirement of reporting parent company, business activity information could help increase the usability of the PRTRs for environmental rating.

When merging the Toxic Release Inventory and GHG databases of the US Environmental Protection Agency, we recognized that the relation of FRSIS and TRIID is 1:m, there have been more TRIID for the same FRSID. There are 114 FRSIDs where at least 2 facilities report with different TRIIDs to the TRI. In such cases, we have loaded GHG observations for all records of FRSIDs, even if the TRIID was different. This implies double counting for about 0.2% of the sample, the readers have to be aware of. Reallocation of GHG data could be possible if the entities reported the allocation of GHG between different TRIFDs.

Summary

This research paper introduces a novel methodology for the integrated assessment of climate change transition and physical risks associated with industrial plants across Europe, Northern America, and Australia. As global governments align reporting regulations with climate-related financial disclosure recommendations, the study becomes crucial for understanding and measuring key aspects of climate risks. Analyzing data from 70,000 plants reporting to Pollutant Release and Transfer Registers and Greenhouse Gas Reporting Programs, the research measures transition risks through reported greenhouse gas emissions and physical risks through historical cooling energy needs, flood exposure, and photovoltaic power potential. The study's pioneering approach, integrating information from major international registers, offers valuable insights into climate risk exposure before reporting obligations become legally mandated for a substantial number of companies. Notably, the research uncovers a lack of strong correlation between climate change transition and physical risks, emphasizing the challenges in managing global climate change risks. As climate-related financial disclosure becomes a universal norm, this research contributes to the evolving landscape of climate risk management and underscores the importance of standardized methodologies in the face of impending regulatory changes.

References

1. Bingler, J. A., Kraus, M., Leippold, M. & Webersinke, N. Cheap talk and cherry-picking: What climatebert has to say on corporate climate risk disclosures. *Finance Res. Lett.* **47**, DOI: 10.1016/j.frl.2022.102776 (2022).

2. Principale, S. & Pizzi, S. The determinants of tcfd reporting: A focus on the italian context. *Adm. Sci.* **13**, DOI: 10.3390/admsci13020061 (2023).

3. on Climate-related Financial Disclosures, T. F. Recommendations of the task force on climate-related financial disclosures (2017).

4. Simane, B. *et al.* Occupational heat stress in the floriculture industry of ethiopia: Health risks and productivity losses. *Health* **14**, DOI: 10.4236/health.2022.142020 (2022).

5. Bonafede, M. *et al.* Workers' perception heat stress: Results from a pilot study conducted in italy during the covid-19 pandemic in 2020. *Int. J. Environ. Res. Public Heal.* **19**, DOI: 10.3390/ijerph19138196 (2022).

6. Reboredo, J. C. & Ugolini, A. Climate transition risk, profitability and stock prices. *Int. Rev. Financial Analysis* **83**, DOI: 10.1016/j.irfa.2022.102271 (2022).

7. Bank, W. Energy transition and universal access (2021).

8. Fatica, S., Katay, G. & Rancan, M. *Addressing physical climate risk: the case of flood protection* (2023).

9. Holger, D. At least 10,000 foreign companies to be hit by eu sustainability rules. *Wall Str. J.* (2023).

10. Sörme, L., Palm, V. & Finnveden, G. Using E-PRTR data on point source emissions to air and water-first steps towards a national chemical footprint. *Environ. Impact Assess. Rev.* **56**, 102–112, DOI: 10.1016/j.eiar.2015.09.007 (2016).

11. DeVito, S. C., Keenan, C. & Lazarus, D. Can pollutant release and transfer registers (PRTRs) be used to assess implementation and effectiveness of green chemistry practices? a case study involving the toxics release inventory (TRI) and pharmaceutical manufacturers. *Green Chem.* **17**, 2679–2692, DOI: 10.1039/c5gc00056d (2015).

12. Strezov, V., Zhou, X. & Evans, T. J. Life cycle impact assessment of metal production industries in Australia. *Sci. Reports* **11**, DOI: 10.1038/s41598-021-89567-9 (2021).

13. Erhart, S. & Erhart, K. Environmental ranking of european industrial facilities by toxicity and global warming potentials. *Nat. Sci. Reports* DOI: https://doi.org/10.1038/s41598-022-25750-w (2023).

14. Mistry, M. N. A high-resolution (0.25 degree) historical global gridded dataset of monthly and annual cooling and heating degree-days (1970-2018) based on GLDAS data, DOI: 10.1594/PANGAEA.903123 (2019). Supplement to: Mistry, MN (2019): Historical global gridded degree-days: A high-spatial resolution database of CDD and HDD. Geoscience Data Journal, https://doi.org/10.1002/gdj3.83.

15. Dottori, F. *et al.* Development and evaluation of a framework for global flood hazard mapping. *Adv. Water Resour.* DOI: 10.1016/j.advwatres.2016.05.002 (2015).

16. OECD-JRC. Handbook on constructing composite indicators, methodology and user guide. (2008).

17. OECD. Guidance document on elements of a prtr: Part i. *"Series on Pollut. Release Transf. Regist.* (2014).

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Author contributions statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, methodology, software, data curation, writing, original draft preparation, visualisation.

K.E. participated in the conceptualization, background database construction and curation.

S.E. participated in the conceptualization and formulation of research, analyzed and visualized the results and wrote the main manuscript text. All authors discussed the results and contributed to reviewing the manuscript. S. Sz. participated in the conceptualization and formulation of research, analyzed and visualized the results and wrote the main manuscript text.

All authors discussed the results and contributed to reviewing the manuscript.

Additional information

The authors declare that they have no competing interests.

Data availability

The study is based on publicly available data sources as discussed in the data section. Furthermore, the tables in the study will be publicly available in the Mendeley repository upon publication of the study.

Erhart, Szilárd (2022), “XXX”, Mendeley Data, V1, doi: xxxxxxxxxxxxxxx

Appendix

Descriptive statistics

There are almost 70,000 plants in our sample (Table 4). Cooling degree days (CDD), our heat risk measure varies in the range of 0 and 3,904 CDD calculated from the historical data in the period 1970-2018.[14]

Flood risk minima and maxima was 0 meter and 30 meters, respectively.

Table 4. Descriptive statistics

Statistic	N	Mean	St. Dev.	Min	Max
Heat risk (CDD) [a]	69,028	397	491	0	3,904
Flood risk (m) [b]	69,028	0.4	2.1	0.0	30.0
PV potential (kWh/kWp) [c]	69,028	3.6	0.8	0.0	5.6
GHG (CO2eq tonnes) [d]	69,028	66,852	495,241	0	32,700,000

Notes:
[a] Heat risk (CDD) - Cooling Degree Days
[b] Flood risk (m) - meter
[c] PV potential (kWh/kWp) - kilowatthour per kilowattpeak
[d] GHG (CO2eq tonnes) - CO2 equivalent in tonnes

Figure 3. Flood exposure of industrial company sites in the sample in meter

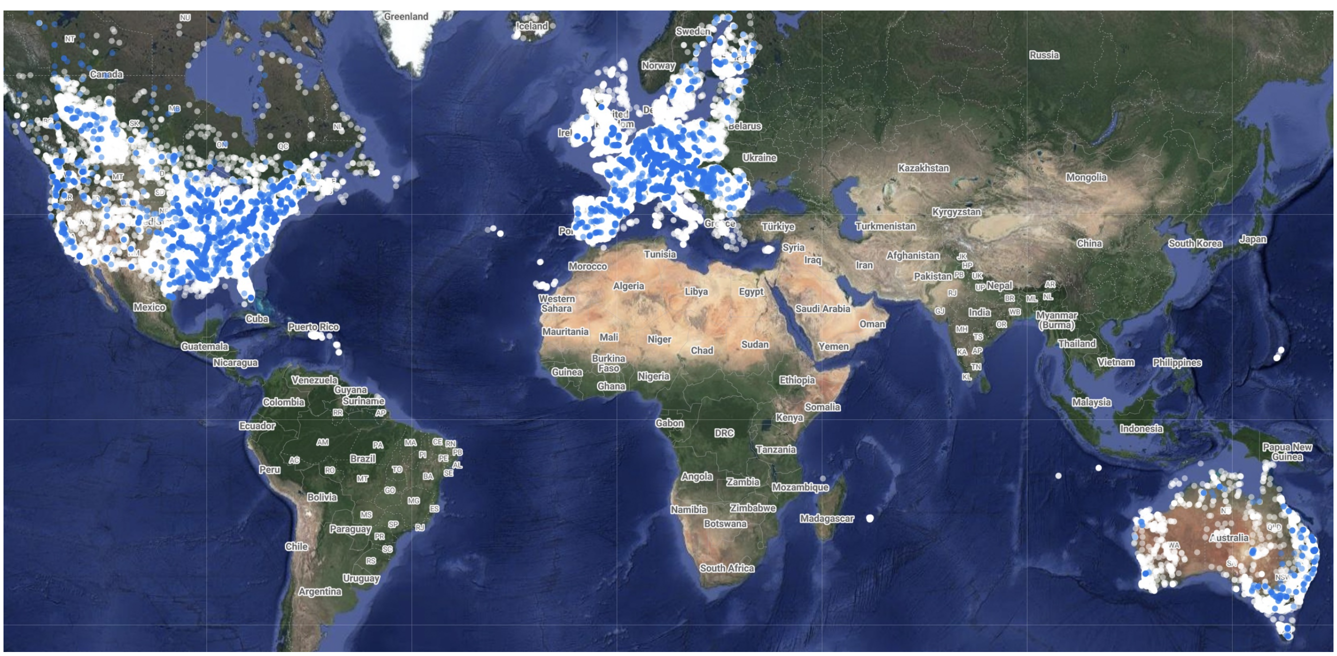

Figure 4. Photovoltaic potential of industrial company sites in the sample in KWh/h

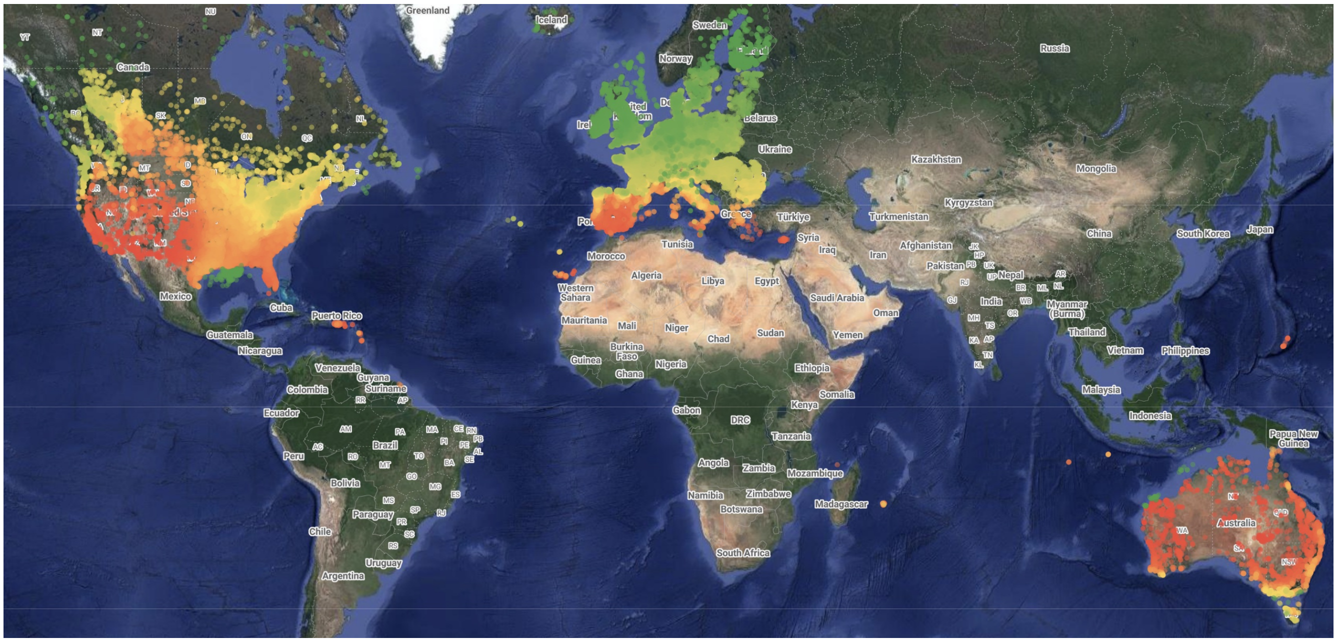

Figure 5. Greenhouse gas emission of industrial company sites in the sample in CO2 equivalents

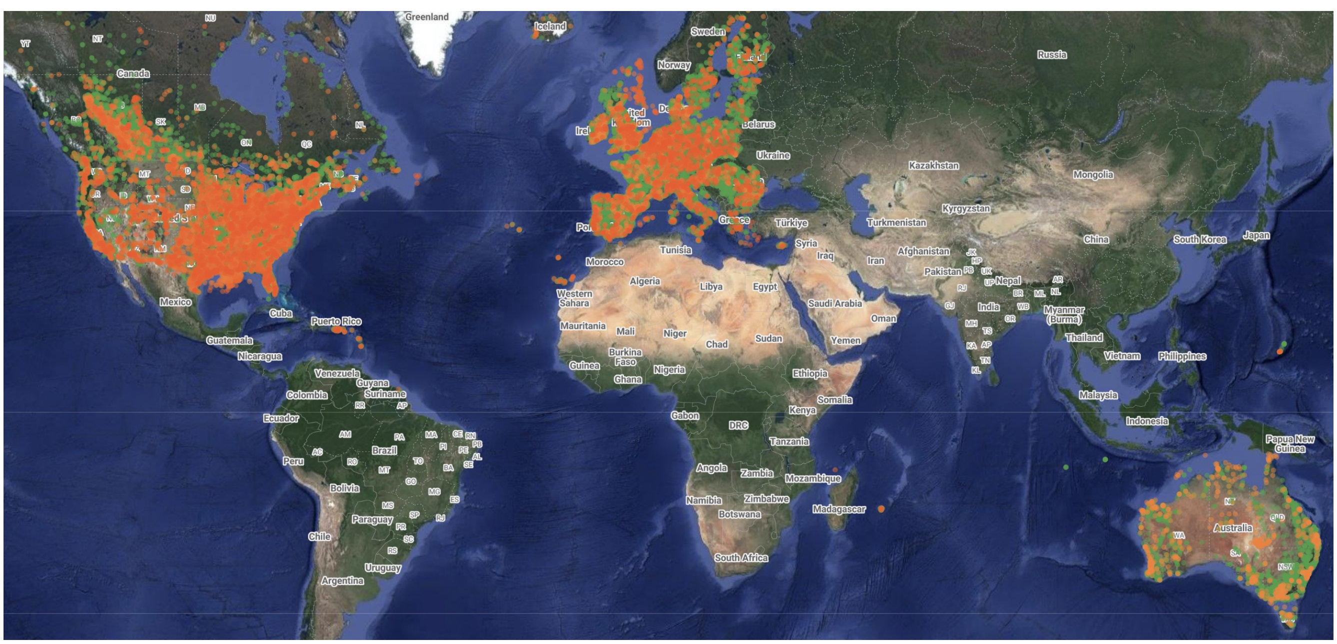

Figure 6. Heat risk of industrial company sites in the sample in Cooling Degree Days