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ENVIRONMENTAL INEQUALITY IN EUROPE

Towards an environmental justice framework for Austria in an EU context

Liesbeth de Schutter, Hanspeter Wieland, Burcu Gözet, Stefan Giljum

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UMWELTBEZOGENE UNGLEICHHEIT IN EUROPA

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VORWORT

Die Diskussion zu umweltbezogener Ungleichheit und Umweltgerechtigkeit thematisiert komplexe empirische, theoretische und politische Fragestellungen. Zunächst geht es um die Verfügbarkeit und Analyse einschlägiger Daten: Welche Aussagen lassen sich über die Ungleichverteilung von Umweltbelastungen und -ressourcen auf der Grundlage empirischer Evidenz treffen? Dann gilt es, diesen Status quo gerechtigkeitstheoretisch zu reflektieren: Welche normativen Vorstellungen gibt es über eine gerechte Verteilungssituation in Umweltfragen? Und schließlich sind daraus politische Schlussfolgerungen abzuleiten: Mit welchen Instrumenten lässt sich die Verteilungslage umweltschonend verbessern?

In Europa war der Zusammenhang zwischen kleinräumiger Umweltqualität, sozialer Ungleichheit und Gesundheit ein wichtiger Ausgangspunkt für Maßnahmen der öffentlichen Gesundheitsvorsorge und der Stadtplanung. Mit strengeren Umweltgesetzen und Bauvorschriften ist es um diesen Problemzusammenhang im Laufe des 20. Jahrhunderts ruhiger geworden. Angesichts der rasanten Wohlstandsmehrung hatten diese gesundheitspolitischen Fragen zumindest an Dringlichkeit eingebüßt. Seit der Jahrtausendwende werden aber – vielfach in Anlehnung an die US-amerikanische Diskussion zu *Environmental Justice* – umweltbezogene Ungleichheiten auch in Europa wieder häufiger problematisiert.

Wie in der US-amerikanischen Diskussion liegt der Fokus in Europa heute erneut auf kleinräumigen Fragestellungen: Wo ist die Luftqualität besonders schlecht, die Lärmbelastung besonders hoch, die Ausstattung mit Grünflächen mangelhaft – und welche Gruppen sind davon betroffen? Das spiegelt auch die Literaturauswertung in der vorliegenden Studie wider. Klar ist allerdings, dass das nur ein Aspekt im breiten Diskursfeld zu Umwelt, Verteilung und Gerechtigkeit ist. Angesichts der klimapolitischen Herausforderungen wird zukünftig beispielsweise verstärkt zu untersuchen sein, wie die Zusammenhänge zwischen Emissionen, klimapolitischen Maßnahmen und Einkommen beschaffen sind.

Im Unterschied zu anderen europäischen Staaten steckt die Diskussion zu Umwelt und Gerechtigkeit in Österreich noch relativ in den Anfängen. Die Arbeiterkammer ist seit rund zwei Jahren darum bemüht, diese Diskussion in Kooperation mit anderen Organisationen zu intensivieren – und damit die Forderung „Gerechtigkeit muss sein“ auch in umweltpolitischen Fragen sichtbarer aufzugreifen. Nach Themenschwerpunkten in AK-Publikationen und einer Kooperationsveranstaltung mit dem ÖKOBÜRO und der Armutskonferenz ist die vorliegende Studie ein weiterer Beitrag dazu. Vertiefende Analysen zur Verbesserung der empirischen Evidenz in Österreich sind für das Jahr 2018 geplant.

Florian Wukovitsch (AK Wien)

Wien, im Dezember 2017

DEUTSCHE KURZFASSUNG

Viele Umweltbelastungen – wie Luftschadstoffe – konnten in Europa durch strengere Umweltgesetze in den letzten Jahrzehnten reduziert werden. Das sagt allerdings nichts über die Verteilung von Umweltbelastungen aus, tatsächlich kann die umweltbezogene Ungleichheit bei allgemein sinkenden Belastungswerten sogar zunehmen. So zeigt sich beispielsweise in Städten oftmals das Phänomen doppelt begünstigter – in Bezug auf Einkommen und Umweltbedingungen – bzw. doppelt benachteiligter Bevölkerungsgruppen. Umweltbezogene Ungleichheit ist insofern eng mit sozialer Ungleichheit verbunden. Bei globaler Betrachtung spiegeln das nicht zuletzt auch die Umwelteffekte wider, die europäische Produktions- und Konsummuster anderswo verursachen.

Neben einer verbesserten empirischen Evidenz ist auch eine konzeptionelle Klärung nötig. Obwohl die Diskussion zu *Umweltgerechtigkeit (environmental justice)* und *umweltbezogener Ungleichheit (environmental inequality)* bereits eine längere Tradition hat, werden die Begriffe nicht trennscharf verwendet. *Umweltbezogene Ungleichheit* im Sinne der Studie kann empirisch gemessen und beschrieben werden, sie bezieht sich auf den Status quo. Mit *Umweltgerechtigkeit* ist demgegenüber gemeint, wie die Situation sein sollte – beispielsweise ausgedrückt in einem Recht auf eine saubere, gesunde und sichere Umwelt. Diese normativen Vorstellungen werden einerseits vom sozialen und politischen Kontext bestimmt, variieren aber auch zwischen Individuen und Gruppen innerhalb von Gesellschaften.

Vor diesem Hintergrund hat die Studie drei Schwerpunkte:

1. Zunächst werden die Ergebnisse empirischer Studien und Berichte zusammengefasst, um die wichtigsten Muster umweltbezogener Ungleichheit in Europa zu identifizieren; zu diesem Zweck wurden insgesamt 81 Dokumente ausgewertet.
2. Anschließend erfolgt ein kurzer Überblick über die wichtigsten Methoden und Datenbanken zur Untersuchung von umweltbezogener Ungleichheit.
3. Zuletzt wird – im Sinne von Umweltgerechtigkeit – für den europäischen bzw. österreichischen Kontext ein konzeptioneller Rahmen für Verfahren zur Realisierung einer gesunden und gerechten Umwelt innerhalb ökologischer Grenzen entwickelt.

Verteilungswirkungen von umweltpolitischen Maßnahmen, die in Europa ebenso im Rahmen der Diskussion zu Umwelt und Verteilungsgerechtigkeit thematisiert werden, können aufgrund beschränkter Ressourcen in dieser Studie nicht berücksichtigt werden.

Ad 1: *Umweltbezogene Ungleichheit* wird in der Studie in drei Dimensionen beschrieben:

a. Zugang zu Ressourcen zur Erfüllung grundlegender Bedürfnisse: Diese reichen vom Zugang zu Nahrungsmitteln, Wasser und Energie bis zu leistbarem Wohnraum, Grünräumen sowie öffentlichen Infrastrukturen wie insbesondere öffentlichem Verkehr. Von einer mangelhaften Versorgung sind vor allem Minderheiten auf dem Land und einkommensschwache Gruppen betroffen.

b. Belastung durch Umweltverschmutzung: Luftverschmutzung ist der verbreitetste Faktor für umweltbedingte Ungleichheit in Europa. Sie ist – wie Lärm, der zweitwichtigste Faktor – meist auf Verkehr zurückzuführen, entsteht daneben aber auch durch Industrieanlagen und Müllplätze bzw. insbesondere in Zentral- und Osteuropa auch durch Kohlekraftwerke.

c. Klimawandel und Naturgefahren: Diese Dimension umfasst Hitzestress, Hochwasser und Wetterextremereignisse, die vor allem in Städten, im Bergland und überflutungsgefährdeten Regionen gehäuft vorkommen. Betroffene sind insbesondere ältere Menschen, einkommensschwache Personengruppen auf dem Land und nicht-versicherte Personen.

Die konkrete Betroffenheit hängt nicht nur von der Exposition, sondern auch von der individuellen Anfälligkeit aufgrund weiterer Faktoren wie Wohnbedingungen und Ressourcen ab. Diese vermitteln zwischen Exposition und Wirkung und ergeben für unterschiedliche Gruppen – wie einkommensschwache (städtische) Haushalte, die (arme) Bevölkerung in bestimmten ländlichen Regionen, Kinder, ältere Menschen oder bestimmte Gruppen von Erwerbstätigen – konkrete Betroffenheitsmuster. Umweltbezogene Ungleichheit umfasst also vielfältige Dimensionen und Mechanismen auf unterschiedlichen räumlichen Ebenen. Entsprechend vielfältig sind auch die empirischen Muster umweltbezogener Ungleichheiten in den betrachteten europäischen Staaten.

Ad 2: Der Fokus des Überblicks über Methoden und Datenbanken liegt auf der Dimension „Belastung durch Umweltverschmutzung", da diese im europäischen Kontext am häufigsten untersucht wird. Dabei stehen unterschiedliche Ansätze zur Verfügung, die sich grob in räumliche und nicht-räumliche einteilen lassen. Die Mehrzahl der Studien beruht auf räumlichen Ansätzen. Als Beispiele für relevante Datenquellen werden die strategischen Lärmkarten, das Europäische Schadstoff-Freisetzungs- und Verbringungsregister (E-PRTR) sowie raumbezogene Daten aus Geoinformationssystemen (GIS) angeführt. Sozioökonomische bzw. demographische Daten können von den nationalen Statistikämtern bezogen werden. Die Datenverfügbarkeit für Österreich ist prinzipiell gut.

Zusätzlich werden multi-regionale Input-Ouput-Analysen (MRIO) vorgestellt, mit denen globale Verteilungsmuster der Aneignung von Ressourcen und der Auslagerung von Umweltbelastungen analysiert werden können. Auch wenn diese Methoden noch selten in einen Zusammenhang mit der europäischen Diskussion zu umweltbezogener Ungleichheit gebracht werden, lassen sich damit die globalen Auswirkungen der europäischen Wirtschafts- und Lebensweise immer besser darstellen.

Ad 3: Den Abschluss der Studie bilden Überlegungen, wie Umweltgerechtigkeit in einem europäischen Kontext befördert werden kann. Ausgangspunkt können dabei sowohl wissenschaftliche Erkenntnisse als auch subjektiv empfundene Ungleichheiten oder manifeste Konflikte sein. In jedem Fall gilt es, zunächst das Problem zu identifizieren und die Betroffenheit bestimmter Gruppen nachzuweisen. Anschließend ist gemeinsam mit Stakeholdern der Problemzusammenhang aufzudecken; darauf aufbauend können sozial-ökologische Lösungsansätze entwickelt werden. Dabei ist gleichermaßen auf prozedurale Gerechtigkeit – also gerechte Verfahren – wie auf distributive Gerechtigkeit auf der Grundlage empirischer Evidenz zu achten.

Im Unterschied zu den USA geht es in Europa weniger um rechtliche Aspekte zur Verhinderung von Diskriminierung, als um die Weiterentwicklung sozialpolitischer Maßnahmen bzw. die sozialpolitische Einbettung von Umweltpolitik, um die Triebkräfte umweltbezogener Ungleichheit zu entschärfen. Neben der Förderung gesunder Wohnumgebungen lassen sich mit dem vorgeschlagenen Konzept auch globale Ungleichheiten in konstruktiver Weise diskutieren.

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We hope the report encourages to look through the lens of environmental justice to see that inequality needs a social-ecological perspective.

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Vienna, 15.09.2017

Summary

Introduction

Environmental pressures within the EU show a decreasing trend in a growing number of fields, for example air pollution. However, environmental inequality among social groups within the EU is a persistent problem that can increase under decreasing average pollution levels. Whether or not this is the case has not yet been researched in a consistent approach at the EU or Member State level. Environmental inequality, in this report, is shown to be associated with growing social inequalities, for example in income, wealth, housing, and access to public amenities in the living environment. Furthermore, urbanisation, leading to hotspots of high population numbers and (coupled) environmental burden, tends to lead to areas where people either enjoy the 'double blessing' of a higher income in a high quality environment, and 'double burden' areas where vulnerable groups tend to be exposed to more polluted environments. Finally, environmental inequalities at the global level are increasingly associated with displacement of environmental pressures in relation to European production and consumption patterns.

Although the terms environmental justice and environmental inequality are often used interchangeably in the literature, they do have distinct meanings. **Environmental inequality (EI) describes the situation how things are** and refers to the unequal distribution of environmental risks and hazards and access to environmental goods and services among societal groups. In general EI can be empirically measured and described. **Environmental justice (EJ) refers to how things ought to be**, for example: "everyone has the right to a clean, healthy, and safe environment in which to live, work, go to school, and play". EJ is thus closely related with the normative value system in the social-political context and is complicated by the fact that justice principles differ among individuals and social groups within societies. As a result, distributive EI is interpreted differently by social groups and can end up in hard to resolve EJ conflicts at the local level.

In research, a growing number of disciplines have started to investigate issues of environmental inequality and environmental justice. Public health researchers, in particular, explore exposures to environmental pollution as a major contributing factor to the production of health inequities. Interdisciplinary approaches, such as in ecological economics, explore environmental inequalities from multiple levels, i.e. the micro-, the meso- and the macro-level in society, aiming at revealing quantitative patterns and causal relations explaining the social production of environmental inequalities, based on an understanding of the interrelated social and ecological system. This report reviews empirical patterns of EI in the EU by a review of existing research from different disciplinary perspectives, and suggests to understand EJ as an overarching approach to move from a situation of EI (distributive problem) to a healthy and just living environment within environmental limits (procedural justice).

Objectives of this report

The objectives of this study were threefold. First, to review empirical papers and official reports on environmental inequality in the European context to identify major issues and potential patterns of environmental inequality in the EU. Second, to give an overview of the main methods and databases to perform studies on environmental inequality. Finally, to review theory underlying EJ and to develop a framework to identify and to support procedural justice aiming at a reduction in environmental inequality (distributive justice) in the living environment in an EU – and Austrian – policy context. The report does not

include research on distributional outcomes of environmental policies – which is recognised as a crucial link in the European context, but outside the scope and budget for this report.

Environmental inequality in the European context

The literature search and review of empirical papers and official reports on EI in the European context involved 81 empirical papers and reports. These were subject to a structured analysis of the spatial scale, the research question or hypothesis, the applied method and the results, including the uncertainty in the evidence of EI. This allowed getting an understanding of important issues – and potential EI hotspots – in relation to EJ in the European context.

Based on the literature review, potential patterns of EI have been identified in relation to three main dimensions, each having a distinct relation to production and consumption activities in the EU context: (A) **Access to resources** supporting the fulfilment of basic needs, of which the most important are resources such as food, water, energy and affordable (social) housing, as well as access to green spaces and public amenities such as transport systems. Rural minorities and other low income groups are most affected by limited access to resources, in combination with generally poor housing quality. That accumulates the impacts on health and leads to multiple deprivations such as cold stress and poor nutritional quality for the most vulnerable social groups. (B) **Burden of pollution:** Pollution, in particular air pollution, creates the most widely distributed environmental inequality in the European context; mainly related to traffic in urban areas but also to industrial facilities and waste sites. In CEE-countries, air pollution is also associated with coal-based energy grids. Noise pollution is closely related to traffic sources. (C) **Climate change and natural hazard risk.** The third dimension points at inequalities in the distribution of the adverse climate impacts related to economic activities. Heat, floods and other adverse weather impacts show patterns of increasing frequency in urban centres, mountainous and flood-prone areas, where elderly, rural poor and uninsured people, often related to socio-political contexts, are most affected by property losses, heat stress and related health impacts, including mortality.

Next to the three 'A-B-C' dimensions, environmental inequality can be distinguished by three interrelated mechanisms: (1) **environmental exposure,** including differential exposure, i.e. the fact that disadvantaged and/or vulnerable groups are more often exposed to higher levels of environmental pollution, (2) **Social susceptibility**, including differential susceptibility where disadvantaged or vulnerable groups often are more susceptible to adverse environmental exposure. Susceptibility is often related to poor housing conditions, neighbourhoods with poor environmental quality and to a lower development level in terms of capabilities (Preisendörfer, 2014). Finally, exposure and susceptibility together determine the actual **social impact** (3). Impacts mainly involve health impacts or other, often multiple forms of deprivation at the level of the *affected social group,* which is not always the lowest income group, but may concern children, elderly, unemployed, or workers in less developed countries among others. The following table summarises the dimensions and mechanisms of EI as identified in this report.

Dimensions and mechanisms of Environmental Inequality

EI Dimension: **EI mechanism:**	**Access to resources**	**Burden of Pollution**	**Climate change & natural hazard risk**
1. Exposure	Poor access to public and other basic services	Emissions Noise Siting patterns	Heat Floods Land-slides

			Snow avalanches
2. Susceptibility	Rural areas Poor housing quality Capabilities	Poor housing quality Poor neighbourhood quality Commuter patterns Individual factors Capabilities	Urban centres Poor housing quality Area-specific (flood-plains) Capabilities
3. Social impact	Health Deprivation Isolation Time	Health Deprivation	Heat stress/ health Property damage Deprivation Death
Affected group	*Rural minorities* *Rural poor* *Carless people*	*Low income groups* *Children, Immigrants* *Low education* *Unemployed* *Global South*	*Elderly* *Rural poor* *Farmers* *Uninsured* *Global South*

We conclude that environmental inequality is a complex problem involving multiple dimensions and mechanisms at different spatial levels, which are often intertwined. For example, noise pollution often comes together with traffic related air pollution, industrial siting is associated with air pollution, noise pollution, energy- and material use, waste flows and global climate change. As a result, there is an emerging notion of potential risks related to the loss of causal relations in the explanatory framework that drive patterns of EI, as well as to the phenomenon of cumulative impacts (multiple simultaneous impacts). Several countries in the EU show evidence of multiple environmental inequalities, in particular the UK, Germany, the Netherlands, France, Italy and the Czech Republic.

Methods and data for environmental inequality research

The report also aims at providing a brief overview of methodological approaches and data sources that have been or can be used for assessments of EI. As the dimension of "Burden of Pollution" was identified to be the most widely researched in the European context, the analysis of methods and databases also focused on this dimension, taking local exposures to air pollution as an example. In general, there are **four broad groups of methodological approaches for the assessment of exposures** to pollution: (a) unit-hazard coincidence approaches, (b) distance-based approaches, (c) risk-based approaches, and (d) non-spatial approaches. The first three approaches represent various versions of spatial assessments and are the most widely applied methods. Non-spatial approaches include methods such as direct field measures or questionnaires. These four groups of methodologies are not exclusive and can also be applied in a mixed method.

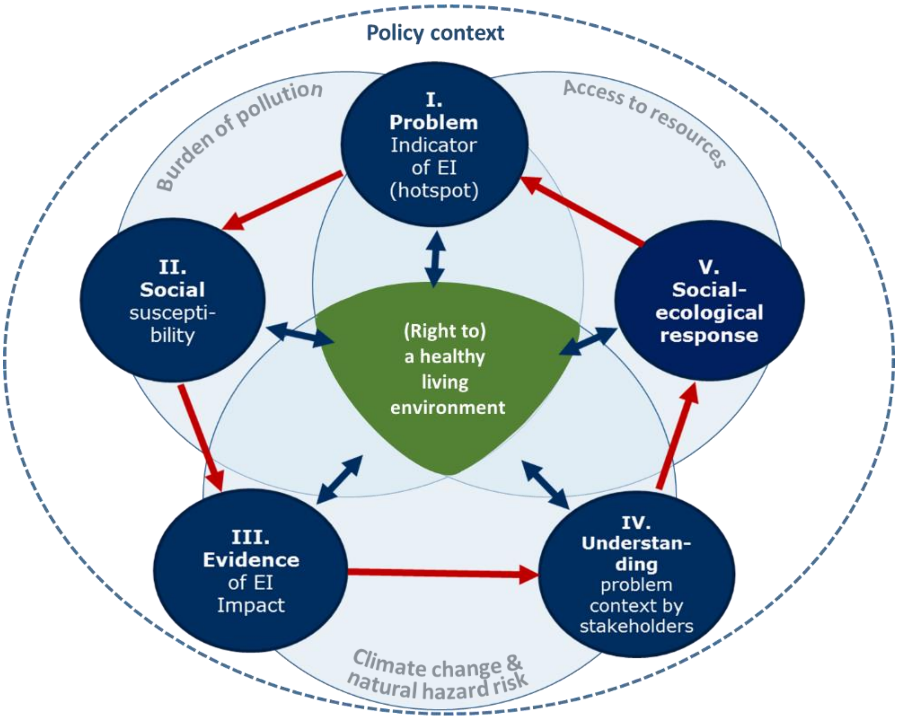
The majority of analysed studies take advantage of data obtained from detailed dispersion models, which are available for most of the major metropolitan areas and cities in Europe. In terms of socioeconomic or demographic datasets, the main data sources are the national statistical offices which conduct the national population census. **Data availability for Austria is generally good** which enables advanced and spatially explicit EI assessments. For example, noise pollution maps exist for metropolitan areas and pollution data can be sourced from the European Pollutant Release and Transfer Register. Various other relevant GIS datasets for Austria, such as the spatial distribution of public green spaces, can be sourced free of charge from Open Government Data platforms.

In addition to territorial impacts, the analysis also covers methods which so far have not, but can be applied in the global context of EU related EI. These methods can reveal global **inequalities in the appropriation of global natural resources as well as patterns of environmental impacts** driven by EU production, trade and consumption. Putting these assessments in the context of EI and EJ, gives an indication how global drivers impact local populations and their living environment and, hence, contribute to the explanatory framework of distributive inequalities. Large-scale research projects are currently ongoing to advance methodologies for establishing these links on a fine geographical scale.

Towards an environmental justice framework in an EU context

Based on the literature review and a review of social theory and concepts in relation to environmental justice, a framework was compiled to **engage stakeholders in EJ processes (procedural justice) towards an improvement of the quality of the living environment on the basis of robust evidence of EI (distributive justice) in a just policy context**. Normative imperatives complicate stakeholder processes in multi-dimensional contexts towards environmental justice as an end-goal. Therefore, EJ has been defined as a process which – in line with EJ related concepts such as the SDGs – 'work' towards a healthy living environment where people have a say and can fulfil their fundamental needs while respecting environmental limits.

The framework aims at an objective starting point of the EJ process at the level of scientific research into potential EI (hotspots) - in terms of access to resources, burden of pollution and/or climate change and natural hazard risk - but can also emerge from a subjective (perceived) inequality or a situation of an EJ conflict, e.g. related to an industrial siting proposal or decision, or disproportional impacts of environmental policies. From a policy perspective, the framework aims at addressing social inequalities related to environmental burden. The following figure illustrates the proposed EJ framework.



Environmental justice framework to assess and reduce environmental inequality in the European context

The proposed framework involves five iterative steps, embedded in the wider policy field: (I) **Problem identification**: analysis of the dimension(s) and distribution of environmental exposure among social groups in terms of access to resources, burden of pollution or risk of climate change or natural hazard in the spatially explicit living environment (which can also be a working environment, or the area where children go to school). The problem is indicated as a potential environmental inequality (hotspot). (II) **Social susceptibility for (potential) exposure**; the physical quality of the living environment, i.e. quality of housing, architectural design, green spaces, etc., plays an important role in the relation between exposure and actual (health) impact related to the exposure. Susceptibility for environmental burden may thus be higher or lower for a specific social group and it is recommended to recognise this 'explanatory factor' as a procedural step in EI research. (III) **Evidence of EI impact**: Evidence of EI at the impact level, e.g. health impacts, but also losses in case of flooding, needs to be collected in qualitative or clinical research approaches. Evidence of environmental impact significantly strengthens the claim of EI (which is generally subject to high uncertainty related to the multiple interrelated factors in the EI problem environment). (IV) **Understanding the problem context (explanatory framework):** Causal relations, e.g. traffic related air pollution, are easier to identify – and to agree upon – in the local context than in wider spatial contexts. Therefore, stakeholder participation to learn about causal relations and responsibilities at this stage is a key ingredient in the process of EJ in the local context, increasingly also in national or international contexts (with the Paris climate agreement as the most prominent example). (V) **Developing a shared social-ecological response by stakeholders**, finally, occurs when drivers and impacts of EI are sufficiently understood or acknowledged (social equity), allowing stakeholders to adopt policies or other social-ecological responses supporting vulnerable social groups to fulfil fundamental human needs, as well as to take responsibility for the production of EI.

Not visible in the framework are the similarities and differences between the European and US approach to environmental justice. Both regions include distributive, procedural and substantive elements of EJ, but differ in the value system underlying public policy: the US traditionally recognises the universality of natural rights of the individual and, hence, focuses on discriminated groups. The EU relates environmental burden more to social differences and, hence, aims at including the production, or drivers, of such inequalities in environmental and/or social policies. From an EU/Austrian policy perspective, environmental justice works towards embedding environmental regulation in social policy, indicating the need for social-ecological policies that support environmental quality in the places where our everyday lives occur.

Considering the systemic nature of environmental inequalities, largely related to economic goals in the EU and global context, an environmental justice frame adds an important research perspective to inequality research, both within spatially explicit contexts and in the global context. With respect to the latter, methodologies to connect distant drivers of environmental pressures and related EI, associated with EU consumption, would advance the explanatory framework of global EI patterns, connecting to the field of political ecology. These areas, as well as risks and inequalities related to cumulative environmental impacts, are recommended for further research.

Definitions

Environmental justice (EJ) "means everyone has the right to a clean, healthy, and safe environment in which to live, work, go to school, and play" (Mohai et al., 2009);

Distributive justice is concerned with how environmental 'goods' (e.g. access to green space) and environmental 'bads' (e.g. pollution and risks) are distributed among different groups and the (perceived) fairness or equity of this distribution (Laurent, 2010);

Procedural justice is usually understood as the opportunity for "all people regardless of race, ethnicity, income, national origin or educational level" to have "meaningful involvement" in environmental decision-making. It is concerned with the importance of access to environmental decision making processes (Schlosberg, 2009);

Climate justice is used and defined in different ways, but primarily mobilised to contest the unequal impacts of climate change, both geographically and socially (Chatterton et al., 2013);

Environmental Inequality (EI) refers to "the unequal distribution of environmental risks and hazards and access to environmental goods and services" (Sustainable Development Research Network, 2012);

Social inequality is the existence of unequal opportunities and rewards for different social positions or statuses within a group or society (Wade, 2014);

Air pollution is the contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide. Outdoor and indoor air pollution cause respiratory and other diseases, which can be fatal (WHO, 2017);

Environmental impact is the effect that activities of people and businesses have on the physical environment (Turner, 2006);

Social impact is the effect of activities on the social fabric of the community and well-being of the individuals and families (Turner, 2006);

Cumulative impacts refer to the total harm to human health and the environment resulting from combinations of stressors over time (Scammell et al., 2014).

1. Introduction

Although the terms environmental justice and environmental inequality are often used interchangeably in the literature, they do have distinct meanings. **Environmental inequality describes the situation how things are** and refers to the unequal distribution of environmental risks and hazards and access to environmental goods and services among societal groups (Sustainable Development Research Network, 2012). **Environmental justice refers to how things ought to be**, for example: "Environmental justice means everyone has the right to a clean, healthy, and safe environment in which to live, work, go to school, and play" (Mohai et al., 2009). Although environmental inequality (EI) can be empirically measured and described, the interpretation of the results from an environmental justice (EJ) perspective depend on the – normative - justice principles that can differ among individuals, social groups and societies. This report reviews empirical patterns of EI in the EU, based on existing research, and suggests an approach to move social groups from a situation of EI to a healthy living environment from an EJ perspective.

Environmental justice claims were first raised in the United States in 1982 when civil rights activists organized to stop the state of North Carolina from dumping 60.000 tonnes of soil contaminated with polychlorinated biphenyls (PCBs) in the county with the highest proportion of African Americans (Bullard, 2008). Warren County became a symbol of the birth of a new social movement and of an issue that mainstream middle-class white environmentalists had failed to see: that people of colour and poor communities were facing ecological risks far greater than 'whites' (Mohai et al., 2009). Supported by grassroots initiatives concerning the unfair distribution of environmental pollution to ethnic minorities and poor people, the EJ movement offered opportunities to call for a better quality of life through a healthier environment for all. These movements, however, were not only about an improvement in the environmental conditions, but also about social inclusion, participation in decision-making and recognition (Schlosberg, 2009).

In Europe, EJ campaigns were initiated in the 1990s by professional advocates such as the NGO Friends of the Earth (FoE). By collaborating with academics, FoE successfully developed an EJ agenda and linked this to research on the social distribution of polluting industrial facilities that revealed social biases in siting patterns (Walker, 2012). Recognition at the European level followed shortly after with the UNECE Convention in Aarhus (1998) where its members agreed to 'guarantee the rights of access to information, public participation in decision-making, and access to justice in environmental matters …" (Laurent, 2010). Contrary to the US, EJ in the EU did not focus on racial discrimination but on patterns of deprivation with income as the primary social metric. This does not mean that environmental inequality does not have a racial dimension in Europe as, for example, Molnár et al. (2012) show how Roma communities in Europe are affected by environmental inequalities.

From the above, it can be inferred that **EI and EJ involves both a social and an environmental dimension.** In fact, environmental inequality can be understood as a social deprivation to fulfil one or more needs in an environmental context (Agyeman et al., 2002). Figure 1 plots EI and EJ as a function of social inequality and environmental burden. Environmental inequality occurs when social inequality coincides with a (relatively) high environmental burden (Quadrant I). Relative means that the environmental burden, or the consequence of environmental policy, on a specific social group is disproportionally adverse in comparison to others. Opposite, in Quadrant IV, is the desired situation where there is social justice and environmental quality (low environmental burden). In Quadrant II, the environmental burden is high, but for all social groups (an environmental problem without EI) and in situation III, social inequality is high but environmental exposure is low. Situation III may occur in less developed countries with limited economic activity or in developed countries with growing economic inequality and displacement of polluting industrial activities to areas elsewhere.

The green arrows reflect the effect of environmental policies and regulation, which have resulted in a steady decline of environmental burden in some important fields such as air pollution in the territorial context of the EU (EEA, 2017a). The blue arrows indicate policy efforts towards social justice, for instance, the right of everyone to education, health care, decent housing and democratic participation. EJ issues refer to social groups in a spatially explicit living environment (Van Kamp et al., 2003) and connect with the quality of life debate (Pacione, 2003), the societal aim for human flourishing (Schlosberg, 2009) and, most recently, with the UN Sustainable Development Goals (United Nations, 2015). The latter, in particular goal 10 ('reduce inequalities'), clearly addresses the adverse trend towards growing income inequality and calls for efforts to reduce inequalities related to race, ethnicity, economic or any other status within a country (UN Economic and Social Council, 2016). In line with this, environmental justice works towards embedding the reduction of EI in social-ecological policies to increase environmental quality and social justice in the places where our everyday lives occur – as indicated by the red arrow in Figure 1 (Laurent, 2011).

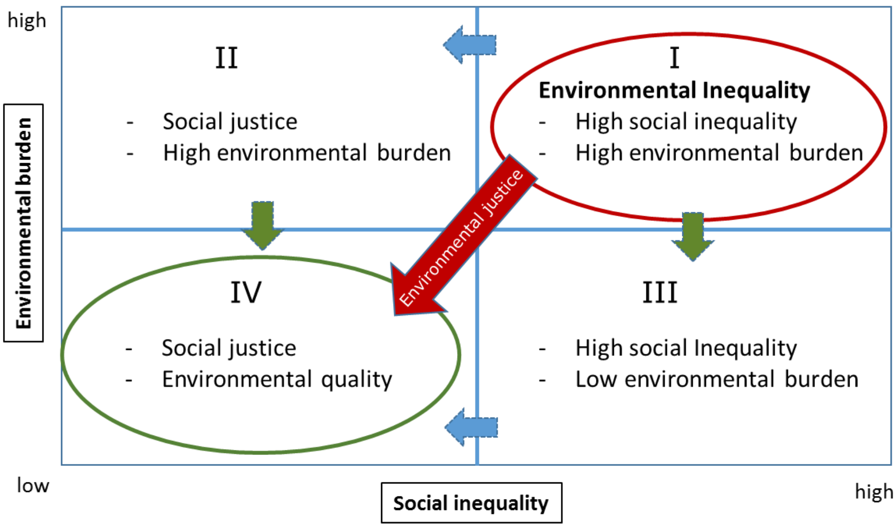


Figure 1: Environmental inequality (red circle) and the process of environmental justice (red arrow) in the interdisciplinary field of the social and environmental sciences (green arrows: environmental policies, blue arrows: social policies)

In research, a growing number of disciplines have started to investigate issues of environmental inequality, including, but not limited to, sociology, economics, psychology, natural sciences, environmental science and law. Public health researchers, in particular, explore exposures to environmental pollution as a major contributing factor in the production of health inequities (Evans and Kantrowitz, 2002). Interdisciplinary approaches, such as in ecological economics, explore environmental inequalities from multiple levels, i.e. the micro-, the meso- and the macro-level in society, aiming at revealing quantitative patterns and causal relations explaining the social production of environmental inequalities, based on an understanding of the interrelated social and ecological system.

EI research involves different environmental dimensions. Contemporary dimensions of environmental inequality in the EU relate to, among others, traffic related pollution (air and noise pollution), energy poverty, access to public transport and to risks related to climate change (Brunner et al., 2012; Laurent, 2011; Martens, 2016). These issues, as well as the more traditional forms of environmental inequality, such as the social distribution of waste siting, will be covered by the literature review in this report.

Furthermore, **EI research is carried out at different spatial levels**, i.e. at the local, national, EU and global level, and relates to the living, the working, the learning and the commuting environment of social groups. The review in chapter 2 shows that EU associated EI is mostly studied in the local, often urban, context. A high concentration of people and economic activity, in particular traffic, as well as sufficient availability of detailed socioeconomic and environmental data support research efforts in urban areas. However, a considerable number of papers investigate patterns of EI at the national level, in particular in relation to air pollution and industrial siting. At the European level, limited empirical research has been carried out in consistent EU-wide approaches, although most environmental themes have been explored by proxy-indicators or a meta-review of national and local studies.

At the global level, the ecological debt of the European Union has been accumulating since the industrial revolution vis-à-vis poor and developing countries, for example in terms of carbon budget and resources use (Laurent, 2011). Furthermore, economic activity is increasingly marked by the global connections between EU consumption and global production regions, which has displaced resource extraction and environmental pollution from the EU to countries elsewhere (Giljum et al., 2015; Steen-Olsen et al., 2012). EU consumption therefore has developed into a major global driver of various environmental and social impacts in low income countries (Duchin and Levine, 2012; Godar et al., 2015; Sonter et al., 2014; Weinzettel et al., 2013). As such, it can be argued that the EU contributes to global environmental inequalities and injustice, both in terms of access to resources as well as in terms of environmental pollution (Robbins, 2011). However, no empirical analysis of EI related inequalities has been found to be carried out from an explicit environmental justice perspective. In chapter 3, a methodological approach will be presented that links EU consumption to global environmental and social impacts related to global supply chains, which potentially contributes to evidence as well as to causal drivers of global patterns of EU driven environmental inequalities.

Related to the foregoing, the **objectives of this study** are threefold. First, to review empirical papers and official reports on environmental inequality in the European context to identify major issues and potential patterns of environmental inequality in the EU (chapter 2). Second, to assess the availability of methods and data to perform studies on environmental inequality (chapter 3). Finally, to review theory underlying EJ and to develop a framework to identify and reduce environmental inequality from the perspective of environmental justice in an EU context (chapter 4). Chapter 5 will summarise and conclude our findings, and will provide an EJ research agenda for Austria.

2. Literature review of environmental inequality issues in EU member states

In this chapter, we present the results of a literature search and review of empirical papers and official reports on environmental inequality in the European context. To our knowledge, no EU wide meta-review of empirical analyses on EI related inequalities from an environmental justice perspective has been conducted. Initially, the literature search covered 'environmental inequality' and 'environmental justice' in google scholar and web of science only, which rendered a limited number of peer-reviewed empirical papers, mainly from the UK and, to a lesser extent, from Germany and France. In a second round, we widened the number of languages from English to German, French and Dutch in the World Wide Web, which increased the number of reports and a broader range of scholarly work (e.g. Master Theses). However, the search still delivered a limited number of empirical studies, in particular from southern European countries. Therefore, in the third and final search, we took an exploratory approach to EI, based on a wide range of keywords listed in the results (papers) from the 1st and 2nd round. Overall, EI in relation to health rendered the largest number of empirical studies. It should be noted that we limited the search to empirical evidence of distributive inequalities, meaning that environmental inequality (potentially) associated with procedural and policy related injustice is not included in this review. The latter – involving social and environmental policies in the institutional context – is considered to be part of the explanatory framework of environmental (in)justice (see chapter 4).

In summary, the literature search has been based on the following keywords:

- Environmental inequality and/or Environmental justice;
- Air pollution (noise, industrial siting, heavy industry, waste siting) and EI, health, income, socioeconomic status, employment, minority;
- Climate justice (flooding, heat stress) and EI, health, income, socioeconomic status, employment, minority;
- Access to resources (green spaces, energy, transport) and EI, health, income, socioeconomic status, employment, minority;
- Cumulative impacts and environment, cumulative impacts and EI, cumulative impacts and health.

The search identified 81 empirical papers and reports on environmental inequality which have been subject to a structured analysis of the spatial scale, the research question or hypothesis, the applied method and the results, including the uncertainty in the evidence of EI. In the now following, we list the spatial, social and environmental dimension, as well as the uncertainty in the evidence of EI patterns in comprehensive tables, and review the papers with the strongest indication of EI patterns to get an understanding of important issues – and potential EI hotspots - in relation to environmental justice in the European context. We realise that this approach results in a potential bias towards papers showing significant EI outcomes, rather than robust EI outcomes in relation to methodological choices. But because the primary purpose of the review is to make a first EU-wide exploration of (likely) EI issues, we feel confident with the approach for this purpose.

The following sections describe the social distribution of environmental burdens in the field of air pollution (2.1), noise pollution (2.2), siting of polluting facilities (2.3), quality of the living environment (2.4), climate change and natural hazard risk (2.5), access to resources (2.6), and cumulative impacts (2.7). Finally, in section 2.8, the results are discussed.

2.1 Air pollution

Breathing fresh air of good quality is fundamental to human health. The other way around: air pollution harms human health and the environment (EEA, 2017c). In terms of human impact, air pollution is the single largest environmental health risk in Europe, causing respiratory problems and shortening lifespans. A large proportion of European populations and ecosystems are still exposed to air pollution that exceeds European standards and, especially, World Health Organization (WHO) Air Quality Guidelines (EEA, 2016a). In order to measure and monitor air quality, air pollution is defined as the contamination of indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere[1]. There are countless types of air pollutants but, in the majority of developed countries, particulate matter, ozone, carbon monoxide, nitrogen oxides, sulphur dioxide and non-methane volatile organic compounds are among the most common (Segal and Nilsson, 2015). Important pollution sources, or drivers, in the European context include traffic, industry, agriculture, and waste sites. With respect to traffic, air pollution is of particular concern in urban areas, where particulate matter and nitrogen oxides tend to increase and to affect human health in traffic hotspots (Cohen et al., 2004; Cohen et al., 2005; WHO, 2009).

With 26 papers and reports on air pollution related EI in our review, covering a large number of EU member states, air pollution shows to be the most frequently analysed environmental problem in relation to social and health inequalities in Europe. Table 1 gives an overview of the reviewed studies on air pollution related EI since circa the year 2000, and indicates whether evidence for environmental inequality has been found. The table (and all following tables summarizing the reviewed papers) distinguishes three spatial levels: (1) the micro-level (urban/local), (2) the meso-level (national/multi-local) and (3) the macro-level (EU/international). It should be noted that our review is by no means exhaustive.

Table 1: Reviewed studies in the field of air pollution and environmental inequality (darker colour indicates stronger evidence, no colour means no significant evidence for EI)

Geography	Type of deprivation	Social inequality factor	Environmental inequality	Authors
Micro-level (urban/local)				
Ostrava region (Czech Republic)	Air quality	SES, income	Positive, multiple deprivations/ low SES	Slachtová et al. (2016)
Strasbourg (France)	PM_{10}, O_3, NO_2, SO_2 and CO	SES	Positive Exposure Health	Bard et al. (2007)
Strasbourg (France)	NO2, other	SES	Positive Exposure	Havard et al. (2009)
London (UK)	PM, BC, PNC, modes of transport	Income	Positive Exposure	Rivas et al. (2017)
Rome (Italy)	Area-based traffic PM	Social classes (income)	Positive with mid-SES Exposure Susceptibility with low SES (likely)	Forastiere et al. (2007)
Valencia (Spain)	NO2	Pregnant women Social class Ethnicity	Very likely Exposure Susceptibility (poor housing)	Llop et al. (2011)
Madrid, Barcelona (Spain)	NO2 from traffic	Children, elderly Immigrants	Positive/mixed (elderly, immigrants)	Moreno-Jiménez et al. (2016)

[1] http://www.who.int/topics/air_pollution/en/

			Exposure	
Malmö (Sweden)	Outdoor NO2	Children, SES, affluence	Positive Exposure	Chaix et al. (2006a)
London (UK)	Traffic related air pollution	Deprivation Geodemographic	Likely (mixed) Exposure	Goodman et al. (2011)
Dortmund (Germany)	PM10, NOx	Children, migrants	Likely Exposure	Flacke et al. (2016)
Leipzig (Germany)	PM10, noise	SES*	Likely, (mixed) Exposure	Weber et al. (2014)
Berlin (Germany)	PM2.5, NO2	Development index	Heterogeneous Exposure	Lakes et al. (2014)
Meso-level (national/multi-local)				
UK Country wide	NO2, SO2, PM10 benzene	SES Urban, rural	Positive Exposure Health impact	Wheeler and Ben-Shlomo (2005)
UK Country wide	NOx, NO2	Age, Poverty Car ownership	Positive Exposure	Mitchell and Dorling (2003)
UK Country wide	NO2, PM10, SO2	SES, income	Positive, growing inequality Exposure	Mitchell et al. (2015)
UK Neighbourhoods NUTS 1	PM10, NO2	Deprivation, demographics, ethnicity	Positive, deprivation & ethnic EI in urban settings Exposure	Fecht et al. (2015)
Germany Country-wide	Air and noise	Income groups	Positive Exposure	Kohlhuber et al. (2006).
Netherlands Neighbourhoods NUTS 1	PM10, NO2	Deprivation, demographics, ethnicity	Positive, ethnic EI (no deprivation) in urban settings	Fecht et al. (2015)
Netherlands Random cohort Southern part	NO2, black smoke	Demographic	Very likely (when living near busy roads) Exposure Health impact	Hoek et al. (2002)
Switzerland Municipalities	Air & noise	Education, income, nationality	Positive, exposure & low education, but size of the town more important	Diekmann and Meyer (2010)
France Municipalities	NOx	Immigrants, unemployed	Positive Exposure	Schwarz et al. (2015)
France Metropolitan areas	NO2	SES	Likely (exposure) , temporal improvements but urban EI persists	Padilla et al. (2014)
Italy Provinces/ NUTS 2	Industrial air pollutants	Demographic	Likely for women and children	Germani et al. (2014)
UK Country wide	NO2, PM10, benzene, CO	Deprivation	Likely	Walker et al. (2003)
Czech Republic 39 cities (>10,000 inh.)	PM10, SO2, NO2	Income, education, employment	Positive, but heterogeneous	Branis and Linhartova (2012)
UK Country wide	NO2, PM10, SO2	SES, income	Heterogeneous	Pye et al. (2008)
Austria (Vienna, St. Pölten, Graz, Klagenfurt, Villach)	Indoor air quality (a.o.) CO2, NO2, PM10, PM2.5, Ethyl-benzol, heavy metals	School children (6-8 yrs)	Mixed: high CO2 levels, PM2.5 in relation to outdoor air pollution, PM10 in relation to indoor sources	Hohenblum et al. (2008)
Macro-level (EU/International)				
EU NUTS 2	PM10	Poor-rich East-West	Likely, Mixed	Richardson et al. (2013)

*Socioeconomic Status

At the micro-level, our review identified 11 studies on EI carried out in urban contexts in 7 member states across the Union: the UK, Germany, France, Italy, Spain, the Czech Republic and Sweden. Several studies show a heterogeneous result (both positive and negative correlations) or a mixed result (different pollutants in the same context with different directions of correlation), but the majority of studies find a likely to very likely association between air pollutant related environmental exposure and some form of social inequality.

Ostrava (Czech Republic) and Strasbourg (France) show the strongest associations between social and environmental distributions related to air pollution. In the Ostrava region, inequalities are reported to be related to polluted environments and social exclusion, where social groups with lower socio-economic status (SES) are more exposed to polluted environments and/or live in inadequate houses (more ambient pollution in the indoor living environment). In Strasbourg, traffic related air pollution has been found to correlate with people with relatively low SES and with a higher risk of myocardial infarction. A follow-up study showed that, because of living at a greater distance from possible pollution sources, higher income groups are potentially less exposed to NO2 and other traffic related pollutants than those in mid-level deprivation areas.

At the meso-level, i.e. nation-wide or 'multi-local' patterns of EI, we reviewed 15 studies in 7 EU member states and Switzerland. Similar to the urban level, the majority of studies cover traffic related emissions in relation to socioeconomic status, with some scholars deepening the analysis towards health impacts and other forms of deprivation.

The UK tops the list with nearly half of the studies. Mitchell and Dorling (2003) carried out the first nation-wide study on the relation between NO_2 emissions and demographic census data (age, poverty, car ownership) at the ward level, covering England, Wales and Scotland. The results showed that the most polluted areas tend to emit the least. These present the poorest areas with fewest cars. Similar results for the UK have been found by Walker (2012), Wheeler and Ben-Shlomo (2005), and Pye et al. (2005). A temporal study (2001-2011) showed that improvements in air quality is greatest in the least deprived areas, thus contributing to a further widening of EI in the UK (Mitchell et al., 2015).

In Germany, inequalities in exposure to air (and noise) pollution shows to be related to poorer housing conditions of East-Germans and, hence, reflects inequalities in susceptibility. In the Netherlands, as in the UK, air pollution and EI is most strongly associated with traffic sources and, hence, is mainly observed in urban areas or along busy roads. In France, varying associations between deprivation and ambient air pollution are found, but incinerator related emissions (NO_x) were disproportionally distributed among unemployed people and immigrants. Industrial air pollutants in Italy are higher in provinces with higher shares of women and children – indicating traditional social inequalities rather than racial discrimination. In the Czech Republic, low SES groups are more exposed to air pollution in smaller cities.

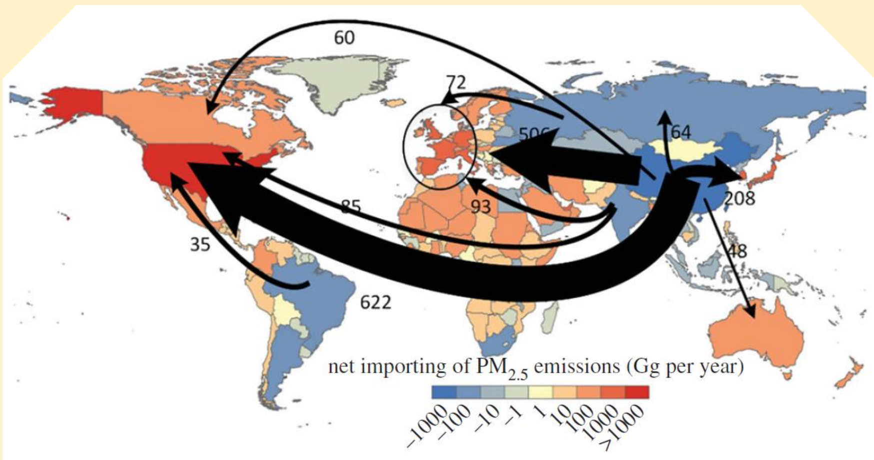
To our knowledge, only one study has empirically explored the social distribution of air pollution **at the EU level**. Particulate air pollution and health inequalities have been investigated in relation to income groups in a temporal analysis by Richardson et al (2013). It was shown that air quality improved between 2004 and 2008 but that inequality between member states persisted. PM10 inequality showed to be more related to East-West differences in average income than to structural patterns of inequality within countries. In fact, some of the most polluted regions in Western Europe are also among the richest. Populations of lower income regions appeared to be more susceptible to the effects of

PM10, in particular in relation to specific diseases in Eastern Europe and to respiratory mortality among males in Western Europe. The authors conclude that income-related inequalities in exposure to ambient PM10 may contribute to EU-wide mortality inequality (Richardson et al., 2013).

BOX I: EU related EI in the global context

At the global level, environmental inequalities are driven by EU consumption patterns: several studies link EU final demand to global supply chains of products and goods that are either produced outside the EU or for which raw materials are extracted elsewhere. By linking the monetary values of product flows to environmental databases, such as material use or emissions, EU consumption becomes a driver of global environmental inequalities, in particular via North-South or East-West trade relations. Such environmental footprint perspectives not only are a tool to assess patterns of global scale environmental inequalities, they may also contribute to the understanding of causal mechanisms of environmental inequalities, i.e. help explaining why such inequalities exist.

For example, Meng et al. (2016) developed a global consumption-based particular matter (PM2.5) emission inventory to track primary PM 2.5 emissions embodied in supply chains and evaluate the extent to which local PM2.5 emissions are triggered by international trade. In the figure, the largest net-importers (in red) of embodied PM2.5 emissions in export flows from China (black arrows) are the United States, closely followed by the EU. Other studies have estimated that both per-capita and total mortality attributable to PM2.5 are highest in Asia, amounting to 63 deaths per 100,000 population and 2.3 million total deaths, respectively, in 2010 (Apte et al., 2015). Linking final consumers to the pollutants related to the production of goods and services, may thus provide valuable insights into global environmental inequalities for which EU policy makers, producers and consumers are co-responsible. Similar 'Footprints' can be calculated for e.g. CO_2 or NO_x emissions when robust environmental databases are available.



Territorial PM2.5 emissions of China linked to foreign consumption in 2007 (Meng et al., 2016)

2.2 Noise pollution

Noise is defined as a "disruptive or damaging sound" and can have significant impacts on mental and physical health (WHO, 2011). Noise pollution in Europe is estimated to contribute to at least 10,000 cases of premature deaths and to large scale annoyance and sleep disturbance, and is therefore considered the second most important environmental factor after air pollution (Hänninen and Knol, 2011). Road traffic is the most dominant source of environmental noise, both in urban and in rural contexts (EEA, 2014).

Furthermore, high noise and pollutant exposure levels result in many widespread conflicts between use of space and quality of life (Weber et al., 2014).

The EU Environmental Noise Directive aims to protect and/or improve people's health by its focus on a reduction in the number of people exposed to noise pollution, but does not specifically address social inequalities in noise exposure (EC, 2011; EU, 2002). Furthermore, results of research into objective and subjective indicators of residential exposure to road traffic noise in the context of environmental justice underline the need to select, operationalise and examine noise-related indicators, as it is claimed that objective noise exposure predicts noise annoyance insufficiently. This may fail to identify distributive EI and, hence, to initiate an environmental justice process (Riedel et al., 2014).

Table 2: Reviewed studies in the field of noise pollution and environmental inequality (darker colour indicates stronger evidence, no colour means no significant evidence for EI)

Geography	Type of deprivation	Social inequality factor	Environmental inequality	Authors
Micro-level (urban/local)				
Munich (Germany)	Noise pollution Air pollution	Area based poverty rates	Positive with high poverty rates	Mielck et al. (2009)
Marseille (France)	Road traffic noise	SES (census block)	Positive, but with mid-level SES	Bocquier et al. (2012)
Paris (France)	Background noise	Migration background Education Dwelling value	Positive in neighbourhoods with high shares of advantageous countries	Havard et al. (2011)
Birmingham (UK)	Airport related noise	Age Ethnicity Deprivation	Weak (ethnicity, deprivation) Negative (age)	Brainard et al. (2004)
Vienna (Austria)	Traffic noise (street level)	Composite SEP at neighbourhood level	Double blessing (double burden)	Siedl (2016)
Berlin (Germany)	Background noise	SES	Heterogeneous (likely)	Lakes and Brückner (2011)
Leipzig (Germany)	Road traffic noise Air pollution	SES Physical environment	Heterogeneous	Weber et al. (2014)
Meso-level (national/multi-local)				
Germany	Traffic noise	SES	Positive (higher exposure low SES)	Hoffmann et al. (2003)
Switzerland	Road traffic noise	Income Education Migration background	Positive with lower SES, small differences	Meyer (2011)
Macro-level (EU/international)				
EU	Environmental noise (traffic, neighbourhood, etc.)	Income Social status	(slightly) positive for low income groups in EU-15 Likely health impact	WHO (2012)
Netherlands Spain UK	Aircraft noise exposure Road traffic noise exposure	School children, age 7-10	Positive with aircraft noise (recall & recognition memory, reading comprehension)	Clark et al. (2012)

At the micro-level, our review rendered 11 studies examining the socio-spatial distribution of environmental noise (see Table 2). The majority of them concerns exposure to road traffic noise in urban settings. Of these, none established an objective correlation with health impacts and only one study (Mielck et al., 2009) resulted in evidence of EI in relation to the most vulnerable social groups (in Munich). Contrary to air pollution, noise pollution shows a more heterogeneous pattern among social groups as both affluent and deprived people tend to be affected by traffic noise; affluent people generally prefer central locations and/or close to public infrastructures and disadvantaged social groups tend to live in more industrial areas or close to high density traffic roads. Marseille and Paris showed patterns where mid- or even high-level SES (in Paris: people from more advantageous countries), is associated with higher noise distribution. However, spatial autocorrelation and collinearity between neighborhood explanatory variables could not be prevented, emphasizing the need to systematically perform sensitivity analyses with multiple socioeconomic characteristics to avoid incorrect inferences (Havard et al, 2011). Vienna, Berlin and Leipzig showed no patterns of structural EI, although Vienna and Berlin showed a 'double burden/double benefit' pattern, i.e. more areas with high SEP and low levels of noise pollution than areas with low SEP and low noise pollution.

At the meso-level, noise pollution and social inequality is an understudied topic; we discovered only one older study, based on a Federal Health Survey in **Germany in 2003,** showing that people of lower socioeconomic status are more likely to live in busy to extremely busy main- and through roads and that this social group feels significantly more often affected by traffic noise pollution. Reversely, people with higher socioeconomic status were more likely to live in quiet environments. The conclusion is that noise pollution in living environments is unevenly distributed, with people of lower socioeconomic status suffering more than others. Similar results have been found for **Switzerland,** based on a large-scale survey in Basel and Bern, where support is found for the hypothesis of higher environmental burden for lower social classes, although disparities between classes proved to be rather small.

At the macro-level, the WHO conducted an EU-wide study of self-reported noise exposure at home in relation to income in 2012. The results show that, in Western Europe, individuals below the relative poverty level, in particular single parents, are significantly more exposed to noise pollution than individuals above the relative poverty level. No such pattern has been identified for C/E European countries; subjective noise pollution is higher in western than in eastern member states.

Road and airport noise have been assessed in relation to cognitive learning skills of school children in the **Netherlands, Spain, and the UK**, as children are particularly susceptible to noise pollution (Clark et al., 2012). Adverse impacts of aircraft noise on recall & recognition memory as well as reading comprehension have been shown. No such effects have been found in relation to road traffic noise exposure.

2.3 Siting of polluting facilities

In this section, we look at EI research focussed on point source pollutions. In environmental inequality research, point sources are causal drivers of environmental impact, which may contribute to the explanatory framework for the **potential impact or risk of human deprivation**. Siting of point source facilities thus is a critical issue in environmental justice processes. In the now following, we review studies investigating the social distribution of both industrial and waste siting in relation to different forms of human deprivation.

Industrial siting

At the micro-level, industrial siting has been investigated in two industrial cities in France (Lille and Lyon), where it was found that socio-economically disadvantaged groups live closer to polluting industrial facilities, although significant differences were found between the two cities, related to differences in social makeup of Lille (more heavy industry) and Lyon (more high-tech).

Table 3: Table 3: Reviewed studies in the field of industrial siting and EI (darker colour indicates stronger evidence, no colour means no significant evidence for EI)

Geography	Type of deprivation	Social inequality	Environmental inequality	Authors
Micro-level (urban/local)				
Lille; Lyon (France)	Distance based proximity index	SES	Positive, mixed results	Nguyen 2011
Meso-level (national/multi-local)				
England, Wales	Pollution hotspots (industrial, waste)	Deprived groups	Positive	Walker et al. 2003
Scotland	Pollution hotspots (industrial, waste)	Deprived groups	Positive	Fairburn et al. 2005
France	Incinerator siting patterns	SES Non-natives	Positive, siting patterns follow non-natives	Laurian and Funderburg (2013)
Czech Republic	Energy (coal) plant distribution	Demographics Employment Education Ethnicity (a.o.)	Positive, with education and ethnicity	Frantál and Nováková, 2014
Austria	Distance to industrial site	Employment Education Migrant background	Positive (not in Vienna)	Glatter-Götz, 2016

At the meso-level, early research on EI related to industrial siting has been carried out in England and Scotland, where it was found that people from the most deprived decile lived disproportionally close to polluting sites and that industrial and waste sites were also more clustered in deprived areas. In France, evidence supports a pattern of incinerator siting in areas with high levels of immigrants, resulting in disproportional health risks (cancer and reproductive malformations). Higher shares of immigrants, as well as unemployed people, in the vicinity of industrial sites are also found in Austria (except for Vienna). In the Czech Republic, EI patterns and health risks are likely to be associated with coal energy plants.

Waste siting

The association between social makeup and residence characteristics in the vicinity of waste sites has been repeatedly documented in England and Wales (Damery et al., 2007; Fairburn and Smith, 2008; Walker et al., 2003). Most of them analysed the correlation between income and deprivation with localization of solid waste and other polluting facilities, finding that facilities were disproportionally located in the more deprived areas. For *landfills,* the patterns of relationship between deprivation and population proximity are less distinct at the sub-regional level (Pye et al., 2008). In Scotland, socially deprived areas are disproportionately exposed to municipal landfills and have been since at least 1981. Furthermore, the results suggest that area deprivation may have preceded disproportionate landfill siting to some extent, particularly in the 1980s, but landfill siting also preceded a relative increase in deprivation in exposed areas (Richardson et al., 2010).

Forastiere et al. (2011) conducted a health impact assessment of landfilling and incineration in three European countries: Italy, Slovakia and England. The study involved a multiple regression of distance-based indicators, excess risk estimates from epidemiological studies and air pollution dispersion modelling in relation to SES of population groups. It was found that, both in Italy and in England, populations with lower SES were more likely to live closer to waste disposal sites. The situation was different for two incinerators in Slovakia since they are located in urban areas where people tend to enjoy a higher socioeconomic status.

The relation between waste management and health **at the EU level** has been investigated by means of a literature review by Martuzzi et al. (2010). Based on patterns of association between waste-related environmental pressures and SES, it is suggested that some of the observed inequalities in exposure and health represent a case of environmental injustice as they are the result of social processes and may be prevented, at least partly. Disentangling health effects and linking them with waste management is considered difficult, due to differences in applied methodologies in the different studies.

Table 4: Reviewed studies in the field of waste and/or waste transfer siting, and EI (darker colour indicates stronger evidence, no colour means no significant evidence for EI)

Geography	Type of deprivation	Social inequality	Environmental inequality	Authors
Meso-level (national/multi-local)				
Italy Slovakia England	Distance incinerator or landfill Air pollution (PM10, NO2) Health	Gender Age SES	Positive with low SES for Italy and England, Positive with med/high SES in Slovakia	Forastiere et al. 2011
Scotland	Proximity to municipal landfills	Area deprivation	Positive Siting	Richardson et al. 2010
England	Air quality of active waste sites	Deprived population	Most deprived populations more likely to live near waste or landfill site	Fairburn and Smith, 2008
North-West England	Waste sites Landfills	Social class	Lower social classes live more likely nearby waste sites	Damery et al. 2007
Wales	Proximity to urban locations of recycling and waste transfer sites	Deprivation	Positive with transfer sites, negative with landfills	Pye et al. 2008
England Wales	Waste facilities	Deprivation	Waste facilities disproportionally located in more deprived areas	Walker et al. 2003
Macro-level (EU/international)				
EU	Waste sites	SES Community deprivation	Likely, association with health difficult	Martuzzi et al. 2010

2.4 Quality of the living environment

In a large number of studies reviewed, it has been shown that physical and social differences in the living environment play an important role in the type and intensity of deprivation perceived by social groups, but that it is hard to separate the physical and social factors as independent variables. In general, both aspects influence the quality of the living environment and, hence, social equity in neighbourhoods or at larger spatial scales. The general research question 'How is environmental quality in the living environment distributed among social groups?' is central to research in this field. Our review shows that factors such as housing quality, housing density, environmental pollution, green spaces and the average socioeconomic status of people in the neighbourhood all contribute to (in)equalities in the (perceived) physical and social environment.

Table 5: Reviewed studies in the field of inequalities related to the physical and social living environment (darker colour indicates stronger evidence, no colour means no significant evidence for EI)

Geography	Type of env. deprivation	Social inequality	Environmental inequality	Authors
Micro-level (urban/local)				
Vsetin (Czech Republic)	Housing quality Environmental state neighbourhood	Minorities (Roma)	Positive in terms of residential segregation	Matousek and Sykora, 2011
Leicester (UK)	PM10 emissions Multiple deprivation index	Children Minorities	Heterogeneous; with respiratory health of children, not with minorities	Jephcote et al. 2014
Porto (Portugal)	Env. quality Walkability	Individual SES Neighbourhood SES	Heterogeneous; neg. for individual SES, pos. for neighbourhood SES	Robeiro et al. 2016
Amsterdam (Netherland)	Traffic noise Air pollution Green spaces Safety risks	Income	Negative, but low income categories have less access to areas with high levels of env. quality	Kruize et al. 2007
Meso-level (national/multi-local)				
Slovakia Hungary	Environmental quality of rural settlements	Minorities (Roma)	Positive, unequal distribution of env. quality	Harper et al. 2009
UK	Multiple area based environmental deprivations	Income	Positive, also with health impacts	Pearce et al. 2010
Belgium	Housing quality	Income	Positive	Lejeune et al. 2016a
Belgium	Living environment - Environmental - Social - Housing density	Income Education Tenure status	Positive for all combinations, except for air pollution (no EI)	Lejeune et al. 2016b
UK	Brownfield land	North-South	Positive; unequal brownfield land distribution, weak health correlation	Bambra et al. 2015
Netherlands	Possibility for physical activity (as health constituent)	Individual SES Neighbourhood SES	Positive, but direction differs with SES cohort	Van Lenthe et al. 2005
Macro-level (EU/international)				
EU (meta-review)	Indoor pollution Neighbourhood risks	SES, income	Likely, though magnitude of impacts hard to aggregate	Braubach and Fairburn, 2010

At the micro level, the most severe inequalities in the physical and social environment are shown to be related to minority populations, in particular to Roma communities. Scholars point at distributive and procedural injustices contributing to socio-spatial isolation of Roma communities in Vsetin (Czech Republic). In Leicester, polluted and multiple deprived living environments are shown to be linked to respiratory health of children, but not with minorities. In Porto, the physical environment and environmental quality, including walkability, could not be related to individual SES, but positive to area based SES (meaning that environmentally deprived areas show to have a lower average SES, but that individuals with a lower SES within those areas could not be associated with poorer environmental conditions than individuals with higher SES). In Amsterdam, negative externalities in the environment seemed to be accepted by inhabitants, where acceptance is related to wealth compensation in the region (higher pollution by – in this case – an airport, but compensated by economic development and higher area income).

At the meso-level, Slovakia and Hungary are also found to distribute poorer quality living environments to Roma communities. In the UK and in Belgium, income inequality has been shown to correlate with the burden of multiple area-based deprivations, as well as to housing quality in particular (in Belgium). The UK shows an unequal distribution of polluted soils among the population in the North and South, but without significant differences in health impact. In the Netherlands, income inequality has been associated with area characteristics supporting physical activity in the living environment; poor income groups tend to commute more often by bike or foot, but show less physical activity (than higher income areas) in relation to leisure activities.

At the macro-level, evidence of social inequities and environmental risks associated with housing and residential location has been reviewed by Braubach and Fairburn (2010). The authors found a limited number of adequate studies and only for a few countries. Most studies identified that less affluent population groups are most exposed to environmental risks in the place of residence. Inequities were reported for risks experienced within the neighbourhood such as exposure to dampness, chemical contamination, noise, temperature problems and poor sanitation, as well as to higher traffic-related pollution and shorter distances to pollution sites. Increased exposure to environmental risks within more affluent population groups was rarely identified. The authors conclude that social status, in particular low income, is strongly associated with increased exposure to environmental risks in the private home or residential location. However, hard conclusions on the magnitude of inequalities in the living environment were hindered by the variety in the applied methods in the different studies and the lack of data for many countries.

2.5 Climate change and natural hazard risk

Climate change confronts a large number of stakeholders with evidence of inequality and claims of environmental injustice that reach from the local to the global level, posing threats to the poorest and most vulnerable people around the world (Walker, 2012). Climate related inequalities can largely be traced to extreme weather effects, including heat waves, cold temperatures, droughts and floods. Occurrences of such events in the European context are likely to increase, in particular in terms of floods and periods of heat stress (Pachauri et al., 2014). At the policy level, it is becoming increasingly important to find a just framework that can deal with environmental change and (migratory) consequences (Sgro et al., 2013). The now following shows a selected number of research conducted in the field of climate related inequalities in the European context. Reviewed studies show a wide diversity in topics and methods, we therefore give a graphical overview of the countries where EI research has been carried out in regarding access to resources, such as energy or green spaces. The papers are referenced in the text.

Flooding

Werritty et al. (2007) assessed **social impacts of flood risk and flooding in Scotland**. They found that the intangible impacts (such as emotional losses, living in temporary accommodation and dealing with insurers) were more severe than the material losses particularly amongst the elderly and low income households. The level of economic protection that groups had to help them cope with flooding were also assessed, and showed that tenants in social housing had the lowest levels of protection (Pye et al., 2008).

Understanding the **differential impact of hazardous events on groups in society** is critical to reducing the negative impact of natural disasters such as earth quakes, landslides and flood hazards on vulnerable groups in society. (Frigerio and De Amicis, 2016) define a social vulnerability index (SVI) for Italy by applying an inductive method, where measurements of social vulnerability are based on the underlying factors that influence a community's or area's ability to prepare for, deal with and recover from an impact. The most vulnerable areas could not be predicted by a single indicator map but by a pattern of ageing, unemployment and population growth. Furthermore, results show a clear spatial clustering between advantaged and disadvantaged groups, indicating some degree of segregation in Italy.

With respect to flooding risk and insurance in the UK, research of authoritative data from government and the insurance industry shows that the **financial burden of flood risk management costs and insurance provisions tends to shift away from the taxpayer to the ones that are at risk.** The authors conclude that any increase in flood frequency and severity in the UK is likely to affect the financially deprived communities to a greater extent than others, not least because they are less likely to be insured (Penning-Rowsell and Priest, 2015). In England, local stakeholders play an important role in funding the financial gap for implementing structural flood protection (Thaler and Hartmann, 2016). Flooding in most hotspots in Germany and in The Netherlands is uninsurable. It can thus be concluded that social inequalities of flood risks depend on the social-political context at the local or national level.

Heat stress

*The **relationship between climate and heat related mortality** has been extensively studied (see a.o. Mora et al. (2017)). During the heatwaves of 2003, 2006 and 2007, many European countries faced the impacts of extreme heat. As a result, health impacts received recognition among many European countries and resulted in various health action and climate adaptation plans (EEA, 2012). The risk of heat illness exists for the whole population. However, epidemiological studies have identified broad groups that are at higher risk of dying during a heat wave or from heat stroke, particularly the elderly.*

In the European population, Ebi et al. (2006) showed that **the elderly are most affected** by both heat and cold. Furthermore, several studies have specifically examined the interaction between temperature and socioeconomic status, suggesting that lower socio-economic groups are at greater risk of the adverse effects of extreme temperatures than others. Other studies, however, found no evidence of such associations (Pye et al., 2008).

Another approach to empirically capture aspects of heat-stress related inequalities has been taken by Wiesböck et al. (2016) in the city of **Vienna, Austria**, who derived descriptive results from qualitative case studies, i.e. two families with different ethnical backgrounds in Vienna: a Turkish family and an Austrian family. The scholars find structural vulnerabilities in relation to potential heat stress in the family with a Turkish background.

For example, ethnic segmentation in employment (e.g. cleaning) produces a gap in occupational status which carries adverse health consequences. This leads to higher susceptibility for climate related heat stress. It is concluded that, in the face of projected increases in the number of heat waves, it is essential to complement quantitative approaches with qualitative perspectives to understand heat-related health outcomes in terms of social and environmental inequalities.

2.6 Access to resources

In a recent publication on transport justice (Martens, 2016), it is argued that access to resources over space requires the fair treatment of people, not of places. Access to resources from a social and environmental perspective includes, but is not limited, to: (1) access to public facilities, (2) access to energy services, (3) access to green spaces and (4) access to (green) transportation systems. Access to basic public facilities in the environmental domain includes access to potable water, solid waste disposal and sewerage and to affordable (social) housing. Provisioning systems for these services can be considered fundamental for the fulfilment of subsistence needs at the household level. In Europe, energy services are increasingly privatised and therefore treated separately in this review. Reviewed studies show a large diversity in topics and methods, we therefore give a graphical overview of the countries where EI research has been carried out in relation to access to resources. The papers are referenced in the text.

Access to basic (public) facilities

In the EU, public provisioning systems of basic environmental services generally cover a large majority of the population. The trend towards urbanisation and out-migration of sparsely populated rural areas contributed to the increase in coverage of such services.

From an environmental inequality perspective, however, research shows that public services are unequally distributed with respect to minorities, in particular Roma communities in several **Central and Eastern European countries** (Filčák, 2012b; Molnár et al., 2012). Although the adoption of the EU's racial equality directive (in 2000) greatly enhanced legal protection against racial and ethnic discrimination, including access to public services, Filčák (2012a) revealed higher exposure to risk, or worse access to, environmental resources in the **Roma settlements** compared to their non-Roma neighbourhood. The largest inequality existed in access to clean water. The Roma were also more often affected by flooding and pollution exposure. The same pattern is described by Steger et al. (2007) in a case study in eastern Slovakia. Waste management and the problem of illegal dumps were clearly perceived as a focus area in the Roma communities. Typical of many Roma communities in Europe, the lack of sufficient sewerage and waste treatment creates a context for cumulative negative health impacts associated with contagions related to poor living conditions (Harper, 2009).

Access to energy

Although there is no clear definition or measure of 'access to energy', energy inequality is generally related to energy poverty, i.e. problems or inability of vulnerable households to access and afford sufficient levels of energy services, in particular for heating. It has been estimated that, at the peak of energy prices before 2009, more than 70 million people within the EU were living in conditions of fuel poverty (EPEE, 2009).

First only recognized in the UK and Ireland, a growing public recognizes the problem of energy deprivation throughout the EU, in particular in households in Eastern, Central, and Southern Europe (Bouzarovski et al., 2012).

In the **UK**, energy poverty links to the complex nexus of income, energy prices and energy efficiency, including factors on the supply side, such as energy scarcity and the deployment of renewable energy sources and (related) network investments. These factors are claimed to have increased the financial burden for the end-user. Finally, a factor of particular importance in relation to equitable resource use and access to energy, is the fact that energy poverty is increasingly recognised as a systemic inequality related to social, ecological and economic differences between income groups (Berger and Bregenz, 2012; Bouzarovski et al., 2012).

In **Austria**, some research has been carried out into the issue of energy poverty. One of the first studies into the issues showed the financial inability of low income households to increase their energy efficiency (Proidl, 2009). Based on micro-census data, it has been shown that the lowest income quartile spends 8.3% of their income on energy, whereas this is only 3.3% in the highest quartile in 2009/10. In a qualitative approach, Brunner et al. (2012) showed that (1) income poor households have limited potential to increase energy efficiency (2) energy poor households tend to live under general conditions of poverty, (3) the property owner-tenant relation prevents improvements in housing quality.

Dubois and Meier (2016) investigated the topic of fuel or **energy poverty at the 'macro' scale in the EU**, i.e. using proxy indicators for (1) energy services deprivation available at the national level (EU SILC survey), (2) energy affordability and (3) for energy efficiency. It has been shown that, although energy poverty is a larger problem in poorer member states, inequality mainly affects low income households in France, Spain, Hungary, Poland, Greece, Malta and Latvia. In N-W Europe, i.e. the UK, Netherlands, Denmark and Germany, energy poverty occurred in specific household groups, for example low income households with children in the Netherlands and Germany, whereas single households in Denmark were the main affected group.

Access to green spaces

Natural and semi-natural green spaces not only have micro-climatic, cultural, economic and social importance, but also health-promoting capacities (Pauli and Hornberg, 2010). They serve as exercise and recreation areas which can enhance mental and physical health (Frumkin, 2003) as they motivate a wide range of age groups to exercise (Maas et al., 2008). Size, condition, and amenities of green areas strongly associate with the subjective perception of safety in the living environment and with individual preferences of leisure activities (Spitthöver, 2000).

In **England**, scholars find that the least deprived population groups are two to three times more likely to be living near to a Local Nature Reserve, whereas the more deprived populations are the least likely to be living near to woodlands (Fairburn and Smith, 2008). In **Scotland**, it was shown that people living in deprived areas were more likely to in the vicinity of new woodlands, which has been promoted by social policy. The example indicates that there is no simple relationship between deprivation and green space (Fairburn et al., 2005). Provisioning of urban green spaces in **Berlin** has been investigated in relation to the quality of life of residents, differentiated by age and immigrant status, without finding a significant correlation (Kabisch and Haase, 2014).

Access to transportation systems

Martens (2016) investigated the issue of inequality in terms of access to transportation systems in Amsterdam. A person's transport mode accessibility to work has been related to the person's residential location and to ownership of a car or not (as an indicator of income). It was shown that people dependent on public transportation perceived a lower than average accessibility of transport mode to work, also in comparison to car users during peak hours of road congestion. The author claims that the empirical evidence is an argument for policy makers to give priority to improvement of public transportation accessibility of non-car owners. Although the research largely neglects climate friendly and healthy transportation modes, in particular biking and the potential of improved biking facilities, it is shown that environmental inequalities exist in the field of mobility services, and that lower income groups are likely to be more affected than high income groups.

2.7 Cumulative impacts

'Cumulative impacts' refer to the total harm to human health and the environment from combinations of stressors over time (Scammell et al., 2014). Scholars claim that, similar to the cumulative impacts that alter global ecosystems (MEA, 2005), chronic human diseases may typically not arise from single causes, but from complex interactions between individual, social and environmental conditions (Schettler, 2006). Cumulative impacts are examined at three levels: ecological, community and at the individual (health) level (Krieger, 2001), but neither standard definitions agreed upon 'cumulative' or 'multiple' impacts, nor are there standard approaches to their measurement. The challenge lies in understanding the interactions between different types of stressors, and their combined impact on individuals who vary significantly in their susceptibility to impacts. To advance knowledge and understanding in this complex field, interdisciplinary approaches and methods need to be further developed in order to effectively incorporate cumulative impacts in health impact assessments (Pye et al., 2008).

One of the few studies looking at evidence for cumulative impacts, investigated the influence of the living environment in relation to health inequalities among children in Europe (Bolte et al., 2010). The authors conducted a literature research on empirical studies in the field and discovered a pattern which indicates that the living environment of children in low socio-economic positions, as a particularly vulnerable group, is associated with an increased exposure to traffic related air-pollution, noise, lead, tobacco smoke, inadequate housing and residential conditions as well as less opportunities for physical activity. However, due to differences in methodologies, and a lack of data for many topics and countries, it was not possible to analyse – and reveal patterns of – cumulative impacts and health inequalities in a coherent approach.

2.8 Conclusions

Based on an extensive review of empirical studies and reports at the local, national and EU-wide level, potential environmental inequalities have been identified in relation to seven environmental fields: air pollution, noise pollution, industrial siting, waste siting, the quality of the living environment, access to resources and climate change & natural hazard risk. Figure 2 gives a graphical overview of EU member states where research on environmental inequality has been carried out, either at the local or at the national level, and irrespective of the evidence of EI. Moreover, if countries are unmarked, this does not necessarily imply that the country does not show incidences or patterns of EI; it only shows that there has not been any known EI related research effort. Interestingly, except for one study on air pollution in Sweden, no empirical EI studies have been found for Scandinavian countries. This may be related to the social investment approach and progressive environmental policies – focused at reducing inequalities – in the Nordic countries (Bohnenberger, forthcoming). However, Bradley et al. (2008) provide evidence for a mismatch in distributive inequalities in Sweden (high income groups with higher environmental footprints) and policies that tend to support 'eco-friendly' lifestyles of low income groups, thus keeping the driver of global, future and internal EI out of scope.

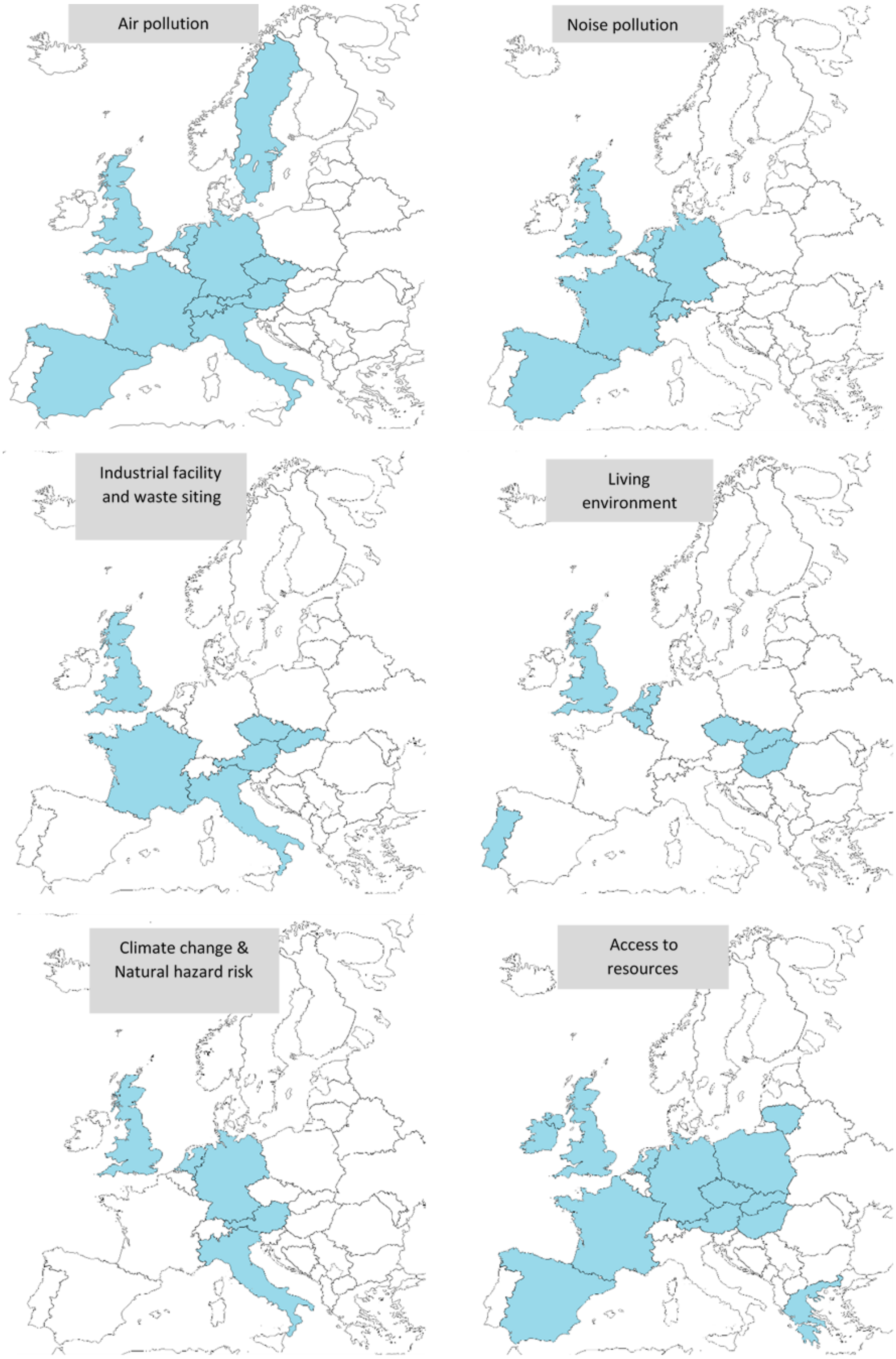


Figure 2: Overview of EU member states that conducted EI related research, per environmental field

The 7 environmental fields indicating potential patterns of environmental inequality can be grouped into three dimensions, each having a distinct relation to production and consumption activities in the EU context:

A. **Access to resources** supporting the fulfilment of subsistence needs, of which the most important are basic resources such as food, water, energy and affordable (social) housing. In a developed country context, resources include services such as waste transfer, green spaces to fulfil leisure and activity needs, as well as adequate accessibility to (green and) efficient transportation services. Rural minorities and other low income groups are most affected by limited access to resources, in combination with generally poor housing quality. That accumulates the impacts on health and leads to multiple deprivations such as cold stress and poor nutritional quality. EI related access to basic resources is concentrated in a limited number of specific socio-spatial contexts, but increasing land, housing and energy prices have started to affect larger areas and groups of vulnerable households. Inequalities in access to resources points at issues related to the provisioning or the affordability (prices) of basic and/or public resources (fresh water, affordable energy, transportation services, green spaces) in the spatial context and, hence, at the need to embed EI/EJ in the social-ecological policy context.
B. **Burden of pollution** Air pollution is the most widely distributed environmental inequality in the European context; mainly related to traffic in urban areas but also to industrial facilities and waste sites. In CEE-countries, air pollution is also associated with coal-based energy grids. Noise pollution is closely related to traffic sources. Several countries still show evidence of potential exposure related to point sources of pollution (industrial facilities). Housing quality is shown to be a critical factor in relation to the potential impact of environmental exposure; people with poor housing quality and/or living in poor neighbourhoods show to be most susceptible to air and noise pollution. Low income groups, children, immigrants, low educated and unemployed people all tend to be disproportionally affected by environmental pollution. Vice versa, the 'double blessing' phenomenon, where high income groups – generally accompanied by higher environmental footprints - benefit from higher quality living environments, points at the issue of responsibility and distribution policies from an EJ perspective.
C. **Climate change and natural hazard risk.** The third dimension points at inequalities in the distribution of the adverse climate risks and impacts related to economic activity. Heat, floods and other adverse weather impacts show patterns of increasing frequency in urban centres, mountainous and flood-prone areas, where elderly, rural poor and uninsured people, are most vulnerable for property losses, heat stress and related health impacts. To our knowledge, this type of inequality has not been analysed in a structured, quantitative approach from an environmental inequality perspective. Current impacts may still be limited in the European context, but are very likely to increase (IPCC, 2014). Furthermore, climate change, and its global complex of causes and effects, raises questions of responsibility for (potential) impacts in vulnerable regions worldwide, pointing at the potential role of EJ in global institutional frameworks.

Next to the three dimensions, environmental inequality can be distinguished by three interrelated mechanisms: (1) **environmental exposure,** including differential exposure, i.e. the fact that disadvantaged and/or vulnerable groups are more often exposed to higher levels of environmental pollution, (2) **Social susceptibility**, including differential susceptibility, where disadvantaged or vulnerable groups often are more susceptible to the environmental exposure. Susceptibility is often related to poor housing conditions, neighbourhoods with poor environmental quality and to a lower development level in terms of capabilities (Preisendörfer, 2014). Finally, exposure and susceptibility together determine the actual **social impact** (3). Impacts mainly involve health impacts or other, often multiple forms of deprivation at the level of the *affected social group,* which is not always the lowest income group, but may concern children, elderly, unemployed, or workers in less developed countries among others (see Table 6).

Table 6: Dimensions and mechanisms of Environmental Inequality

EI Dimension: **EI mechanism:**	**Access to resources**	**Burden of Pollution**	**Climate change & Natural hazard risk**
1. Exposure	Poor access to public and other basic services	Emissions Noise Siting patterns	Heat Floods Land-slides Snow avalanches
2. Susceptibility	Rural areas Poor housing quality Capabilities	Poor housing quality Poor neighbourhood quality Commuter patterns Individual factors Capabilities	Urban centres Poor housing quality Area-specific (flood-plains) Capabilities
3. Social impact	Health Deprivation Isolation Time	Health Deprivation	Heat stress/ health Property damage Deprivation Death
Vulnerable group (of being disproportionally affected)	*Rural minorities* *Rural poor* *Carless people*	*Low income groups* *Children,* *Immigrants* *Low education* *Unemployed* *Global South*	*Elderly* *Rural poor* *Farmers* *Uninsured* *Global South*

Based on the above, we can conclude that environmental inequality is a complex problem which involves multiple dimensions and mechanisms at different spatial levels, and that are often intertwined. For example, noise pollution often comes together with traffic related air pollution, industrial siting is associated with air pollution, noise pollution, energy- and material use, waste flows and global climate change. As a result, there is an emerging notion of the potential risks related to the loss of causal relations in the explanatory framework that drives patterns of EI, as well as to the phenomenon of cumulative impacts (multiple simultaneous impacts). Several countries in the EU show evidence of multiple environmental inequalities, in particular the UK, Germany, the Netherlands, France, Italy and the Czech Republic.

With respect to Austria, a limited number of (non peer-reviewed) studies have explored potential patterns of EI. These studies include industrial siting at the national level, indoor air quality in classrooms in large cities, traffic noise in Vienna, flooding risk in Austria, heat stress in Vienna and access to energy, or fuel poverty, in Vienna. None of the studies give evidence for significant environmental inequalities, although studies on noise pollution, industrial siting and energy poverty point at a potential pattern of double burden areas (high burden, low income) and double blessing (low burden, high income), as compared to other combinations (high burden, high income and low burden, low income). Peer-reviewed empirical research into EI patterns in Austria is largely lacking, in particular in the field of traffic and industry related environmental inequalities.

3. Methods and data

The previous chapter showed that environmental inequalities can be grouped into three categories: (a) access to resources, (b) burden of pollution and (c) climate change and natural hazard risks. The literature review found air pollution to be the most researched environmental inequality issue in Europe; mainly related to traffic in urban contexts. Therefore, the primary aim of this chapter is to provide methodological approaches and data sources that have been or can be used for EI assessments in relation to local or spatially explicit patterns of air pollution.

As three of the four methodological approaches, described in chapter 3.1, use spatial data, it is possible to analyse other EI dimensions at the micro-level, when the data sets are spatially-explicit or can at least be converted into such format. Note that this applies to both the environmental and the socioeconomic data. The described approaches are therefore also applicable for the spatial assessments of other exposures, such as noise, heat, flood risks or access to public or green spaces (see Table 7 below).

An additional objective of this chapter is to introduce another set of methods, i.e. multi-regional input-output (MRIO) analysis, which is in principle well suited for assessments of all three environmental dimensions, but in particular for (b) Burden of pollution and (c) Climate change (in terms of carbon emissions). As MRIO analysis is a vast research field on its own, an extensive discussion of its potential applications for EJ and EI assessments would be beyond the scope of this chapter; hence only a brief introduction into global drivers and patterns of EI is included in section 3.2.

Chapter 3 is structured as follows: Section 3.1 gives a short introduction into the most basic principles of any statistical assessment, in this case to air pollution exposure, followed by a description of the main methodological approaches and available databases for spatially explicit EI research. This section includes a brief overview of potential data sources for the case of (i) Europe and (ii) Austria and Vienna. Section 3.2 provides a brief introduction into MRIO analysis and related data availability. The chapter ends with a conclusion (section 3.3).

3.1. Methods and data to analyse micro-patterns of EI

The basic principles

In environmental inequality assessments, the direct or indirect comparison of at least two groups of people is central. Each group can be identified by its characteristic attributes (poor vs. rich or African American vs. Hispanic) which are associated with specific variables (income or ethnicity). In a nutshell, the main goal of environmental inequality assessments is to determine whether or not social variables like income, ethnicity or health are dependent on or correlated with environmental variables such as air pollution. In statistics, dependence or association is any statistical relationship, whether causal or not, between two variables. Correlation most often refers to the extent to which two variables have a linear relationship with each other[2]. Figure 3 illustrates the basic relationships between variables of relevance in the environmental inequality context.

[2] Familiar examples of dependent phenomena include the correlation between the physical statures of parents and their offspring, and the correlation between the demand for a product and its price.

Figure 3: Stylized representation of the variables associated with environmental inequality

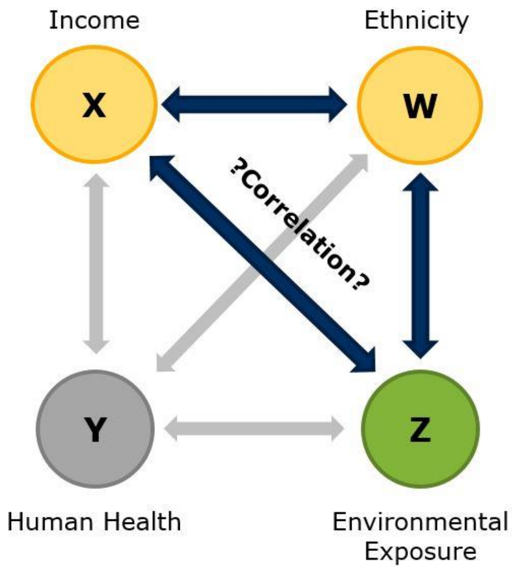


Figure 3 shows four of the most important variables in environmental inequality research (taken from the context of the United States): ethnicity, exposure to air pollution and to a lesser extent income (for example compare with Zwickl et al., 2014). Although many studies don't look into potential associations between environmental exposure and health, it is important to stress that income or environmental exposure tends to be correlated with health status (compare with Kawachi and Kennedy, 1999; Lynch et al., 2000). Correlations are useful because they can indicate a predictive or causal relationship which can help to ease the uptake of research findings by policy makers, for example in processes towards environmental justice (Walker, 2012).

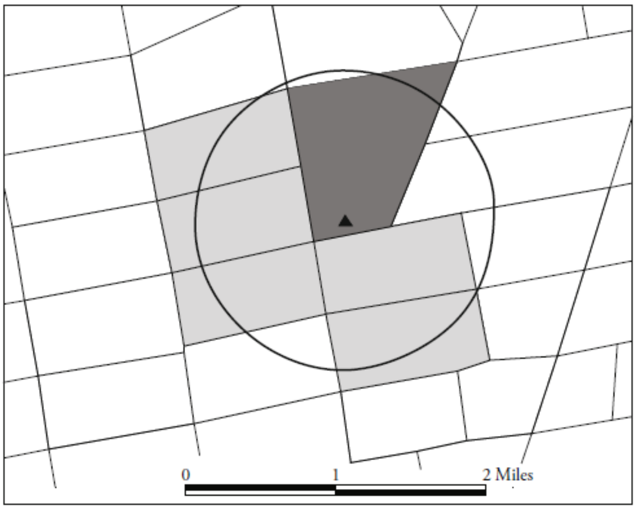
The four main approaches applied in air pollution related EI research

In general, there are four broad groups of methodological approaches for the assessment of exposures to air pollution (or other EI issues within a spatial context):

a) unit-hazard coincidence approaches
b) distance-based approaches
c) risk-based approaches
d) non-spatial approaches

The first three approaches represent various versions of spatial assessments (compare with Mohai and Saha, 2006). As will be shown later, these are the most widely applied ones. Furthermore, there is the group of non-spatial approaches. This group includes research approaches which make use of methods such as direct field measures or questionnaires. It is important being aware that these four groups of approaches are not mutually exclusive, meaning combinations are possible. Figure 4 illustrates the difference between the first two approaches: unit-hazard coincidence and distance-based.

Figure 4: Comparing unit-hazard with distance-based approach (Mohai & Saha, 2006)



In the early stages of EJ research in the United States (United-Church-of-Christ, 1987), quantitative studies assessed environmental inequality by comparing the demographic and socioeconomic characteristics of predefined geographical units i.e. grid cells that host a hazardous facility or waste site (see the dark grey grid cell in Figure 4) with the characteristics of those units that do not host such a facility (all the other grid cells in Figure 4). This approach, known as the **"unit-hazard coincidence" approach**, does not consider the exact location of the hazard within the host unit (black triangle in Figure 4), or its proximity to nearby non-host units. To overcome those shortcomings, several distance-based methods were developed over time. These approaches seek to account for the precise geographic location of facilities and determine their distance to nearby local units such as zip code areas or census tracts. This is achieved by modelling a circular buffer zones around the facilities (see Figure 4). Distance-based approaches allocate the area of a hypothetical circular buffer zone to the grid cells falling into this zone. Subsequently, socioeconomic or demographic characteristic of the cells inside the circle are compared with the ones outside the circle.

Recently, so-called **risk-based methods** emerged which do not take the detour of indirectly measuring disparities through the proximity to emission sources, but directly via the levels of emissions people are exposed to (for example Moreno-Jiménez et al., 2016). The application of air pollution dispersion models for example tackle the simplified assumption that emissions are evenly dispersed around facilities. Therefore, the so-called dispersion maps not only account for a neighbourhood's proximity to polluting facilities (like the distance-based approaches) but also the local weather conditions and the physical structures at place (e.g. chimney height). Another advantage is that with emissions data, analyses do not stay limited to point sources of emission, but are also able to picture diffuse sources such as traffic, opening the door for addressing new questions related to environmental inequality (Glatter-Götz, 2016). Figure 5 exemplifies the type of data provided by dispersion models showing results for noise (laerminfo.at, 2017) and NO_x exposure (Kurz et al., 2014) in Vienna.

Figure 5: Left: Noise from road traffic 24h-average (laerminfo.at); Right: NOx average values for 2005 (Kurz et al., 2014)

Methods and data in European air pollution-related EI research

This chapter presents the results of the EI method review encompassing 24 studies and reports that assess air pollution exposure in European countries. Note that the present list of studies slightly differs from the review in Chapter 2.1 because of two reasons. First, four studies have been removed because they are lacking transparent descriptions of the methods. Second, two studies which analyse the locations of incinerations (Laurian and Funderburg, 2014) and coal-fired power plants (Frantál and Nováková, 2014) were added to the list because of their close linkages to air pollution assessments. These two studies were originally reviewed in Chapter 2.3. Papers have been reviewed by a structured (country) analysis with an emphasis on the general methodological approach, air pollutant of interest and the socioeconomic indicators (see Table 7).

Table 7: Reviewed studies in the field of environmental inequality and air pollution in European countries

Geography	Type of Pollutant	Social dimension	Authors	Approach
Strasbourg (FR)	PM_{10}, O_3, NO_2,SO_2,CO	SES	Bard et al. (2007)	Risk-based
Strasbourg (FR)	NO2, other	SES	Havard et al. (2009)	Risk-based
London (UK)	PM, BC, PNC,	Income	Rivas et al. (2017)	Direct field measurement
Rome (IT)	Area-based traffic PM	Social classes (income)	Forastiere et al. (2007)	Risk-based
Valencia (ES)	NO2	Pregnant women Social class Ethnicity	Llop et al. (2011)	Questionnaire + direct + unit-hazard
Madrid/Barcelona (ES)	NO2 from traffic	Children, elderly Immigrants	Moreno-Jiménez et al. (2016)	Distance/Risk-based
Malmö (SWE)	Outdoor NO2	Children, SES, affluence	Chaix et al. (2006a)	Risk-based
London (UK)	Traffic related air pollution	Deprivation Geodemographic	Goodman et al. (2011)	Risk-based
Dortmund (DE)	PM10, NOx	Children, migrants	Flacke et al. (2016)	Risk-based
UK Country wide	NO2, SO2, PM10 benzene	SES Urban, rural	Wheeler and Ben-Shlomo (2005)	Risk-based
UK Country wide	NOx, NO2	Age, Poverty, Car ownership	Mitchell and Dorling (2003)	Risk-based
UK Neighbourhoods (NUTS 1)	PM10, NO2	Deprivation, demographics, ethnicity	Fecht et al. (2015)	Risk-based
DE Country-wide	Air and noise	Income groups	Kohlhuber et al. (2006).	Questionnaire
NL (Neighbourhood)	PM10, NO2	Deprivation, demographics, ethnicity	Fecht et al. (2015)	Risk-based
NL (Southern part)	NO2, black smoke	Demographic	Hoek et al. (2002)	Distance/ Risk-based
CHN (Municipalities)	Air & noise	Education, income, nationality	Diekmann and Meyer (2010)	Risk-based
FR (Metropolitan areas)	NO2	SES	Padilla et al. (2014)	Risk-based
FR	Incinerator siting patterns	SES Non-natives	Laurian and Funderburg (2014)	Unit-hazard

IT (Provinces / NUTS 2)	Industrial air pollutants	Demographic	Germani et al. (2014)	Risk-based
IT, SLO, UK	incinerator/landfill & PM10, NO2	Gender, Age, SES	(Forastiere et al., 2011)	Distance/ Risk-based
CZR 39 cities	PM10, SO2, NO2	Income, education, employment	Branis and Linhartova (2012)	Risk-based
CZR	Energy (coal) plant distribution	Demographics, Employment, Education Ethnicity (a.o.)	(Frantál and Nováková, 2014)	Unit-hazard and Distance-based
AT (Vienna, St. Pölten, Graz, Klagenfurt, Villach)	Indoor air quality, a.o. CO2, NO2, PM10, PM2.5,	School children (6-8 yrs)	Hohenblum et al. (2008)	Direct field measurement
AT	Distance to industrial site	Employment Education Migrant background	(Glatter-Götz, 2016)	Distance-based

The results of the analysis of available literature can be summarised as following:

Which are the main data sources and statistical methods? The majority of studies take advantage of data obtained from detailed dispersion models. In this regard it is important to mention that many studies apply a mixed method approach which combines data from less detailed dispersion models with for example distance measures (see Hoek et al., 2002). Another example is the analysis of Moreno-Jiménez et al. (2016) which uses spatial interpolation techniques to obtain dispersion-maps on the basis of different assumptions. However, it seems that (more or less detailed) dispersion models are already available for most of the major metropolitan areas and cities in Europe. In terms of socioeconomic or demographic datasets the main data sources are the national statistical offices which conduct the national population census. With regard to the statistical methods used, most studies apply a simple ordinary least square (OLS) model (for example Havard et al., 2009). A few studies apply multivariate statistics including principle component analysis (Bard et al., 2007; Padilla et al., 2014). Box II gives a detailed description of a method applied to analyse potential EI in income and PM10 at the European level.

Which are the general limitations of the methodological approaches applied in the reviewed studies? With regard to air pollutants such as PM_{10} and NO_2 the most pressing limitation seems to be the fact that most studies were not able to consider indoor pollution. For example, the types of heating and cooking appliances used may represent the largest part of NO_2 exposure. Other limitations may relate to the issue of cumulative impacts (multiple exposures), multiple causalities (complexity in explanatory framework) and to the spatial level, where smaller geographies tend to show higher levels of EI than the more aggregated level (see also Box II).

Which other important issues should be taken into account? In general, population density and environmental pollution tend to be correlated, meaning that EI measures have to be based on population-weighted averages, reflecting the average environmental burden experienced by the population in the spatially explicit context (see Box II). Furthermore, an issue that has been mentioned by a small number of studies is a potential bias stemming from the statistical phenomenon of "spatial autocorrelation" (Chaix et al., 2006b; Havard et al., 2009; Padilla et al., 2014). Spatial autocorrelation stands for the non-independence of data, e.g. air pollution from a highway in one grid cell, leading to elevated pollution levels – and health impacts - in neighbouring grids. Controlling for spatial autocorrelation can strongly reduce the strength of the association, e.g. between air pollution and socioeconomic status, and supporting causalities. Several methodologies can be used to identify the existence of spatial clustering (Haynes et al., 2001). It is of high importance to control for spatial autocorrelation when assessing the association between spatially-explicit variables in order to allow for a sound and robust analysis of EI.

BOX II: Example of method and data in air pollution related EI research

Particulate air pollution and health inequalities have been investigated in a temporal European wide analysis by **Richardson et al (2013)**. The starting point is existing evidence for the fact that groups or areas with lower socioeconomic status (SES) typically have poorer health than more advantaged people or areas. The scholars aimed at investigating unequal exposure to health-damaging characteristics of the physical environment at the EU-wide level. The following research questions have been formulated:

1. To what extent do potentially health-damaging levels of PM_{10} vary across EU regions?
2. Are regions with lower average household income disproportionately exposed to lower air quality?
3. Are populations of regions with lower average household income disproportionately susceptible to the health effects of lower air quality?

The **method** includes a three-stage quantitative analysis: (1) a spatial and temporal PM_{10} concentration analysis across NUTS 2 regions, (2) correlation analysis between mean PM10 concentrations for regions grouped by income quintiles by average household income, and (3) assessment of the relationship between air pollution (PM_{10}) and health (regional mortality rates) in ordinary least square (OLS) regression analyses. **Data** included average household income and ambient PM10 concentrations for 2004 and 2008. Household income, estimated as purchasing power consumption standard units (Eurostat), has been used as an indicator of SES. PM_{10} has been estimated from the EEA's public air quality database 'AirBase' (10x10 km grid), containing monitoring data from the European Air Quality Monitoring Network. As population and PM pollution tend to be correlated, population-weighted regional PM averages have been calculated to reflect the average air quality experienced by the population. Health data, finally, are based on age- standardized and sex-specific premature mortality rates related to diseases with a plausible link to PM_{10}, including respiratory disease, circulatory disease and chronic liver disease at the NUTS 2 level (Eurostat).

The **results** of Q1 (listed above) showed that PM_{10} concentrations are greatest in southern and Eastern Europe, that the majority of regions exceed the WHO guideline (20 $\mu g.m^{-3}$), but that the EU threshold (40 $\mu g.m^{-3}$) is rarely exceeded. With respect to Q2, significant negative correlations between household income and pollution were found across Europe. Lowest income regions are exposed to highest PM levels, largely located in Eastern Europe, highest income quintiles are also exposed to higher than average values, mainly in Western Europe, while intermediate level income areas experience the lowest PM10 values. With respect to Q3, it was found that PM_{10} is more strongly associated with plausibly related mortality outcomes in Eastern than in Western Europe. Populations of lower income regions appeared more susceptible to the effects of PM_{10}.

The importance of scale was highlighted in the **discussion** as evidence for environmental inequality has clearly been found for Eastern Europe, but not for Western Europe where pollution levels are relatively low and the most polluted areas generally are high income regions. The association between PM_{10} and health indicate a higher susceptibility in Eastern Europe, but other factors such as physical inactivity, nutrition, high blood pressure and other factors than smoking (for which the results have been corrected) may have influenced the results. With respect to limitations in the method, air pollution captured ambient air quality for each region, but this does not necessarily equate with the actual exposure to the people, which is also affected by indoor air quality and individual activity patterns. Furthermore, the analysis did not recognize the simultaneous multiple exposures experienced by populations (cumulative impacts). Finally, as other researchers found opposing results by applying the same method at different levels of aggregation, it can be concluded that the level of aggregation (NUTS 2 level) is high for this type of research. Further analysis at smaller geographies is recommended as it is likely that wider inequalities will be found, due to a greater range in pollution and SES values.

Data availability for EI studies

Europe-wide

As shown in the method review before, dispersion models are already available for many metropolitan areas and cities in Europe (e.g. London, Madrid, Malmö, and Dortmund). Furthermore, in terms of socioeconomic or demographic datasets the main data sources in the reviewed studies are the national statistical offices which conduct the national population census. Nevertheless, in the following we will give a brief overview of the most important spatially-explicit Europe-wide data sets that are available for the assessments of EI.

With regard to socioeconomic data, the **European Regional Database** (ERD; Cambridge Econometrics, 2006) is the primary source for spatially explicit, Europe-wide, disaggregated economic sector data. Data are available at the NUTS 3 level of disaggregation - except for some indicators limited to the NUTS 2 level. Multiple indicators on e.g. employment, GDP, gross fixed capital formation, hours worked and demography are provided. Time coverage is from 1980 to 2012 (data release July 2015). However, one major drawback of the ERD is that it is not publicly available, meaning only registered users have permission to access the data. Besides the ERD, to the knowledge of the authors, important Europe-wide data source providing socioeconomic and demographic data for spatially-explicit assessments (foremost NUTS 2 level but also some indicators for NUTS 3 level) is **Eurostat's European regional statistics** (Eurostat Regional Yearbook, 2012) and the, related, territorial database 'LUISA'[3]. The European regional statistics comprise spatially-explicit accounts of e.g. health, education and labour, whereas LUISA contains a large number of socio-demographic and environmental databases. However, the major drawback for both is the moderate spatial resolution (NUTS 2) for most of the indicators.

The **Pollutant Release and Transfer Register** (E-PRTR; EEA, 2017b) is the only Europe-wide and spatially explicit environmental database available today that can be used directly for EI assessments. The E-PRTR provides key environmental data from industrial facilities in European Union Member States including Iceland, Liechtenstein and Norway free of charge. The E-PRTR contains data reported annually by approximately 30.000 industrial facilities covering 65 economic activities across Europe. For each industrial facility, information is provided concerning the amounts of pollutant releases to air, water and land as well as off-site transfers of waste and of pollutants in waste water from a list of 91 key pollutants including heavy metals, pesticides, greenhouse gases and dioxins for the year 2007 onwards. Some information on releases from diffuse sources is also available. However, two major drawbacks exist. First, a facility has to report only if it falls under one of the 65 E-PRTR economic activities and exceeds specific emission and/or capacity thresholds. Such capacity thresholds for thermal power stations are e.g. the heat input of 50 megawatts or the capacity of 3 tons per hour for non-hazardous waste incinerations (European Commission, 2006). So for example, if a waste incarnation's capacity is less than 3 tons per hour, the E-PRTR will not report this facility. All industrial facilities that do not exceed a specific emissions or capacity thresholds are not listed in the E-PRTR. Second, the coordinates of the industrial facilities that are reported in the PRTR facility reports are in many cases erroneous. For example, in a case study carried out for Austria, 55 of the total 247 sites in Austria had to be corrected due to imprecision of the geographical data or defectiveness. As the accurate location of the emission source is crucial for the analysis,

[3] http://data.jrc.ec.europa.eu/dataset?q=LUISA&sort=sort_criteria+desc

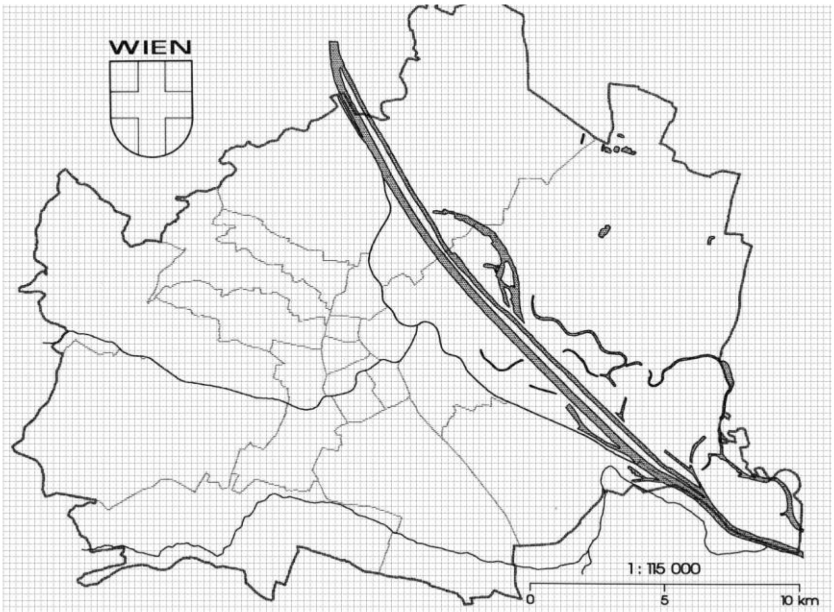
in that study, all sites had to be controlled manually using information from, for example, Google Maps (Glatter-Götz, 2016).

Austria & Vienna

After having discussed methods and datasets in the European EI literature we now turn to the situation in Austria. In general, the data availability for Austria is good, which enables EI assessments applying the methodological approaches described above, such as the risk-based approach.

Spatially explicit socioeconomic data can be sourced from the **national statistics office (Statistik Austria)**. Data on higher aggregated geographical units, such as federal states (Bundesländer) or districts (Bezirke), can be downloaded free of charge from the official Statistics Austria website. Whereas higher detailed socioeconomic data requires the payment of a fee. Depending on the variables of interest and the geographical scope, costs range between 4.000 and 14.000 € per dataset. The highest level of spatial data available is a 250 by 250 meter grid cell. Further information can be found at the regional statistics registry of Austria (Statistics Austria, 2017). To provide an indication for the geographical detail of available data, the following graph shows the 250 by 250 meter grid for the city of Vienna.

Figure 3: Illustration of the 250 by 250 meter grid for the city of Vienna



With regard to the environmental dimension, there is a good data availability for Austria: Most of the datasets are of high spatial resolution and free of charge. For example, noise pollution maps for metropolitan areas is provided by the platform "Lärminfo.at", maintained by the Austrian Ministry for the Environment (laerminfo.at, 2017). Maps assessing flood hazards are available from the same Ministry (BMLFUW, 2017). Various other relevant GIS datasets for Austria, such as the spatial distribution of public green spaces, can be sourced free of charge (Open Government Data, 2017). With regard to dispersion models, we found only one academic study that made use of this kind of data (Kurz et al., 2014).

3.2. Methods and data to analyse global drivers and macro-patterns of EI

In an increasingly globalised economy, issues of environmental inequality should not only be analysed from the local (territorial) perspective, but also from the global perspective, i.e. assessing inequalities in the distribution of access to resources, pollution or contribution to climate change stemming from the specific spatial patterns of international trade, production and consumption. Although these issues have not yet been analysed within the framing of environmental inequality, we consider this aspect as an important upcoming topic and therefore provide a brief introduction to available methodologies and data sources that can be used for assessments of the global dimension of EI.

Methods to assess global impacts

Methods to assess the world-wide interlinkages between environmental pressures, international trade, manufacturing and final consumption have improved significantly over the past few years (Giljum et al., 2013). The approach most widely applied for consumption-based (i.e. footprint-type) assessments at the country level is **multi-regional input-output (MRIO) analysis**. MRIO models link domestic economic structures of a large number of countries with bilateral trade data on the product level and thus provide a detailed representation of international supply chains in the global economy (Tukker and Dietzenbacher, 2013; Wiedmann et al., 2011). Extending the core MRIO model with environmental data allows quantifying the direct and indirect resource use and the different types of pollutants (e.g. PM or NOx) embodied in internationally traded products and consumed in end-markets (Teixidó-Figueras et al., 2016).

Environmentally extended MRIO models have already been applied to various environmental pressures, including GHG emissions (Andrew et al., 2013; Wiebe et al., 2012), air pollution (Kanemoto et al., 2014; Meng et al., 2016), nitrogen pollution (Oita et al., 2016), water use (Chen and Chen, 2013; Lenzen et al., 2013), land use (Weinzettel et al., 2013) and material use (Bruckner et al., 2012; Wiedmann et al., 2015). Also related environmental impacts embodied in international trade have been investigated, including deforestation (Karstensen et al., 2013), water scarcity (Lenzen et al., 2013a) and biodiversity loss (Lenzen et al., 2012; Oita et al., 2016).

Studies based on MRIO assessments can reveal inequalities in the appropriation of global natural resources by different countries world-wide (see Box II below) as well as different patterns of environmental impacts determined by global patterns of production, trade and consumption. Putting these assessments in the context of EI/EJ issues is a new research field and only a few studies exist so far, which indicate, how these global drivers impact local population and their living environments (Flach et al., 2016; Godar et al., 2015). But large-scale research projects are currently ongoing to advance methodologies for establishing these links on a fine geographical scale.[4] Box III in the next chapter also explains the potential contributions of these studies to the EI/EJ debates.

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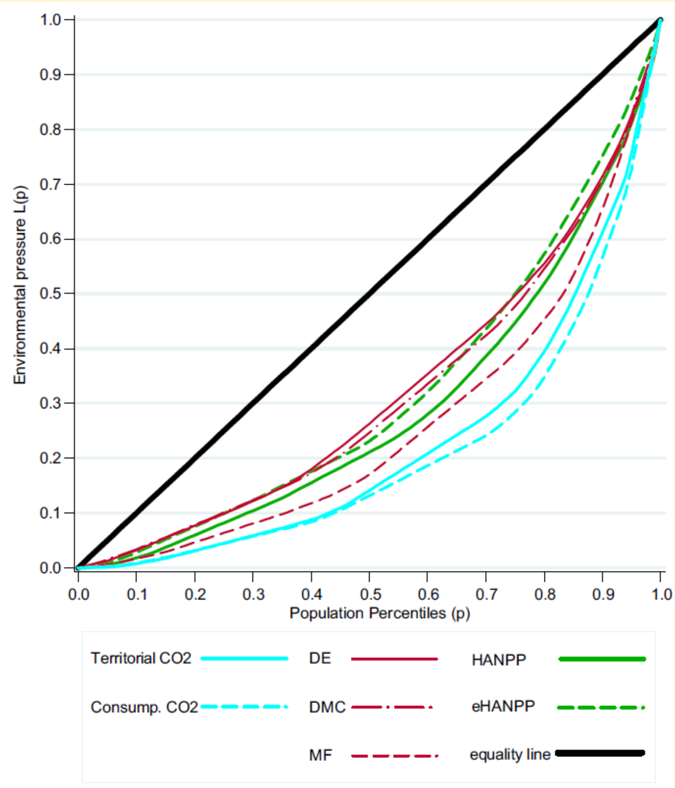
[4] See, for example, the "FINEPRINT" project by the Sustainable Resource Use group at WU Vienna (https://www.wu.ac.at/en/ecolecon/research/sustainable-resource-use/erc-fineprint/).

BOX III: Global inequality of environmental footprints

Teixidó-Figueras and colleagues (2016) analysed the international distribution of various resource use indicators. The assessment encompassed both territorial (national production) and footprint (national consumption) indicators for land-related pressures (human appropriation of net primary production, HANPP), for material use (domestic material extraction and consumption and material footprint), and for carbon emissions (territorial carbon emissions and carbon footprints). In general, the authors conclude that inequality tends to be higher for footprint indicators than for territorial ones. Especially carbon emissions are the environmental pressure that shows the highest international inequality. The following graph illustrates the globally unequal distribution of assessed resource use indicators.

Lorenz curves of environmental indicators (Teixidó-Figueras et al., 2016)



As can be seen from the figure, the consumption indicators of greenhouse gases and raw materials (the blue resp. red dashed lines) are more unequally distributed then the territorial counterparts (continuous line) which highlight the importance of international trade. For example, approx. 20% of the global population account for approx. 70% of the global carbon footprint. The authors show that international trade worsens environmental equity in terms of energy and material use. When resource use is measured on a territorial basis, environmental inequality tends to be lower and more tied to geographic endowments and demographic characteristics. However, once the resource use indicator is trade-corrected, i.e. measured as a footprint including elements embodied in goods and services, then its international inequality tends to be higher and more linked to economic factors. This is true for material and fossil energy (carbon emissions) indicators.

Data bases for global studies

In the past few years, several data bases have been developed, which allow assessing global patterns of production, trade and consumption. Table 8 provides an overview of the properties of available MRIO data bases for assessments on the national level.

Table 8: Available global MRIO databases

Database name	Countries	Sector detail (industries x products)	Time series	Environmental data covered
GTAP-MRIO	World (140)	57x57	1990, 1992, 1995, 1997, 2001, 2004, 2007, 2011	GHG emissions, land use
OECD/ICIO	World (70)	30x30	1995-2011	GHG emissions
WIOD	World (40+RoW)	35x59	2000-2014	GHG emissions, material flows, energy, land use
Eora	World (around 190)	Variable (20-500)	1970-2013	GHG emissions, material flows
EXIOBASE	World (44+5 Rest of the world regions)	163x200	1995-2013	air pollutants, water use, energy, material extraction, land use

As Table 8 illustrates, the available MRIO databases have different strengths and weaknesses. With around 190 countries, the Eora database provides the highest number of countries separately covered and also includes the longest time series. However, large parts of the MRIO system are not based on statistical data, but estimated through a mathematical algorithm. With data up to 2014, the WIOD system currently provides the most recent data. EXIOBASE is the most detailed MRIO database, both concerning sectors (163 industries, 200 products) as well as the number of environmental issues covered. For the investigation of global environmental inequalities, EXIOBASE is the most suitable database, allowing to cover the largest number of environmental issues.

3.3. Conclusions

This chapter showed that the most widely applied methods for assessing the environmental inequality of exposures to air pollution in the European context are, in fact, the more sophisticated risk-based approaches. This type of method makes use of (spatial) dispersion models which seem to be available for most of the major metropolitan areas and cities in Europe including Vienna. Many studies apply a mixed method approach which combines data from less detailed dispersion models with, for example, distance measures. Nevertheless, when studying EI and exposures to industrial air pollution on the European level (e.g. NUTS 2), distance-based approaches seem to be more practicable because the geographical information on industrial facilities provided by the E-PRTR can be used directly. In terms of socioeconomic or demographic datasets, our analysis showed that the main data sources are the national statistical offices. The same is true for the case of Vienna and Austria (see BOX). Hence, it can be concluded that, although spatially explicit data are available at the member state level, there is limited, standardised data available at the European level. This probably explains the low number of empirical studies at the European level, and indicates the importance of database development for scholarly research in the field of EI and EJ in the European context. Finally, this chapter showed that environmentally extended multi-regional input-output are very promising and novel methods for the assessments of environmental inequalities in relation to global resource use or climate impacts of consumption activities.

4. Towards an environmental justice framework for Austria in an EU context

In chapter one, we identified environmental justice as a process from environmental inequality towards social justice and environmental quality. Based on the review in chapter two, we can now conclude that the problem of environmental inequality can be observed in multiple EU member states, in different environmental fields and at different spatial levels. This activates the process of environmental justice: Is the disproportional environmental burden unjust? Despite empirical evidence of environmental injustice, claims of environmental injustice are often weak, contradictory or ambiguous, and not seldom lead to long-lasting environmental justice conflicts[5], as justice implies:

i. **Articulation of a value-based, normative element:** 'What is a fair distribution?' 'How should the environmental burden be distributed?' (Walker, 2012).
ii. **Understanding of causality in a complex problem environment:** 'What has driven the inequality?' 'Who should take responsibility?' EI involves multiple, interrelated drivers and a broad range of actors in a multi-level policy context, contributing to the complexity of the problem environment. Analysing and understanding causalities related to patterns of injustice can be a difficult and timely process and can hinder the design of effective solutions (Mitchell et al., 2015; Snowden and Boone, 2007)
iii. **Democratic participation**: Participation is a condition for a democratic society to be able to reason about its normative foundation ('who or what to protect?'). However, the most vulnerable tend to have a 'low voice' and future generations and nature have no voice at all (Holden et al., 2017). As a result, outcomes of EJ (related) processes tend to be biased towards the interests of powerful stakeholders, not necessarily leading to a solution or improvement for the least well off (Boyce et al., 1999; Mitchell et al., 2015).

Nevertheless, scholars in the field of EJ agree that the above conditions, among others, are pivotal for recognising and combating environmental inequalities among social groups in society (Elvers et al., 2008; Martens, 2016; Walker, 2012). This chapter will review social theories underlying normative value systems in relation to environmental justice (4.1) and, in section 4.2, develop into a process framework to support stakeholders in the science-policy domain to work on EI issues from a lens of environmental justice.

4.1 Social theory and concepts in relation to environmental justice

An environmental justice (EJ) lens raises questions about how environmental impacts are distributed among different groups in society, about the processes leading to an unequal distribution of such impacts, and it provides a critical framework for understanding and, ultimately, reducing environmental inequalities in various spatial and political contexts (Walker, 2012). In essence, EJ is concerned with the question how [fair] things ought to be and, hence, with a normative outcome vis-à-vis the current situation. In praxis, however, powerful stakeholders tend to influence the outcome of environmental regulation which may not always be beneficial for vulnerable social groups (Boyce et al., 1999; Walker, 2012; Walzer, 1983). An example is the improvement of air quality in England between 2001 and 2011, accompanied by an increase in environmental inequality (Mitchell et al., 2015). The question how environmental inequalities can increase as a result of measures to improve environmental quality relates, among others, to the justice principles

[5] http://www.ejolt.org/maps/

applied in the social-political context of society (Martens, 2016; Thaler and Hartmann, 2016).

Environmental problems, including environmental inequality, are claimed to be fundamentally embedded in the organisation of human societies (Beck, 1992). Although early economic development in Western societies showed some egalitarian tendencies regarding the provision of basic goods and (public) services, neo-Marxist analyses link empirical cases of social and environmental inequalities and degradation to economic activity of capitalist societies (Mol and Buttel (2002) p. 33). In the 1980s, the neo-classical production perspective with the state as protector of society was increasingly challenged by changing social practices and institutions in a globalising world. As a result, market-based instruments started to replace state-led strategies, non-state actors emerged in environmental policy making, and new, 'hybrid' public and private governance approaches emerged to protect the 'common goods', including the state of the environment in the modern welfare state (Mol and Spaargaren, 2002). As a result, the underlying philosophy of EU environmental policy has changed over time from a precautionary approach towards justifying actions based on balances between costs and benefits (Gollier and Treich, 2003).

Within Europe, environmental quality started to improve in the 1990s, at least for a number of environmental dimensions (EEA, 2016b), but social inequalities persisted as a result of contradicting concepts of justice, among others. EJ principles differ in interpretations of fair resource distribution and in answering the question 'Who to protect for environmental exposure?' Thaler and Hartmann (2016) compare inherent notions of justice in approaches to flood risk management in Europe. The scholars distinguish (1) utilitarian approaches aiming at maximizing utility (Mill), reflected by justice mechanisms that protect the large majority for flooding risk (cost efficient) but not the most vulnerable, (2) libertarian justice approaches (Hayek), where environmental risk is mainly carried by the individual, and (3) egalitarian approaches (Rawls) aiming at maximizing equality and, hence, protecting the most vulnerable. All three principles of justice are applied in the EU context. Although the literature review (chapter 2) indicates a tendency of member states to take a utilitarian approach, it should be noted that flood risk protection involves multiple processes, each based on context specific justice principles within a single member state. Austrian policy makers, for example, consider flood risk management as a public good to be financed by national tax money. In doing so, they apply egalitarian protection standards but take a utilitarian approach to the selection of risk protection measures and a mixed utilitarian/liberal approach to cost sharing of flood impacts. The example of flood risk management shows that stakeholders 'operate' in a multi-level policy context, in which the 'moral imperative of justice is accommodated to social reality' (Elvers et al., 2008).

At the global level, concepts such as the ecological footprint (Wackernagel et al., 1997) and other applications of consumption-based environmental accounting, show that a reduction of environmental burden in high income countries can be linked to a displacement of polluting activities to other regions (Steen-Olsen et al., 2012; Weinzettel et al., 2013) as well as to an increase in social inequalities in the global context (Martinez-Alier, 2014; Piketty, 2014; Robbins, 2011). Such inequalities go beyond economic inequalities, and include the quality of ecosystem services, access to resources, material consumption, waste accumulation and impacts of climate change, among others. With respect to climate change, for example, Sgro et al. (2013) write that there is European consensus that the amount of research on environmental degradation, climate change and migration of vulnerable groups is quite substantial and that policy makers and researchers should start processes that lead to evidence-based policies. In line with this, the United Nations defined

17 sustainable development goals (SDGs) for 2030 in a global commitment 'to leave no one behind' and to promote prosperity and people's well-being while protecting the environment (Dodds et al., 2016; UN Economic and Social Council, 2016; UNEP, 2015). Although the SDGs don't explicitly promote environmental justice as a tool to achieve SDGs, it can be argued that prosperity and wellbeing for all requires a combined perspective on ecological sustainability and social justice: 'A truly sustainable society is one where wider questions of social needs and welfare, and economic opportunity, are integrally related to environmental limits imposed by supporting ecosystems' (Agyeman et al., 2002).

Overall, we can conclude that environmental justice adds an important extension to economic inequality, showing that the concept is interrelated with human rights, democracy, freedom and sustainable development (Holden et al., 2017). We therefore define **environmental justice as a democratic process towards social justice** where stakeholders reason about – and adopt - normative principles that potentially reduce environmental inequalities. But when EJ is defined as a process to circumvent the complicated issue of a normative end, the question 'what level of inequality is just?', remains. In chapter 1, we 'defined' the desired situation as one where the living environment of all people is characterized by environmental quality and social justice. It was also shown that the field of EJ connects with the quality of life debate, the societal aim for human flourishing and with the SDGs. Earlier, Stephens et al. (2001) concluded that EJ research needs to address access to a broad range of environmental resources, including physical needs (shelter, food, clean air and water); economic needs (transport infrastructure, access to work and services); and aesthetic, mental and spiritual needs (such as quietness or access to the countryside). These are all normative claims, but pointing in the same direction of a healthy living environment where people, or social groups, have a say (participation), are capable to fulfil needs, and respect the physical limitations of the natural environment – conditions which have been articulated in *Our Common Future* (Holden et al., 2017; WCED, 1987). **We therefore propose to regard environmental justice a process towards a healthy living environment (Mohai et al., 2009) where all stakeholders (social groups or members of a community) participate and learn about the mechanisms and structures that produce social differentiation in environmental terms, and develop and adopt social-ecological responses that enhance the fulfilment of fundamental needs[6] within, and take responsibility for, environmental limits.**

Figure 4 pictures environmental justice as a process from environmental inequality towards a healthy living environment (adapted from Figure 1). Important to note is that, although the living environment integrates aspects of the local, national and even global level in environmental terms, <u>measurement or judgement about the quality of the living environment is always restricted to a defined geographical area</u> (Van Kamp et al., 2003). This condition for EI research raises issues with respect to the multiple environments an individual takes part in, for example the residential area or the working environment.

[6] Fundamental human needs, as empirically defined by Max-Neef: http://www.wtf.tw/ref/max-neef.pdf

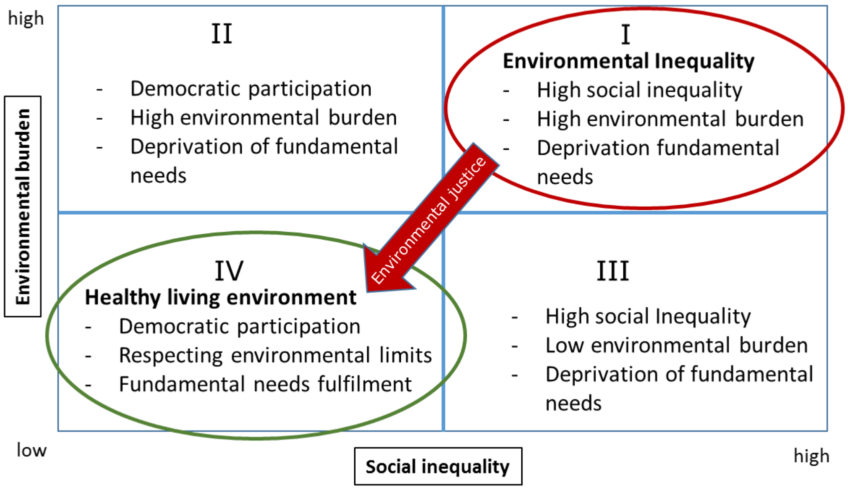


Figure 4: Environmental justice (red arrow) as a process from environmental inequality towards a healthy living environment within environmental limits

4.2 Towards a framework for environmental justice in an EU context

A practical EJ framework serves as a tool for stakeholders seeking to make environmental regulation and social practices more sensitive to human needs (Martens, 2016). Although some scholars appeal for conceptual clarity and a 'unifying framework', others argue that the ethical and ideological character of justice theory serves mainly to maintain plurality in different practical and analytical contexts (Martens, 2016; Van Kamp et al., 2003). As environmental justice is defined as the process from environmental inequality towards a healthy living environment where people can fulfil their needs within environmental limits, the most basic framework towards EJ claim making consists of three elements (see Figure 5) (Walker, 2012):

1. **Evidence**: Descriptive evidence of environmental inequality (how things are), e.g. a bias towards waste sites located among lower social classes;
2. **Justice**: Prescriptive living environment as the democratic improvement of environmental conditions and social principles (how things ought to be), e.g. waste sites should be equally distributed among people in society;
3. **Process**: the participatory EJ process towards understanding why things are how they are, e.g. lower social classes live in areas with lower housing prices as a result of proximity to waste sites, allowing stakeholders to understand injustice and to develop and agree on measures towards 'Justice'.

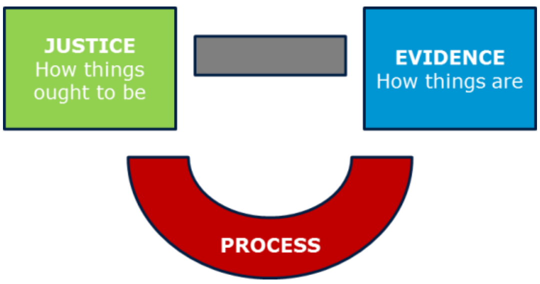


Figure 5: The three elements of environmental justice claim making (Walker, 2012)

Elvers et al. (2008) understand EJ as an emergent feature to be addressed in environmental decision making, where the strong moral imperative of justice is to be continuously accommodated to social reality. The notion of 'emergence' signifies that EJ is not completely controlled or predicted, but the result of a heterogeneous process which is affected by multiple dimensions. By a literature review of papers on environmental justice processes, the authors identified four steps in the EJ process, each consisting of two dimensions. The 8 dimensions are both descriptive process steps in EJ as well as prescriptive categories in terms of desirable output of environmental policies; they should be understood as decision fields, referring to areas of action whenever an environmental regulation can be blamed for promoting injustice. No clear boundaries exist between the different elements in the iterative process model, which is triggered by existing environmental regulation and at the same time influencing environmental regulation.

Stage I in the framework concerns the analysis of potential environmental inequalities associated with existing regulation (how things are). In this stage, objective evidence for potential environmental inequalities is collected, both in environmental (e.g. NO_x pollution) and social terms (e.g. income). Stage II involves the transformation of environmental inequality to impacts in terms of health and/or subjective wellbeing, as well as a robust assessment of the level of uncertainty in the evidence base. Stage III involves moral reflections on social justice principles that constitute the frame from which the identified inequalities and impacts can be interpreted in an environmental justice context. Finally, in stage IV, policy fields and the need for public involvement are addressed and information towards implementation or adaptation of environmental regulation is shared in a participative process (see Figure 6).

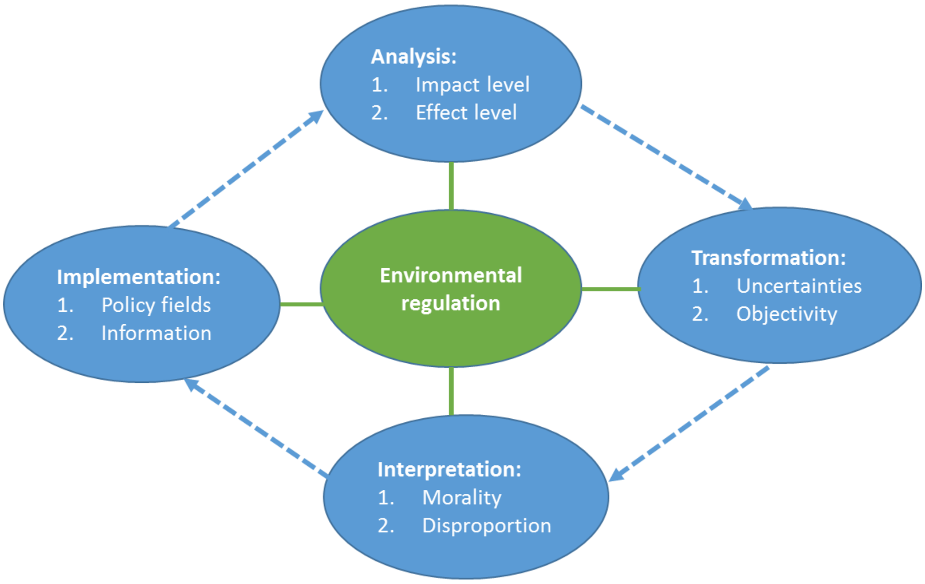


Figure 6: Iterative Framework for Environmental Justice towards enhanced environmental regulation (Elvers et al. 2008)

It should be noted that the framework of Elvers et al. is primarily aiming at environmental regulation and, hence, neglects the fact that environmental policies can have differentiated social impacts (Laurent, 2010). From the latter perspective of EJ, improvement of the qualities in the living environment requires a perspective from both the least well off (in relation to the environmental burden) and the perspective of high income groups (in terms of the production of environmental inequalities) in the policy context. As a result, the issue of 'policy inequality' emerges from an environmental justice lens, meaning that the outcome of policies or other regulatory measures need to be taken into account as they may improve the overall environmental outcome, but increase EI among social groups (Richardson et al., 2013).

Based on the conceptual elements of (i) Walker's framework (justice-evidence-process), (ii) Elvers et al.'s iterative process steps, (iii) the distinguished EI mechanisms (exposure, susceptibility and impact) and (iv) potential policy related inequalities, a framework can be compiled to engage stakeholders in EJ processes (procedural justice) towards an improvement of the quality of the living environment on the basis of robust evidence of EI (distributive justice), embedded in the policy context. The EJ framework aims at taking an objective starting point at the level of scientific research into potential environmental inequalities, in terms of access to resources, burden of pollution and/or climate change and natural hazard risk (the three dimensions of EI that emerged from the review in chapter 2), but it can also start on the basis of a perceived inequality or an EJ conflict, for example related to an industrial siting proposal or decision. Figure 7 illustrates the proposed framework.

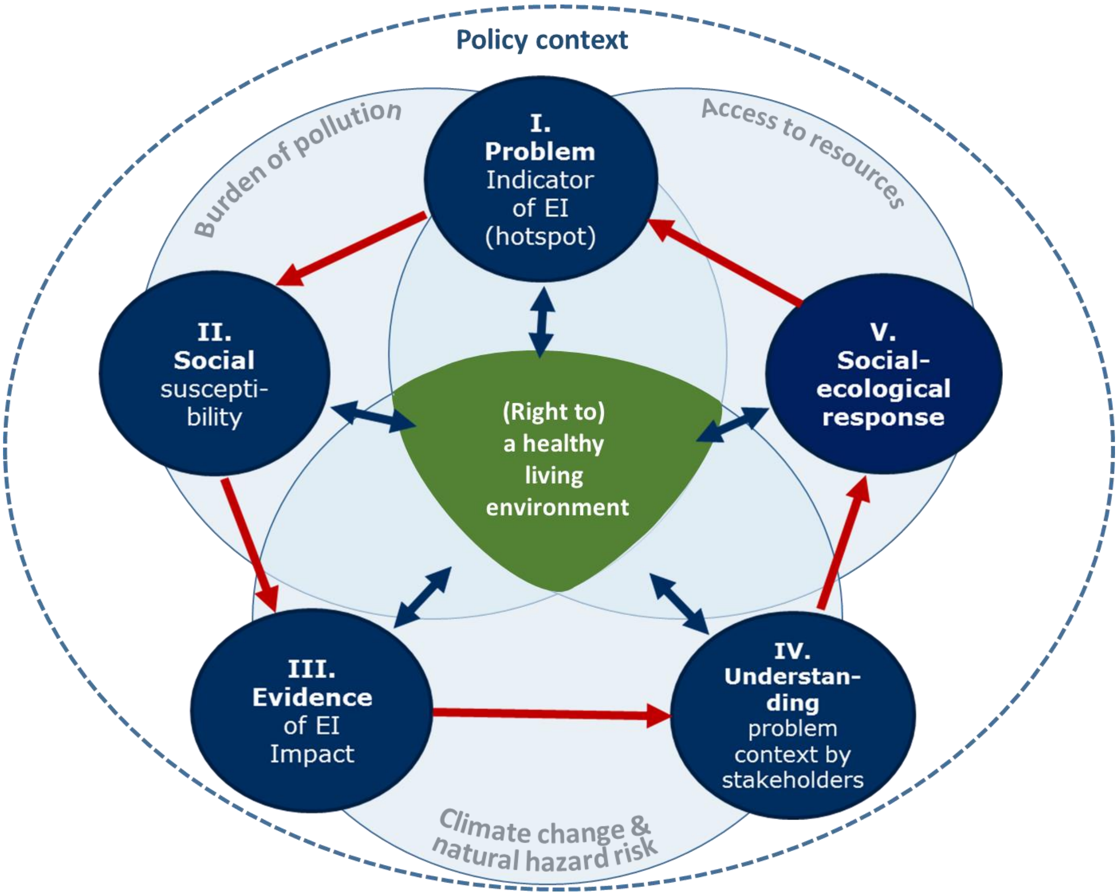


Figure 7: EJ framework to assess and reduce EI issues in the field of access to resources, burden of pollution and/or climate change & natural hazard risk in the European context

The proposed framework involves five iterative steps:

I. **Problem identification**; analysis of the social distribution of environmental exposure in terms of access to resources, burden of pollution or risk of climate change or natural hazard in the spatially explicit living environment. The problem is indicated as a potential environmental inequality (hotspot). In the choice of indicators, there is general consensus in the literature that both objective and subjective indicators are preferred in the investigation of person-environment relations. In practice, research goals play an important role, for example, a screening of EI hotspots in relation to noise pollution in an urban area can be very well analysed on the basis of available socioeconomic and environmental databases and, within hotspots, complemented by subjective measures.

II. **Social susceptibility for (potential) exposure**; our review in chapter 2 shows that the quality of the living environment plays an important role in the relation between exposure and actual (health) impact related to the exposure. The quality of the living environment relates to issues such as quality of housing, design of the neighbourhood, cumulative impacts, average income in the neighbourhood, and personal factors such as windows along a busy street. Susceptibility for environmental burden may thus be higher or lower for a specific social group and it is recommended to recognise this 'explanatory factor' in EI research. Further research is needed to establish an analytical relation between the quality of the living environment and susceptibility for specific environmental exposures (e.g. noise pollution, street design and health impact).

III. **Evidence of EI impact**; a large number of studies into EI remain at the indicator level where the empirical evidence of EI impact is inferred on the basis of statistical databases. As a result, most EI research is based on potential exposure, where uncertainty of causality is relatively high. Evidence of EI at the impact level, e.g. health impacts, but also losses in case of flooding, generally needs to be collected in qualitative or clinical research approaches. Output of this stage in the EJ process indicates the uncertainty in the evidence of EI.

IV. **Understanding the explanatory framework**; Causal relations, e.g. traffic related air pollution, are easier to identify – and to agree upon – in the local context than in wider spatial contexts. Therefore, stakeholder participation to learn about causal relations and responsibilities is a key ingredient in the process of EJ in the local context, increasingly also in national or international contexts (with the Paris climate agreement as the most prominent example). In the wider geographical context, EI needs to be understood as systemic externalities of more complex economic behaviour and justice principles where explicit causal relations are often lost or blurred and, as a result, the explanatory framework of EI remains weak or poorly understood. Systems approaches, e.g. multiregional footprint approaches, among others, can help to give analytical insights on the relation between production, consumption and related EI patterns in a wider geographical context (see Box III below). A stronger role of quantitative, empirical approaches at the science-policy interface in EJ processes can be expected.

V. **Responsibility of stakeholders**, finally, occurs when drivers and impacts of EI are sufficiently understood or acknowledged (social equity), allowing stakeholders to adapt the principles of social justice in order to allow affected social groups to fulfil fundamental human needs, including clean air and good health. In the case of the polluted city centre, for example, a limitation on parking spots freeing up space for biking trails could be experimentally tested or modelled in terms of social distribution of environmental burdens and benefits.

In principle, the framework in Figure 7 could be applied in all EJ contexts, not only in the European. However, multi-stakeholder processes – as a crucial element in the EJ process – require well-functioning democratic principles where stakeholders, and all citizens, have access to relevant information[7], where each person has a right to a healthy living environment, where statistical offices provide temporal updates of spatially explicit socio-

[7] Aarhus Convention: Convention on access to information, public participation in decision-making and access to justice in environmental matters: http://www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf

economic and environmental data, and – preferably - where open, participative processes are supported by cooperative stakeholders. But also in the EU, it is reported that equality bodies face difficulties in gathering evidence and securing necessary data related to racial and ethnic groups. In racial and ethnic conflicts in particular, it is argued that dispute settlement mechanisms, such as an EJ process at the local level, tend to take an individualistic approach to equal treatment which prevents an effective combatting of wider patterns of inequality (Uyen, 2013).

Not visible in the framework are the similarities and differences in between the European and US approach to environmental justice. Both regions take distributive, procedural and substantive elements of EJ on board, but differ in the value system underlying public policy: the US traditionally recognises the universality of natural rights of the individual and, hence, focuses on discriminated groups. The EU relates environmental burden more to social differences and, hence, aims at including the production, or drivers, of such inequalities in environmental and/or social policies (Laurent, 2010).

4.3 Conclusions

This chapter articulates the relation between value-based principles in a society and environmental justice which, reflected by the social-political context, tends to be based on a mix of utilitarian, libertarian and egalitarian principles. Such normative imperatives complicate stakeholder processes in multi-dimensional contexts towards environmental justice as an end-goal. Therefore, EJ has been defined as a process which – in line with EJ related concepts such as the SDGs – 'work' towards a healthy living environment where people have a say and can fulfil their fundamental needs while respecting environmental limits. The latter emphasises the need to widen the scope from vulnerable social groups towards producers of EI (largely high income groups) and social-ecological policies affecting the distribution of income and related environmental burden. Based on existing frameworks and the review in Chapter 2, a five-step framework for EI research has been developed for the science-policy interface in the European (and Austrian) context, supporting the identification and reduction of EI hotspots towards the end goal of a healthy living environment for all within safe and just environmental boundaries.

5. Conclusions

Summary of key insights

The aim of the report was to provide experts and other stakeholders interested in the field of EI and EJ an overview of empirical research conducted in the European context, both in terms of evidence of inequalities, in terms of spatial level and in terms of available databases and methods applied. Furthermore, based on the results of the review and existing concepts for EJ, a framework has been developed as a tool for stakeholders to engage in evidence-based EJ processes on the basis of a robust approach to reduce inequalities in the living environment (analogue to the US context). However, different than the racial focus of EJ in the USA, the EU relates environmental burden more to social differences and, hence, aims at including the production, or drivers, of such inequalities in terms of environmental and/or social policies. From a policy perspective, it can be concluded that environmental justice works towards embedding environmental regulation in social policy, indicating the need for social-ecological policies to increase environmental quality in the places where our everyday lives occur (Laurent, 2011)

The review of 81 empirical studies at the local, national and EU-wide level, shows that **potential environmental inequalities exist in relation to seven environmental fields: (1) air pollution, (2) noise pollution, (3) industrial siting, (4) waste siting and transfer, (5) the physical quality of the living environment, (6) access to resources and (7) climate change and natural hazards.** The strongest indicators of patterns of EI have been found for traffic related air and noise pollution related to traffic in urban contexts (and thus adding to a cumulative environmental burden in urban contexts). The living environment emerged as a field which played a particular role in terms of susceptibility for environmental exposure from other sources. In light of further urbanisation, the quality of the living environment can be expected to become an increasingly important theme from the perspective of environmental (and climate) justice.

The report shows that **EI research is conducted in a large number of EU member states, although concentrated in the UK, Germany, France,** and, to a lesser extent, in the Netherlands and Austria. EI research in Austria covers EI related to the distribution of potential point source pollution of industrial facilities at the national level, indoor air quality in classrooms in large cities, traffic noise in Vienna, flooding risk and heat stress in Vienna and access to energy, or fuel poverty, also in Vienna. None of the studies give evidence for significant environmental inequalities, although most studies point to the bias towards more double burden areas and double blessing areas. It should be noted that, in Austria, most research is non peer-reviewed.

The majority of reviewed papers concerns context-specific case studies, mainly at the urban level, but also on multi-local levels as a proxy for wider geographical and national patterns. **EI research at the EU level is scarce**, although each environmental theme has been analysed by at least one empirical study or – mostly – by a meta-review of local studies. In such meta-reviews, it has been concluded that comparisons and aggregations of findings and conclusions among empirical studies in different contexts or countries are complicated due to differences in research design and applied methodologies. The limited number of empirical research at the EU level is likely to be linked to the poor availability of standardised, spatially explicit environmental data (which is much better at the member state or lower level). Database development at the EU level is considered important to allow scholarly research in the field of EI and EJ in the European context.

A five-step framework for EI research at the science-policy interface has been developed, supporting the identification and reduction of EI hotspots from the perspective of environmental justice towards the 'end-goal' of a healthy living environment and social justice within environmental limits. The proposed framework aims at taking a more objective starting point at the level of scientific research into potential environmental inequalities, as compared to environmental justice approaches emerging from conflicts based on strong moral imperatives, although the latter can also be the starting point of the EJ process. Adaptation and adoption of institutions to reduce environmental inequalities with respect to vulnerable or less protected social groups requires a participative stakeholder approach which is likely to be more effective when EJ is recognised and embedded in a social-ecological policy context.

Considering the **systemic nature of environmental inequalities, largely related to economic goals in the EU and global context**, we argue that an environmental justice frame adds an important research perspective to inequality research in a structured territorial approach at the EU-wide level. Analysis of EU-wide databases could indicate EI hotspots in relation to economic activities and environmental inequality, linking producers and disadvantaged social groups of EI in an EJ frame. Furthermore, methodologies to connect environmental pressures and related EI, driven by EU consumption or production, would advance the explanatory framework of global EI patterns, connecting to the field of political ecology. Inequalities at the global level, as well as risks and inequalities related to cumulative environmental impacts, are strongly recommended for further research.

Outlook to EJ issues of high relevance for the Austrian context

This final section provides an overview of environmental inequality and environmental justice issues, which were regarded as particularly relevant for the Austrian context by Austrian experts. Experts and researchers in economic and environmental research (WU, IFF, WIFO), in statistics (Statistik Austria), and the labour union (AK-Wien) were brought together in a workshop on environmental inequality and environmental justice, which took place at the Vienna University of Economics and Business (WU) on May 11, 2017.

The following priority issues have been identified as particularly relevant:

Analysis of longer-term developments, taking infrastructure stocks into account

Experts agreed that environmental justice issues might arise by moving from a short-term to a longer-term analytical perspective. For example, ecological modernisation of buildings could trigger a price increase of housing (e.g. rising rents). As a consequence, families with lower income will move to areas with cheaper housing costs. Actions and environmental regulation targeted towards improving the living environment can therefore possibly also involve environmental justice issues, which need to be addressed.

Analysis of the distributive effects of policy measures

Environmentally-targeted policy measures need to be analysed from the perspective of their distributive impacts. For example, the implementation of an ecological tax reform, pursuing a shift towards renewable energies ("Energiewende") or the implementation of a city tax limiting private car use will have different environmental, but also financial impacts on various income groups. There was general consensus that such measures need to be analysed and discussed from an environmental justice perspective. For example, in view of the participative nature of EJ processes, who decides about the implementation of measures, such as a city tax: the commuters affected by such a measure, the people living in the neighbourhood, or all inhabitants of a city?

Fine-scale spatial and temporal assessments of environmental impacts

Experts of the workshop pointed to the fact that environmental burden, such as air pollution with particulate matter (PM) strongly depend on local conditions. For example, a tree row between a street and the adjacent residential buildings can have a positive impact on air quality and significantly reduce PM pollution. Therefore, fine-scale profiles of how people move and where they spend their time is required, in order to assess patterns of environmental burden at their place of work, their place of residence and places, where they spend leisure time (the living environment). Furthermore, it was emphasised that patterns of environmental burden vary significantly at different points in time during one day. It was discussed, whether information systems providing real time data on the respective burden could potentially alter the temporal patterns of people's behaviour, for example, at which time of the day they use certain mobility options (e.g. cars versus public transport/bicycles).

Analysis of multiple burdens and the subjective perception of burden

Some of the experts stressed that the analysis on the interlinkages between multiple environmental loads, such as air pollution in combination with noise, has not yet received sufficient attention in research. In this context, the link between pollution data and health data seems particularly relevant. Furthermore, the subjective perception of environmental burden, such as noise, can significantly vary between individuals and can thus not be generalised for a whole area. More research is required in that field to substantiate assessments of environmental justice.

Adding the global perspective of production and consumption

There was wide agreement among the experts that the current focus of environmental inequality/justice assessments on the territorial perspective should be complemented by a global perspective. Issues such as climate change require a global framing, as was concluded in a working group session on the expansion of the Vienna airport. The same holds true for issues related to the restructuring of economic activities and supply chains on global markets and the related outsourcing of resource use and environmentally-intensive stages of production away from industrialised to developing countries. Environmental justice thus should have a strong international dimension, a perspective that is also supported by various Sustainable Development Goals (SDGs), to which issues of environmental inequality and environmental justice should be closer linked.

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