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Sustainability dimensions of hydrogen production in countries of the Global South

Insights into the current debate and approaches to implementation

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Summary

In this report, we analyse the scope of the current debate about the sustainability dimensions of hydrogen production, especially when production occurs in countries of the Global South. To this end, we map the sustainability dimensions that are being discussed, as well as the extent to which and the perspectives from which they are addressed. Further, the report highlights approaches mentioned in the literature, which not only identify relevant sustainability dimensions, but also make them more tangible and thus accessible. To enable a structured view of the debate, we explore 37 publications by means of a quantitative text analysis. Within this body of literature, we delve deeper into 19 publications in a qualitative text analysis that primarily seeks out concrete instruments already mentioned. With this perspective, we also examine 11 regulations and certification systems on hydrogen and derivatives.

There is a common awareness that the sustainability of hydrogen production needs to be ensured.

- Literature clearly highlights that the sustainability of hydrogen production should be ensured right from the start of the uptake of a possible future hydrogen economy.

The level of detail to which individual sustainability dimensions are discussed varies greatly.

- Greenhouse gas emission (GHG) reductions and eligible renewable electricity procurement (RES-e) sources: these are the two main dimensions addressed when defining the sustainability of green hydrogen. At least in most of the already existing regulatory standards and certification schemes such as the Delegated Regulation (EU) 2023/1184 as part of the revised Renewable Energy Directive (RED) in Europe or the Clean Hydrogen Production Standard in the USA.

- However, there are many more aspects that need to be taken into account when conceptualising green hydrogen as a sustainable product. Ecological, socio-economic and governance aspects factor in here. An increasing number of publications [1], progressive certification schemes [2] and political entities [3] are calling for these issues to be considered in equal measure when assessing the sustainability of hydrogen and Power-to-X (PtX) products.

- Our quantitative text analysis indicates that scant attention is paid to the topics of local stakeholder participation and access to land and indigenous rights. The question of how hydrogen projects are structurally embedded in national decarbonisation strategies has also been insufficiently addressed.

[1] Examples include Brot für die Welt; Heinrich-Böll-Stiftung (2022b); Brot für die Welt; Deutsche Umwelthilfe; BUND; Germanwatch; DNR; Heinrich-Böll-Stiftung et al., PtX Hub (2022), BMWK (2024).

[2] For example, the Green Hydrogen Standard: https://www.greenhydrogenstandard.org/

[3] For example, NWR (2024), Sachverständigenrat für Umweltfragen (2021)

There is a need for concrete implementation approaches which, however, can build on existing instruments.

- Concrete approaches to implementing these further-reaching dimensions can only be found in isolated cases in regulations or certification schemes for hydrogen. The tenders of the German H2Global mechanism[4] are an exception here; in these, a range of additional ecological and socio-economic sustainability criteria with respective instruments are defined.

- The literature offers a discussion of many approaches, some of them quite concrete, for making progress in the implementation of criteria for the respective sustainability dimensions. We refer to these approaches as instruments.

- For example, the mechanism of Free Prior and Informed Consent (FPIC): this is already established in mediation with indigenous communities. It ensures that these communities can give or withhold consent to projects affecting their lands, resources, and livelihoods. It would be worth learning from and extending this mechanism to further areas to protect local groups' access rights to key resources as well as to enable active participation in decision-making.

Specifically designed instruments are needed to accommodate the characteristics of the individual dimensions feeding into the sustainability of hydrogen.

- Different instruments are needed to substantiate different types of sustainability dimensions: some aspects such as GHG emissions are rather straightforward to quantify. Therefore, where possible, quantifiable values should be incorporated in standards and certification schemes for those more tangible dimensions. However, ‘soft’ aspects such as governance may require a somewhat differing approach.

- The question arises of how well instruments can map hydrogen-specific characteristics in each case. Another issue is the level at which instruments operate: some instruments like the Environmental Impact Assessment (EIA) are designed to be applied at project level to provide proof of the sustainability of a facility or product. Other instruments like the integration of the project in the national hydrogen strategy lie at a higher level and are more concerned with the question of what countries or regions are generally suitable for cooperation from a sustainability point of view.

The next step is a clear process towards a set of criteria and instruments in collaboration with exporting countries. This would also contribute to sound investment decisions.

- This report compiles concrete instruments that are mentioned in the literature into factsheets for nine different sustainability dimensions. Here we focus on the socio-economic dimensions that are directly relevant to local stakeholders and rural groups. Namely, 1) water, 2) biodiversity and soil conservation, 3) resources, waste, recycling, 4) local economic development and employment, 5) transfer of skills and knowledge, 6) local energy access and infrastructure in development in project proximity, 7) labour and working conditions, 8) local stakeholder participation and 9) land rights and indigenous rights.

[4] https://www.h2-global.org/

- The overall picture of sustainability dimensions (Figure 1-1) is derived from the literature analysed. The 'basket' of options of instruments provided in the fact sheets can be used to formulate a common baseline of sustainability criteria for hydrogen production.
- It is essential to elaborate this baseline further in close dialogue with exporting countries, local stakeholders and other offtaking-markets. Developing such a joint baseline would also facilitate transparent investment decisions.

Rural areas and communities may be particularly affected by hydrogen projects in countries of the Global South. Efforts should be made to minimise negative effects on the one hand and to generate beneficial ones on the other.

- Access to elementary resources such as land and water is essential for rural livelihoods, which are mainly based on agricultural and pastoralist practices. At the same time, precisely this access to, for example, energy and economic participation is often lower compared to citizens of urban areas. The literature shows that rural groups in countries of the Global South might therefore be severely impacted by hydrogen projects as these claim space for RES-E plants and local resources.
- This is why socio-economic sustainability criteria are especially important for hydrogen production. The aim here should not only be to reduce the negative impacts – such as forced resettlement for instance – but also to mobilise the potential for positive impacts. And this potential does exist. For example, additional investment could be channelled into improving local water supplies or developing transport or social infrastructure.
- To effectively tap into these potentials, continuous engagement with rural groups is essential. Initial approaches on how this can be translated into action are included in the factsheets of this study.

Figure 1-1: Sustainability dimensions in hydrogen production (we focus on the green dimensions in detailed factsheets, see chapter 4.3)

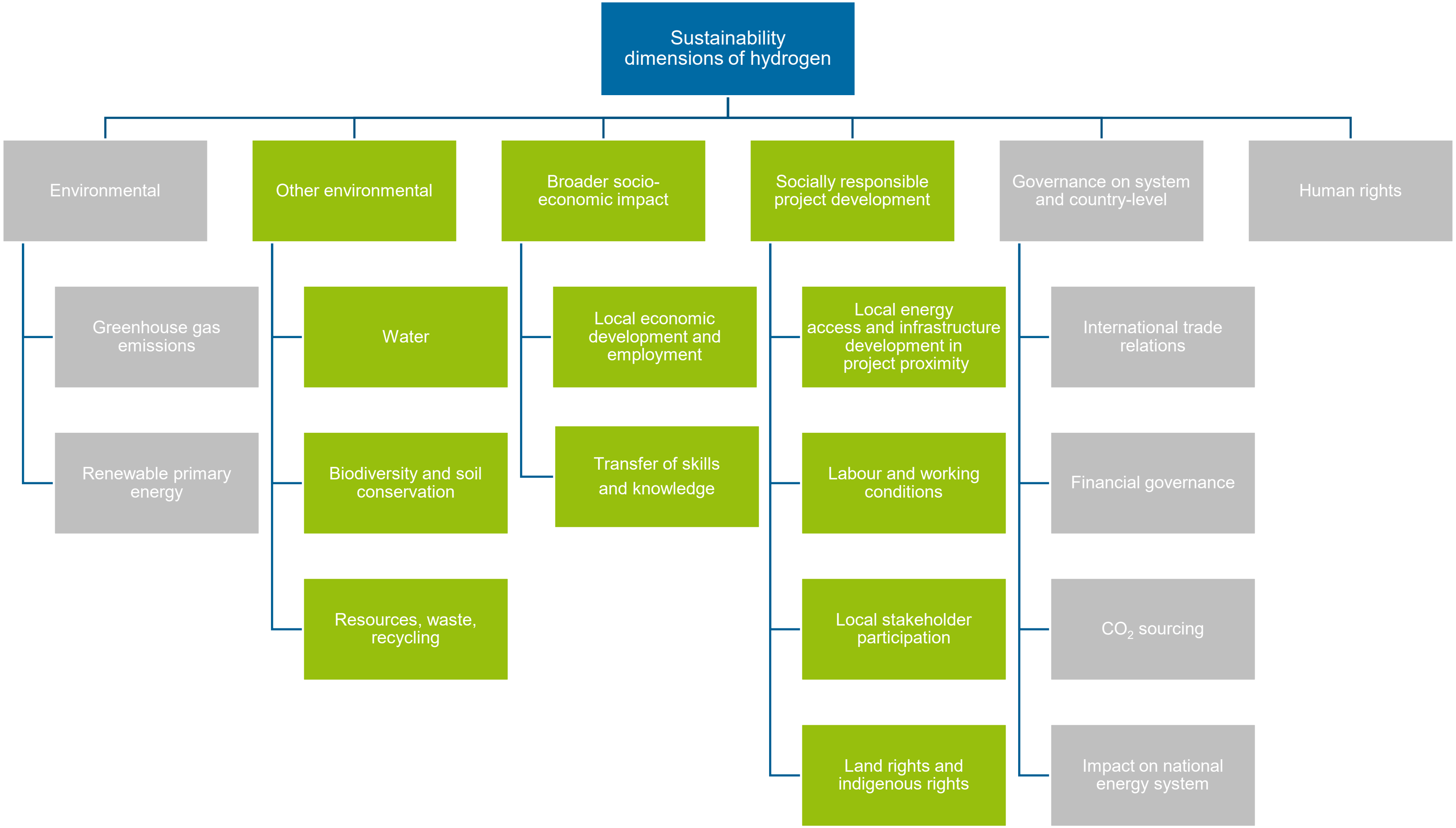

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Table of content

Summary 2

Table of content 6

1 Introduction 7

2 Methods 7

2.1 Quantitative text analysis – methods 8

2.2 Qualitative text analysis – methods 8

3 Findings 9

3.1 Layers and elements in navigating the sustainability of hydrogen 9

3.2 Sustainability dimensions in the literature – a frequency analysis 10

3.3 Factsheets of socio-economic sustainability dimensions 13

3.3.1 Water 15

3.3.2 Biodiversity and soil conservation 20

3.3.3 Resources, waste and recycling 24

3.3.4 Local economic development and employment 27

3.3.5 Transfer of skills and knowledge 30

3.3.6 Energy access and infrastructure development in project proximity 33

3.3.7 Labour and working conditions 37

3.3.8 Local stakeholder participation 40

3.3.9 Land rights and indigenous rights 44

4 References for regulations and certification schemes 48

5 References 50

6 Annex 54

6.1 Quantitative and qualitative text analysis: data base used 54

6.2 Quantitative text analysis: methodological approach 58

1 Introduction

The question of what and how specific instruments are to be used to achieve a sustainable hydrogen production in countries of the Global South is still an open one – also in landmark documents like the recently published German import strategy (BMWK 2024). There may be various reasons for this: some sustainability aspects are not as clearly quantifiable as accounting for CO_2 emissions in the production chain. Others do not take hold at the project level but at the level of state governance and therefore require, firstly, more political sensitivity and, secondly, vehicles for implementation other than catalogues of criteria in certification systems. Nevertheless, they might be just as relevant for assessing the sustainability of hydrogen and derivatives.

These open questions are the starting point for our report. Based on an extensive literature review, we analyse the scope of the current debate regarding sustainability dimensions for hydrogen to find answers to the following questions:

- Which sustainability dimensions are being discussed and to what extent?
- How do different groups within the current debate, i.e. authors of publications, address the individual dimensions? Are the respective dimensions considered, also in existing regulatory and/or certification approaches? If so, how?
- Are there already concrete proposals for implementing the sustainability criteria? What potential instruments does the literature provide for each specific sustainability dimension?
- What are the ‘blank spots,’ i.e. the gaps, in the current debate? What dimensions receive the least attention within the political debate and where is the need for further specification correspondingly high?

2 Methods

We approached these questions along two methodological lines:

1. Using quantitative text analysis (see chapter 3.1) based on Natural Language Processing tools in Python. The analysis incorporated a total of 37 publications[5] on the topic of the sustainability of hydrogen that have contributed to the political and scientific debate in Germany and Europe over the last four years.
2. Using qualitative literature analysis (see chapter 3.2) of 19 selected publications[6] within the corpus of the quantitative text analysis. Additionally, we reviewed 11 regulations and certification systems in detail.[7]

[5] Listed in Annex 5.1.
[6] These publications are highlighted in the table in Annex 5.1.
[7] Listed in chapter 5.

2.1 Quantitative text analysis – methods

In this first part of the analysis, we review the existing literature on the sustainability of hydrogen across the identified dimensions (see Figure 1-1). Its central aim: to gain an understanding of how frequently different groups within the current political and scientific debate address the respective sustainability dimensions.

To do so, we compiled a corpus of current publications that centrally fed into the German and European debate on sustainability dimensions of hydrogen from 2020 onwards. We then attempted to categorise the publications by type of authorship, considering the primary objective and/or the purpose of the authoring entity (see Table below). Using Natural Language Processing tools, we scanned each individual publication for the frequency of references to the 15 sustainability dimensions specified in Figure 1-1. Finally, we grouped this information by publication type to provide a structured picture of the results. A detailed description of the methodology of the quantitative analysis, including the definition of key words used in scanning the publications, is described in Annex 5.2.

Table 3-1: Categories of publication types for the quantitative text analysis

Category of publication in text analysis	**Purpose of the authoring entity**
Academic literature	Focus on politically independent academic research
Mapping tools	Provide potential (area) analysis
Policy recommendations & position papers of associations	Set claims for (inter-)national politics
Reports of institutions focusing on international development cooperation and political education	Advise on international and development policy issues
Reports of institutions focusing on independent and applied research	Foster political climate protection targets

The results of the analysis are detailed in Chapter 4.2.

It should be noted that the analysis is not a large-scale, scientifically comprehensive quantitative text analysis, which would have been beyond the scope of this report. Rather, the analysis mainly serves an illustrative purpose, providing an entry point into the (written) debate on sustainability of hydrogen through a systematically structured overview of word mentions in the literature. Therefore, the results are not to be considered as fixed, but rather of a general and illustrative nature. The precise findings depend on various factors, mostly importantly the wording of the sustainability dimensions, the keywords used for each category, the composition of the literature corpus and the categorisation of the publications.

2.2 Qualitative text analysis – methods

The qualitative text analysis attends to further details on those sustainability dimensions which we see among the most relevant, particularly for local stakeholders and rural communities. To do so, we more closely examined 19 key publications selected from the literature corpus of 3.1 as well as 11 regulatory and certification schemes (mainly relevant for imports to the European region) related to hydrogen.

Publications that are part of the qualitative analysis are marked in the table in Annex 5.1. The regulations and certifications schemes considered are listed in chapter 5.

The findings of this part of the analysis are presented in factsheets for nine selected sustainability dimensions. Central to the factsheets is a section in which we compile the instruments already mentioned in the literature for each dimension in a structured way.

3 Findings

3.1 Layers and elements in navigating the sustainability of hydrogen

Working with a wide range of texts has highlighted the complexity of this report's topic. To navigate this landscape in a structured way, we deem it useful to clearly delineate between different elements relevant to the sustainability of hydrogen (and its implementation) on different layers. In our report, we therefore make a distinction between the following terms.

Table 4-1: Layers and elements to approach the sustainability of hydrogen

Layers	Explanation	Example
Cluster	Comprises several sustainability dimensions that relate to a common topic area.	Ecological effects
Dimension	Describes a specific topic area that is relevant to sustainable production and imports of hydrogen.	Water use
Aspect	Sets a substantive emphasis and concretises the exact effect or requirement within the sustainability dimension.	Access to fresh water
Vehicle [8]	(Political) Medium or level at which sustainability criteria or associated general claims can be conveyed. They can be seen as levers for implementing sustainability criteria and vary in nature and operation, e.g. regulatory, economic or co-operative.	• Regulatory, e.g. Corporate Sustainability Due Diligence Directive • Economic, e.g. loans • Co-operative, e.g. hydrogen partnerships
Criteria	Concrete, verifiable requirement for hydrogen production and imported products.	The project does not use water resources within a region with a level of water stress ≥ low
Instrument	Concrete approach or mechanism that serves to make it verifiable whether a criterion has been met or not	Indicator Baseline water stress [9] from Aqueduct Water Risk Atlas

[8] This layer forms the basis for implementing criteria and, finally, instruments. Depending on the perspective, vehicles can themselves be understood as an instruments (see, for example, Brot für die Welt; Heinrich-Böll-Stiftung (2024)). However, a substantive discussion of which vehicles are available and to what extent they are suitable to address sustainability dimensions of hydrogen is outside the scope of this report and has already been considered in detail in other publications.

[9] https://www.wri.org/research/aqueduct-40-updated-decision-relevant-global-water-risk-indicators?auHash=74cRjEQPsH0NDpgT1NqIfNpqV-QpYNR4oiPo1HRhpGs [10] See Section 5.2 for further details on the methodology.

The last layer is that of instruments, which is at the centre of this report. By this we mean a concrete approach that can be used to make criteria comprehensible. Our analysis shows that these can be of different natures. For initial orientation, we therefore characterise the following types of instruments. This list or categorisation is primarily intended as a rough guide and does not claim to be definitive or complete.

Table 4-2: Types of instruments to assess the sustainability of hydrogen

	Type of instrument	**Explanation**	**Example**
	Assessment mechanism	Structured process or tool used to evaluate, measure, or analyse specific aspects of performance, conditions, or outcomes. It provides a systematic approach to gathering data, making judgments, and guiding decision-making.	Environmental Impact Assessment
	Indicator	Measurable variable that provides information about a specific condition, allowing assessment and tracking of performance, progress, or changes over time.	Baseline water stress from Water Risk Atlas
	Standardised framework	Established set of criteria, guidelines, or specifications designed to ensure consistency and quality. It provides a common framework that can be universally understood and applied.	International Finance Corporation Performance Standards
	Quantitative threshold	Specific numerical value or limit that serves as a benchmark for measuring or evaluating a particular variable.	Project development only permissible at a given distance from coastal areas; percentage of GHG emissions reduction compared to a comparator
	Other	Various instruments of different characteristics that cannot be clearly assigned to the other types, e.g. exclusion of the use of certain areas and/or resources, obligatory reporting duties	Exclusion of the use of certain water sources

3.2 Sustainability dimensions in the literature – a frequency analysis

How prominent are the different sustainability dimensions of hydrogen (see Figure 1-1) in the literature? Are some dimensions referenced more or to a lesser extent by certain types of authorships? We attempted to approach these questions in a structured way with the help of a quantitative text analysis using Natural Language Processing tools. The results of the analysis are shown in Figure 4-1.

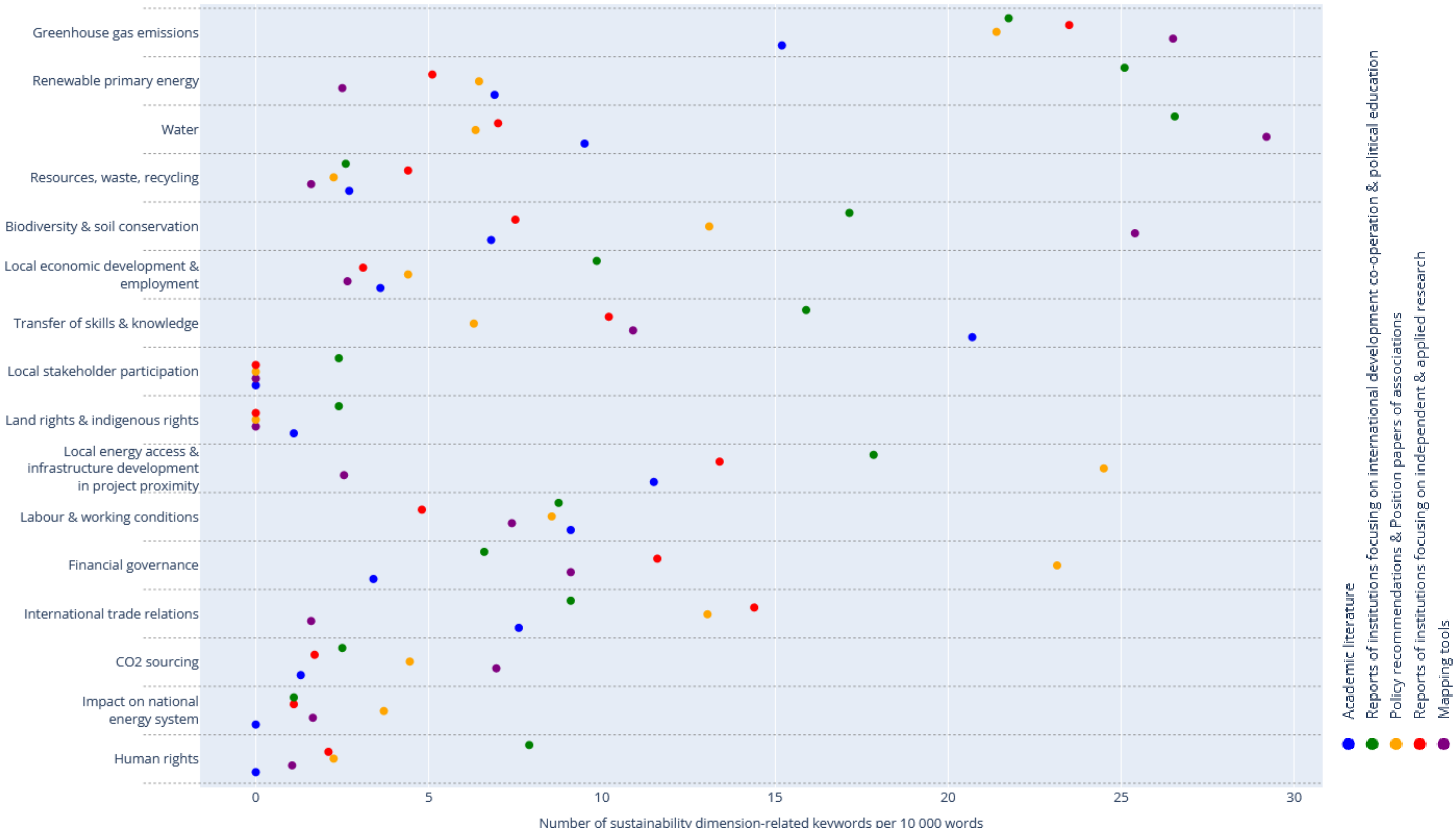
The subsequent figure displays all 15 of the sustainability dimensions identified on the left-hand side; the coloured dots represent the different types of publications. The dots indicate the frequency of references to each dimension – or rather, a set of keywords associated with each dimension that we derived based on the literature corpus. The values represent how often these keyword sets were mentioned per 10 000 words throughout the publications. The median per category is shown here.

Overall, the figure shows a heterogeneous picture across the various sustainability dimensions. This shows that the various dimensions of sustainability are given unequal attention in different publication types:

- Greenhouse gas emissions are prominently discussed across all publication types, stressing their importance in climate impact and sustainability debates of hydrogen.
- Ecological criteria such as water usage, biodiversity and soil conservation, as well as geopolitical aspects and trade relations, are represented, though their prominence varies between publication types. It is noticeable that mapping tools in particular address ecological criteria, but seem to fall short on considering of socio-economic dimensions.
- Socio-economic dimensions like *Local economic development and employment* as well as *Labour conditions* appear in discussions but are less widely covered. This is also the case for the dimensions of *Local energy access and infrastructure development in project proximity* and *Financial governance*. Here, a particularly frequent mention stands out in the publication type *Policy recommendations and position papers of associations* (yellow dots).
- The least mentioned dimensions according to the text analysis are *Stakeholder participation, Land rights*, and *Impact on the national energy system* (e.g. competition for renewable energy export sites versus on-site utilisation). The pictures thus suggests that these issues are being perceived as having less importance in the current discourse. This contrasts with the relevance of these dimensions, especially for the local population in project proximity and rural groups.

[10] See Section 5.2 for further details on the methodology.

Figure 4-1: Sustainability dimensions in the literature – results from the quantitative text analysis



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3.3 Factsheets of socio-economic sustainability dimensions

In this chapter, we aim to show key facts and existing instrument referenced in the literature for selected sustainability dimensions. Our focus here is on socio-economic dimensions that tend to receive scant attention in the current debate. These are also the dimensions for which we see the greatest impact on local groups in project proximity and rural groups in particular. The dimensions in the following are thus all dimensions that fall under the following sustainability clusters:

- **Other environmental (particular focus on the dimension of *Water*)**
- **Broader socio-economic impact**
- **Socially responsible development in project proximity**

In the factsheets, we ask the following questions: Why is this dimension relevant with regard to the sustainability of hydrogen – especially in countries of the Global South and for rural areas? What potential impacts can be expected – both negative and positive?

In addition to these questions, we outline the instruments mentioned in the existing literature for approaching each dimension. The aim here was to identify these instruments in a first step and collect them in an overview, which makes no claims to be exhaustive. Nor do we – within the scope of the project – undertake a more detailed evaluation of what we found. This would be one of the next steps needed for which the factsheets of this chapter can serve as a valuable basis.

Despite the focus on socio-economic dimensions, we want to stress that the remaining dimensions not specifically addressed in the factsheets contribute equally to the sustainability of hydrogen and merit closer examination. However, a more comprehensive consideration lies beyond the scope of this report. On a general level, the literature analysis reveals a fundamentally different picture for the following sustainability clusters, especially regarding the question of how these are already being substantiated with tangible instruments:

- **Environmental:** the reduction of GHG and the use of renewable primary energy appear as the key sustainability issues addressed in all publications. They are also central to prevailing regulations which already provide very concrete instruments, namely precise GHG thresholds, respective accounting methodologies, and additionality requirements for RES-e plants.

- **Governance on system and country-level:** questions of how hydrogen projects are embedded in international economic relations between two countries and geopolitical strategies, the role of financial governance and the interaction with national decarbonisation strategies are increasingly addressed in the literature, along with some specific instruments. Examples here are the Extractive Industries Transparency initiative [11] or World Governance Indicators [12] on political stability or rule of law which make it possible to assess fundamental conditions in countries or regions. Many aspects of this dimension tackle the national level and therefore require political sensitivity and appropriate vehicles, such as energy partnerships for instance.

[11] https://eiti.org/
[12] https://www.worldbank.org/en/publication/worldwide-governance-indicators

- **Human rights:** To ensure completeness, we have assigned human rights its own cluster in our overview of relevant sustainability dimensions (Figure 1 1). However, our impression is that human rights (and related instruments) are mostly a central component of other dimensions. This applies, for example, to *Labour and Working Conditions*, which anchors the human right to work in just and favourable conditions, but also the dimensions *Land Rights* and *Stakeholder Participation*. We therefore decided to not analyse human rights as an individual dimension, but rather to assign them to (more) specific dimensions.

Two further points should be emphasised with regard to the factsheets:

- Some instruments are more applicable at project level; others, such as indicators, describe conditions of a country or a specific region. The latter therefore tackle a different level, namely less to verify the sustainability of a given project, but to evaluate if a specific hydrogen partnership is generally desirable or not, for example. In the factsheets, we captured the full range of instruments mentioned. The next step would be to evaluate this comprehensive 'basket' of instruments, also with regard to appropriate vehicles through which they can be anchored.
- In the presentation of the results of the quantitative analysis for each dimension, the scale is adapted in each case, with the result that it is not standardised. It is important to bear this in mind when comparing sustainability dimensions in this regard.

3.3.1 Water

The role of water in hydrogen production	
Sustainability cluster	Other environmental
Key issues	Access to freshwater sources | water rights | water quality | water desalination
What do you need water for in the hydrogen production process?	Water is one of the two main inputs to electrolysis. Water can be taken from four main sources: groundwater, surface water, seawater from desalination plants and fresh water from the existing network. How much water is needed for the whole hydrogen production chain also depends on the RE technology used to generate electricity, as it is needed to clean PV panels and to cool Concentrated Solar Power (CSP) systems. It is often in sun-rich regions, such as deserts and arid areas, where the renewable energy potential for PV and CSP is the highest, while water is a limited resource.
How much water does hydrogen production require?	Assumptions about how much water is needed for hydrogen production vary widely in the literature. About 0.03 liters per kWh_{hu} hydrogen is needed (in the case of electricity generation by PV plants) and up to 4.29 liters per kWh hydrogen (in the case of electricity generation by CSP plants with water cooling). To meet Germany's projected annual hydrogen demand of 169 TWh in 2045, Oeko-Institut (2022) assume a total water demand of 49 million m^3. Compared to water consumption in other sectors, this appears relatively low. In Spain, for example, more than 300 times of this amount was used for agricultural irrigation only. Yet: even if hydrogen production performs well in absolute terms compared to other sectors, the local impact of even small changes in water availability can be far-reaching.
Why is this sustainability dimension relevant?	
For countries in the Global South?	Regions in countries with high RE potential (PV, CSP or hybrid forms including wind power) for hydrogen production are often arid regions where water availability is limited from the (geographical) outset. In addition, water supply in countries of the Global South is often inadequate and frequently unreliable. Combining these two factors, additional use of local water resources for hydrogen production can have detrimental effects. This applies to the availability of fresh water in terms of quantity and price.
For rural populations?	Water is vital for rural livelihoods, particularly in agriculture. Any impact on its quantity, quality or price can be highly problematic. Rural areas often have limited water infrastructure. In such areas, the introduction of water-intensive processes such as hydrogen production could put further strain on already scarce resources.

What are potential effects?	
Negative	• Competition for local water resources • Especially in arid areas with high potential for solar energy, additional water demands exacerbate existing water stress • Degradation (pollution) of drinking water resources • Rise in local water prices, limiting water access • Violation of prevailing water rights • If sourced *via* SWD: harm to marine flora and fauna if brine is not disposed of appropriately; restriction of related economic activities (e.g. fishery)
Positive, only if measures are taken	• Improvement of local water infrastructure (e.g. reducing leaks of pipelines) • Supply of additional freshwater to local communities from desalination plants for hydrogen production and therefore reduction of existing water stress

What instruments are already specified in the literature? [13]	
	Indicator | Baseline Water Stress – Indicator [14] provided by World Resources Institute (WRI) in the Aqueduct Water Risk Atlas [15] • Measures the ratio of total water demand to available renewable surface and groundwater supplies in a given area – Example: "No development of projects in areas where *Water Stress* is ≤ low" – Referenced by [i.a.]: Fraunhofer IEE (2021), GIZ (2022), Oeko-Institut (2021b), IEK-3; FZJ (2024)

	Indicator | Water Scarcity Footprint (WSF)
	– Indicator that assesses the water stress of a region by putting in comparison water demand versus water availability [16]
	  • Part of this is calculating the Water Footprint (WF) in a life cycle assessment, that measures the environmental impacts of a product or project related to water (indicator for water demand)
	  – The calculation of the WF is formalised in ISO 14046:2014 [17]
	– Referenced by [i.a.]: Cremonese et al. (2023)

	Evaluation mechanism | Preliminary project impact assessment – Assessment of potential impacts of the proposed project via Strategic or Specific Environmental Impact Assessment (EIA) or other similar assessment methods ex-ante hydrological on-site evaluation – Identified risks shall be addressed – Existing guidance documents for EIA: Directive 2011/92/EU [18], International Finance Corporation Performance Standard 1 "Assessment and Management of Environmental and Social Risks and Impacts" [19] – Referenced by [i.a.]: ISCC Plus, LCFS (only for projects involving CCS), GH2 Standard, EU Taxonomy, H2Global, GIZ (2022)

[13] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.
[14] https://www.wri.org/research/aqueduct-40-updated-decision-relevant-global-water-risk-indicators?auHash=74cRjEQPsH0NDpgT1NqIfNpqV-QpYNR4oiPo1HRhpGs
[15] https://www.wri.org/applications/aqueduct/water-risk-atlas
[16] https://www.mdpi.com/2076-3298/5/2/24
[17] https://www.iso.org/standard/43263.html
[18] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0092
[19] https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-1-en.pdf

What instruments are already specified in the literature? [13]

Standardised framework | Annex (B) to the Commission Delegated Regulation 2023/2486

- Defines criteria to "do no significant harm" ('DNSH') for sustainable use and protection of water and marine resources
  - The criteria define the management of risks of environmental deterioration related to water quality and water stress
  - Risks must be identified and addressed with the aim of achieving good water status and good ecological potential in accordance with Article 2 (22) and (23) of Regulation (EU) 2020/852 in accordance with Directive 2000/60/EC [20], which establishes a framework for Community action in the field of water policy
  - A management plan for water use and protection shall be developed in consultation with the relevant stakeholders
  - An EIA needs to be conducted
- Proof of meeting the defined required
- Referenced by [i.a.]: EU Taxonomy, ISCC Plus also refers to the Directive 2000/60/EC to ensure appropriate acquisition of water rights

Standardised framework | Provision of an environmental management system in compliance with EN ISO 14:001:2015

- Globally recognised standard [21] for environmental management systems (EMS)
  - Offers a framework for organisations to design, implement, and continuously improve their EMS to minimise their environmental footprint and achieve environmental goals concerning resource usage, amongst others
- Example: "The project operator shall develop an EMS (addressing the use of water resources) in compliance with EN ISO 14:001:2015"
- Referenced by [i.a.]: H2Global

Standardised framework | Free Prior Informed Consent

- Free, Prior, and Informed Consent (FPIC) is a right granted to Indigenous Peoples to ensure they are given the opportunity to withdraw their consent to a project at any step of project development (detailed information see fact-sheet Land rights and Indigenous Rights)
- Example: "No acquisition of new or modification of the existing water rights can happen without the FPIC of the parties affected"
- Referenced by [i.a.]: ISCC Plus

Quantitative threshold | Set share of investments provided for local water infrastructure

- A set share of the project's investments is provided to improve the local water infrastructure
- Example: "[x]% of the desalinated water for hydrogen production are provided additionally to the local population"
- Example: "[x]% of the total project investments are made available to improve local projects for water supply efficiency"
- Referenced by [i.a.]: Oeko-Institut (2021b), NWR (2021), GH2 Standard

Other | Public reporting of project's contribution to SDGs

- Reporting of the project's expected (social) impact and contribution to the SDGs
  - Focus on SDG 6 "Clean Water & Sanitation"
- Referenced by [i.a.]: GH2 Standard

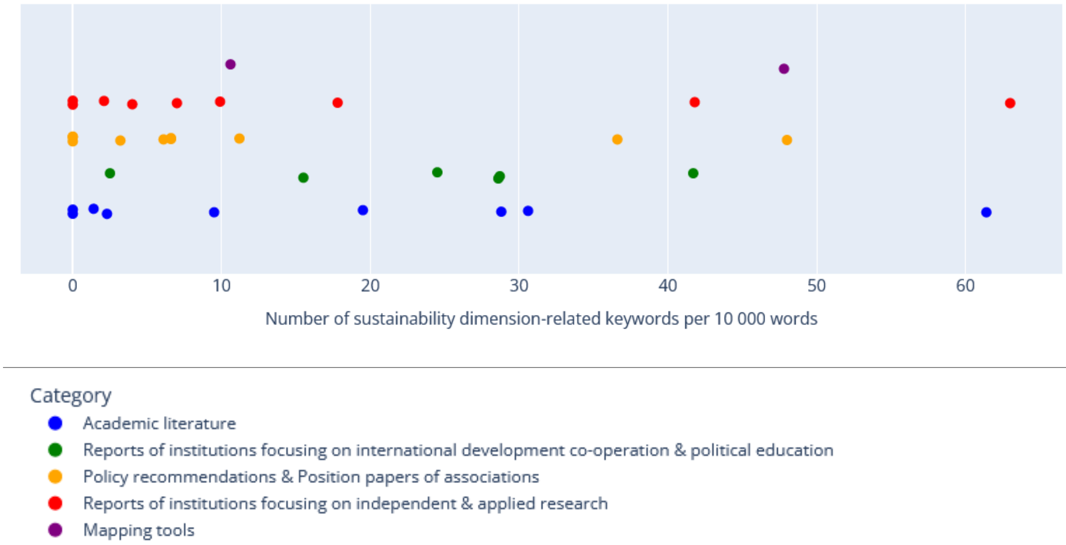
[20] https://eur-lex.europa.eu/eli/dir/2000/60/oj
[21] https://www.iso.org/standard/60857.html

What instruments are already specified in the literature? [13]	
	Other | Exclusion of the use of certain water sources in arid regions – Example: "In arid regions, the use of fossil waterbodies as well as drinking water is excluded." – Referenced by [i.a.]: H2Global, Oeko-Institut (2021b)
	Other | Public reporting of project's potential impact – Reporting of the project's expected impact on local water resources (consumption, pollution) and water rights in a publicly available format – Referenced by [i.a.]: GH2 Standard
Measures specifically related to Seawater Desalination (SWD)	
	Standardised framework | Standards for SWD plants on efficiency and brine disposal – SWD plants should fulfill minimum efficiency standards and yet to be developed international environmental standards on brine disposal – Referenced by [i.a.]: Oeko-Institut (2021b)
	Quantitative threshold | Distance to shoreline (coastal areas or inland waters) – Assumption: proximity to coastal areas or inland waters ensures the supply of water from large water bodies for seawater desalination – Example: "Projects need to be located no further than [x] km to either coastal areas or inland waters" – Referenced by [i.a.]: Fraunhofer IEE (2021), GIZ (2022), IEK-3; FZJ (2024)
	Other | Obligatory reporting of water use and brine disposal – Instrument to track water use throughout the entire production chain, including the disposal of brine from SWD – Example: "In case of desalination plants, reporting of adequate brine management is mandatory." – Referenced by [i.a.]: H2Global, Brot für die Welt; Heinrich-Böll-Stiftung (2022b), Oeko-Institut (2021b), GH2 Standard
	Other | Additionality of SWD plants – To avoid competition of water or price distortions, SWD plants should be additional to the existing ones – Referenced by [i.a.]: Oeko-Institut (2021b)

How is this sustainability dimension discussed in current publications?

- Covered in the majority of publications assessed
- Concrete indicators exist; particularly often referenced:
  - Water Stress by World Resources Institute
  - Impacts related to water resources addressed in EIA
- Part of exclusion criteria for mapping tools

Results from the quantitative text analysis



3.3.2 Biodiversity and soil conservation

General information	
Sustainability cluster	Other environmental
Key issues	Ecosystems | Conservation | Protected Areas | Land-use (change)
Why is this sustainability dimension relevant?	
For countries in the Global South?	The production, storage, transport, and use of hydrogen and its derivatives is associated with encroachment on existing structures - it uses natural resources and land and involves the construction of new facilities. In any case, this entails a change in the prevailing land use patterns in the affected areas and can have a detrimental impact on local ecosystems and biodiversity – both terrestrial and marine. The Global South hosts a major share of the world's biodiversity and protected areas. Cases such as most recently in the Democratic Republic of Congo[22] indicate that the protection of these areas is not guaranteed and may be violated to allow investments for large-scale project development (often destined for export to the Global North). Protecting these ecosystems is therefore vital. Not only for preserving biodiversity but also for maintaining the livelihoods of local communities in affected areas who depend on these natural resources.
For rural populations?	Rural livelihoods that are particularly closely connected to natural resources are at great risk if these resources are degraded. This can result in the loss of both economic stability and cultural identity, a condition particularly severe for indigenous people. Their way of life, traditions, and economic practices are intricately tied to the health of their natural environment, making them especially vulnerable to environmental degradation.
What are potential effects?	
Negative	• Damage to local ecosystems (and livelihoods that depend thereon) • Biodiversity loss • Soil degradation
Positive, only if measures are taken	• Protection of local flora and fauna • Enhancement of conservation measures

[22] https://www.greenpeace.org/africa/en/press/54875/donors-deafening-silence-after-republic-of-congo/

What instruments are already specified in the literature?[23]

Indicator | Country profiles for indices of SDG 14 & 15

SDG 14: "Life below water", SDG 15: "Life on land"

- The United Nations (UN) employ a scoring system to assess the annual progress made by each country towards achieving the goals set out in the Sustainable Development Goals (SDGs)
  - The SDG methodology is based on various quantifiable indicators, followed by a qualitative judgement (e.g. "SDG achieved")
- Example: "Project development only egligible in countries that fulfill the SDGs 14 & 15 to [a certain degree]."
- Referenced by: GIZ (2022)

Evaluation mechanism | Preliminary project impact assessment

- Assessment of potential impacts of the proposed project via Strategic or Specific Environmental Impact Assessment (EIA) or other similar assessment methods ex-ante hydrological on-site evaluation
- Identified risks shall be addressed
- Existing guidance documents for EIA: Directive 2011/92/EU[24], International Finance Corporation Performance Standard 1 "Assessment and Management of Environmental and Social Risks and Impacts"[25]
- Referenced by [i.a.]: EU Taxonomy, H2Global, ISCC Plus, GIZ (2022), Müller et al. (2022)

Standardised framework | Annex (D) to the Commission Delegated Regulation 2023/2486

- Defines criteria to "do no significant harm" ('DNSH') for the protection and restoration of biodiversity and ecosystems
  - The criteria define the management of risks of environmental deterioration related to ecosystems and biodiversity-sensitive areas
  - For projects located in or near biodiversity-sensitive areas (including the Natura 2000 network): conduction of an appropriate assessment in accordance with Directives 2009/147/EC and 92/43/EEC or IFC Performance Standard 6 (see below) and implementation of appropriate mitigation measures (if applicable)
- Proof of meeting the defined required
- Referenced by [i.a.]: EU Taxonomy

Standardised framework | International Finance Corporation (IFC) Performance Standard 6

Biodiversity Conservation and Sustainable Management of Living Natural Resources

- Specific Performance Standard[26] developed by the IFC (World Bank Group) setting requirements of how their clients (receiving direct investments of the corporation) are to manage project related environmental and social risks and impacts
  - Requirements to avoid or minimise risks of habitat loss, degradation and fragmentation as well as addressing the management of ecosystem services
- Example: "Project operators are required to carry out an appropriate assessment of the possible impacts on protected habitats and species in accordance with IFC Performance Standard 6 and implement apt mitigation measures, if necessary."
- Referenced by [i.a.]: EU Taxonomy

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[23] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.

[24] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0092

[25] https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-1-en.pdf

[26] https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-6-en.pdf

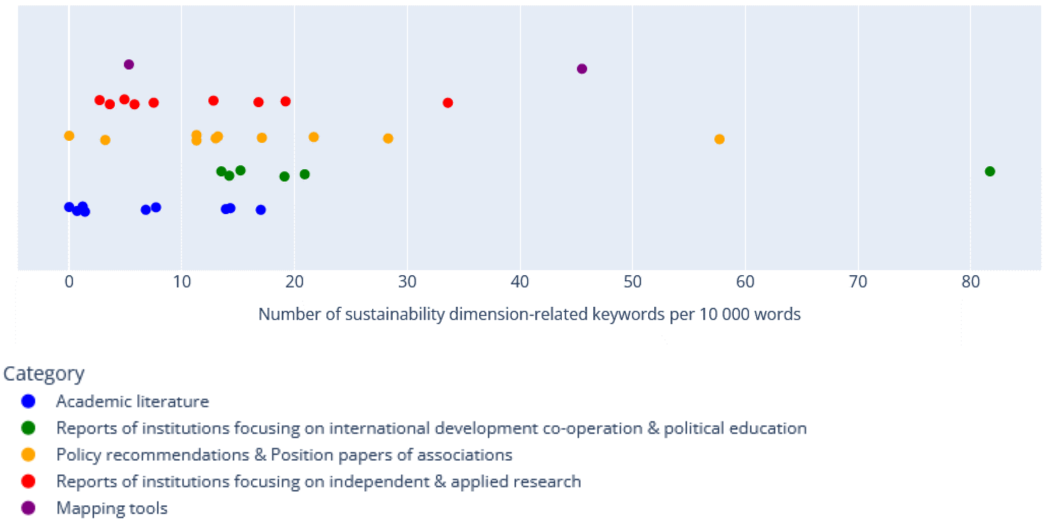
What instruments are already specified in the literature?[23]	
...	**Other |** Exclusion of the use of and minimum distance to protected areas – Protected areas (with high biodiversity value or high CO_2 storage potential) could include, for example, • International Union for Nature Conservation (IUCN) protected areas (I – IV)[27] • Sites recorded on the List of Ramsar Wetlands of International Importance[28] • Sites recorded on the List of Biosphere Reserves of the UNESCO Man and the Biosphere Program[29] • IUCN Other effective area-based conservation measures (OECM)[30] – Minimum distance from occurences of endangered populations – Example: “No project development in protected (marine) areas (plus 1 km buffer).” – Example: “The activity is not carried out at a site that is [x] km or less from the presence (in the last [x] years) of an endangered bird or mammal.” – Referenced by [i.a.]: H2Global, IEK-3; FZJ (2024),Fraunhofer IEE (2021), Oeko-Institut (2021b), Brot für die Welt; Heinrich-Böll-Stiftung (2024), ISCC Plus
...	**Other |** Public reporting of project’s contribution to SDGs – Reporting of the project’s expected impact and contribution to the SDGs • Focus on SDG 15 “Life on Land” and SDG 14 “Life below Water” – Referenced by [i.a.]: GH2 Standard, GIZ (2022)
...	**Other |** Integration of spatial planning practices in national (hydrogen) strategies – In order to avoid land use conflicts, a clear zoning of land use forms is beneficial. This allows to exclude potentially more conflict-ridden land use forms such as areas of high biodiversity value and to focus on less ‘critical’ areas such as space already used for industrial purposes or areas • Such zoning can/should be incentivised as part of a national (hydrogen) strategy – Example: “Project development must be prioritised on areas that are already impacted, e.g. industrial areas. No project development on conflict-prone areas e.g. with high biodiversity value.” – Referenced by [i.a.]: Brot für die Welt; Heinrich-Böll-Stiftung (2022b), Brot für die Welt; Deutsche Umwelthilfe; BUND; Germanwatch; DNR; Heinrich-Böll-Stiftung et al. (2022), IEK-3; FZJ (2024)

[27] https://www.alparc.org/categories-of-apa
[28] https://www.ramsar.org/
[29] https://www.bfn.de/en/unesco-biosphere-reserves
[30] https://www.iucn.org/our-union/commissions/group/iucn-wcpa-other-effective-area-based-conservation-measures-specialist

How is this sustainability dimension discussed in current publications?

- Covered in the majority of publications assessed
- Instruments exist, mostly a project-level; often referenced:
  - Environmental impacts assessed in EIA
  - Exclusion of certain protected areas which are well documented in (geo-) data sets (scope: both region-specific, but also global data sets)
- Part of exclusion criteria for mapping tools

Results from the quantitative text analysis



3.3.3 Resources, waste and recycling

General information	
Sustainability cluster	Other environmental
Key issues	Critical resources | Supply chain | Waste | Recycling
Where do (critical) resources, waste and recycling come into play in hydrogen production?	The leading electrolysis technologies currently on the market, such as Polymer Electrolyte Membrane (PEM) and Alkaline Water Electrolysis (AEL), rely on materials that are classified as Critical Raw Materials (CRM).[31] These include metals such as iridium, platinum, tantalum, cobalt, and nickel (PtX Hub 2022). RES-e modules such as solar systems and wind turbines also require rare earths and metals such as copper, aluminium, cobalt, nickel and lithium (IEA 2022).
Why is this sustainability dimension relevant?	
For countries in the Global South?	The mining process and use of (critical) raw materials, especially those that are not easily recyclable, can have severe adverse effects in the countries where they are extracted. These impacts go beyond the hydrogen producing country and affect other countries of the Global South along the entire supply chain. If practices are not managed correctly, considerable environmental damage can occur such as large-scale land-use change and/or contamination, water pollution or increased seismic activity. This goes along with severe social risks, namely causing health problems for workers at the extraction site, but also for populations in its surroundings. Further, violations of social and environmental justice can occur: in many mining areas located in the Global South land grabbing, child labour and human rights violations have been observed.[32] However, if extraction practices adhere to fairness and sustainability standards, working conditions may improve. Additionally, the integration of effective recycling practices can significantly reduce resource demands for the technologies and – on the bigger picture – the risk for negative social and environmental consequences right up to the starting point of the supply chain.
For rural populations?	Mining areas for (critical) raw materials are often located in rural, remote areas. Ecological and social impacts are felt heavily by local rural groups and indigenous communities. This is particularly problematic as their social, economic, and cultural practices and identities are closely bound up with the natural resources in their immediate surroundings.
What are potential effects?[33]	
Negative	• Social and environmental impacts of resource extraction in supply countries, if not well managed • Including: water pollution, environmental degradation, land grabbing, child labour, adverse health effects • Environmental damage in case of inappropriate or lacking recycling practices for technologies used in hydrogen projects
Positive, only if measures are taken	• Improvement of the working conditions for (critical) resource extraction along the supply chain • Reduction of overall resource demands for technologies used

[31] https://www.consilium.europa.eu/en/infographics/critical-raw-materials/
[32] See for example, https://www.rosalux.de/en/news/id/50891
[33] Effects occur predominantly along the entire supply chain and not necessarily in the country of production.

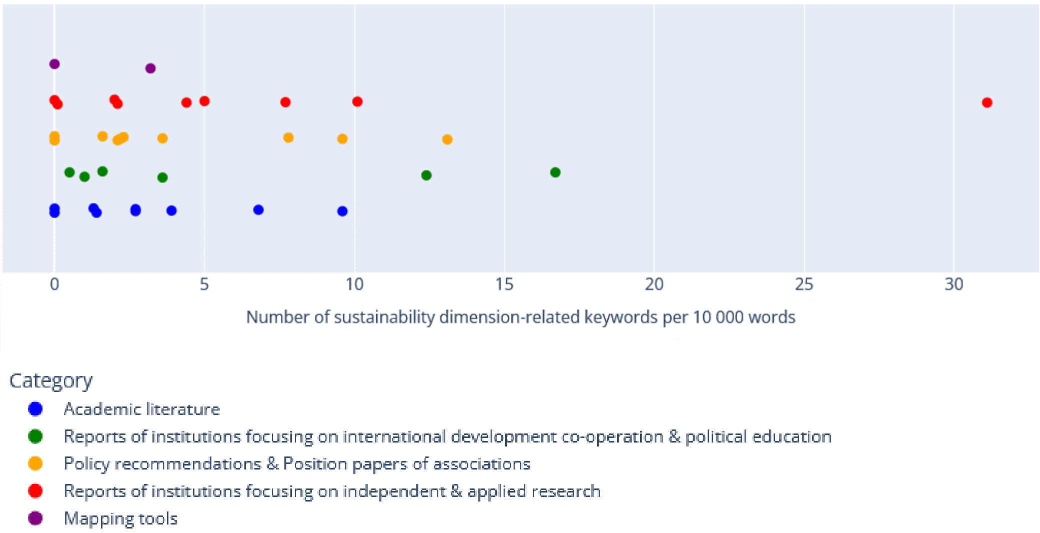
What instruments are already specified in the literature? [34]	
	Evaluation mechanism | Life cycle assessments (LCA) of technologies used – LCA of technologies employed such as wind turbines, electrolysers, to identify and assess the environmental impacts of resource use • Important here: consistent methodologies for LCA accounting in order to ensure comparability; yet in most cases, those methodologies are still to be developed – Referenced by [i.a.]: NWR (2021)
	Standardised framework | Provision of an environmental management system in compliance with EN ISO 14:001:2015 – Globally recognised standard [35] for environmental management systems (EMS) • Offers a framework for organisations to design, implement, and continuously improve their EMS to minimise their environmental footprint and achieve environmental goals concerning resource usage, amongst others – Example: "The project operator shall develop an EMS (addressing the handling of production-related waste) in compliance with EN ISO: 14:001:2015" – Referenced by [i.a.]: H2Global
	Other | Proof of (critical) material procurement from countries with responsible extractive practices – Procurement of materials (for RE modules, electrolysers, etc.) e.g. only from countries that are signatories (with an appropriate status) of the Extractive Industries Transparency Initiative (EITI) [36] • EITI groups together countries who pledge to disclose information throughout the extractive industry value chain including details on the awarding of extraction rights and the flow of revenues through the government or to the public – Example: "Critical materials employed for RE technologies and electrolysers are sourced from countries with a valid status within the EITI." – Referenced by [i.a.]: Brot für die Welt; Heinrich-Böll-Stiftung (2022b)
	Other | Public reporting of project's contribution to SDGs – Reporting of the project's expected impact and contribution to the SDGs • Focus on SDG 12 "Responsible consumption and production" – Referenced by [i.a.]: GH2 Standard, GIZ (2022)

[34] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.
[35] https://www.iso.org/standard/60857.html
[36] https://eiti.org/

How is this sustainability dimension discussed in current publications?

- Not widely discussed across the range of publications analysed
  - Not explicitly covered in existing regulations
  - Referred to most notably in Brot für die Welt; Heinrich-Böll-Stiftung (2024) and PtX Hub (2022)
- Some instruments exist, which are however not hydrogen-specific

Results from the quantitative text analysis



3.3.4 Local economic development and employment

General information	
Sustainability cluster	Broader socio-economic impact
Key issues	Employment opportunities | Value creation
Why is this sustainability dimension relevant?	
For countries in the Global South?	Just because a hydrogen project is being developed in a country does not automatically mean the latter will benefit from it. Particularly in the case of (large-scale) projects that prioritise production for export abroad, there is a high risk that economic added value will only be created outside the project host country. In such one-sided economic relationships, the country of production merely serves as a platform for resource extraction and, apart from the associated negative effects, receives no or only marginal benefits. This risk is particularly high for countries of the Global South, which are often dependent on foreign investment and in an inferior political and economic (negotiation) position. To some extent, such potential structures are also questioned as the perpetuation of (neo)colonial economic relations. At the same time, however, the risks illustrated above contrast with great potentials to create local added value associated with hydrogen development. This can include the creation of basic and skilled jobs and opportunities to integrate local companies along the supply chain. Additionally, on the long-term, hydrogen may be used both in suitable application sectors within the project host country, but also to produce hydrogen derivatives.
For rural populations?	Rural groups are often less integrated in large economic structures from the outset. This is why they face an even higher risk of only suffering the negative effects of resource exploitation with no economic stake. Yet, also rural populations can benefit significantly if efforts are being taken towards sustainable local economic development: this includes the creation of local employment opportunities, but also the potential to support local communities with revenue generated from effective local taxation. For rural groups whose livelihood is based on agriculture or pastoralism, appropriate forms of economic participation need to be explored. This might, for example, entail finding formats for parallel land-use on potential RES-e sites and specific financial participation options, e.g. pastoralists/farmers receiving a reasonable lease for RES-e plants to be installed on their lands.
What are potential effects? [37]	
Negative	• Drain of value creation to foreign markets • No job creation for local stakeholders • Use of project revenues not in the interests of the local population and communities, whilst these are negatively affected by exploitation of their (natural) resources
Positive, without further measures	• Creation of basic (unskilled) jobs, e.g. in the building sector

[37] Effects occur predominantly along the entire supply chain and not necessarily in the country of production.

Positive, only if measure are taken	• Value and job creation on different levels
	  • Creation of career opportunities for local staff
	    • Integration of local companies and labour
	    • Use of hydrogen in local industries
	    • Added value in the exporting country, e.g. by derivative production
	• Revenue through local taxation of value creation

What instruments are already specified in the literature? [38]	
	Indicator | Unemployment rate – Indicator [39] provided e.g. by the International Labour Organization (ILO) in [%] of the total work force to assess the state of a country's/region's labour market by the unemployment rate – Referenced by [i.a.]: IEK-3; FZJ (2024)
	Quantitative threshold | Fixed quota of local companies engaged in the supply chain – 'Local content' quotas for the integration of local companies • Potentially possible at various points in the supply chain, e.g. setting up of RES-e modules, supply of raw materials, general services – Example: "At least a number of [x] local companies [to be clearly determined] must be part contracted or subcontracted by the seller." – Referenced by: NWR (2021)
	Quantitative threshold | Fixed quota of hydrogen/derivatives use in local, 'no-regret' application sectors – Potential future approach for assessing the local use of hydrogen and derivatives – Precondition: statistical data on the use of hydrogen/derivatives in local application sectors which is not yet available – For more detailed evaluation, e.g. classification within potential areas of application and definition of 'no-regret' sectors as provided, for instance, by Agora Energiewende 2021 – Referenced by [i.a.]: GIZ (2022)
	Other | Public reporting of project's contribution to SDGs – Reporting of the project's expected impact and contribution to the SDGs • Focus on SDG 8 "Decent work & economic growth" – Referenced by [i.a.]: Green Hydrogen Standard
	Other | Mention of plans for hydrogen/derivative use in local sectors according to national hydrogen strategies – Potential approach for assessing government plans for the local use of hydrogen [40] : are such plans mentioned at all? If yes, how often? And for which areas of application? – For more detailed evaluation, e.g. classification within potential areas of application and definition of 'no-regret' sectors as provided, for instance, by Agora Energiewende (2021) – Referenced by [i.a.]: GIZ (2022)

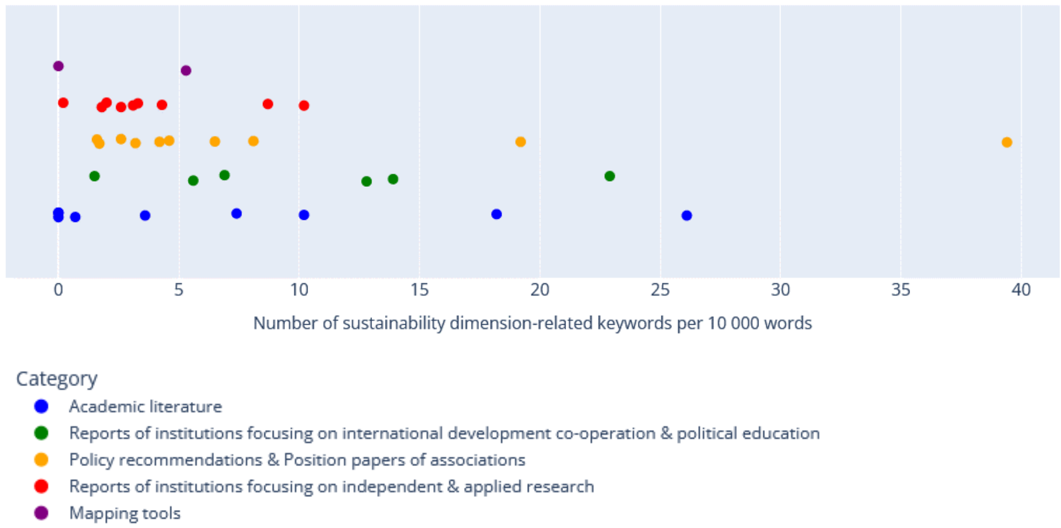
[38] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.
[39] https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS
[40] Transitional suggestion as long as there is no statistical data available on this topic.

...	**Other** | Expected job creation linked to hydrogen/derivative production according to national hydrogen strategies – Data on expected job creation [in total numbers] provided in national hydrogen strategies [41] as approach to assess government plans for potential employment opportunities – Note: the mere number of jobs created/planned does not indicate the quality of these jobs – Referenced by [i.a.]: GIZ (2022)
...	**Other** | Use of a set share of project profits for socio-economic development of host community – Mechanism already employed in the South Africa's independent power producer procurement program (IPPPP) [42] • Includes policy elements such as local content requirement, preferential procurement and local enterprise development – Referenced by [i.a.]: Cremonese et al. (2023)

How is this sustainability dimension discussed in current publications?

- Generally addressed in all publication types
- To date, only a few concrete instruments have been mentioned
  - Substantive proposal from GIZ, some of which are however rather transitional and mainly based on information provided in national hydrogen strategies (if available)
- Geographically multi-layered dimension (local, regional, national value creation)
- Potentially major benefits for the producing countries

Results from the quantitative text analysis



[41] As undertaken, for instance, in Chile's National Green Hydrogen Strategy: https://energia.gob.cl/sites/default/files/national_green_hydrogen_strategy_-_chile.pdf
[42] https://www.ipp-projects.co.za/Home/About

3.3.5 Transfer of skills and knowledge

General information	
Sustainability cluster	Broader socio-economic impact
Key issues	Training | Education | Research | Skills
Why is this sustainability dimension relevant?	
For countries in the Global South?	Hydrogen and derivate production, handling and transport is a highly specialised process whose planning and implementation require excellent technical and management skills. The bulk of this expertise is (historically) concentrated in countries of the Global North and might therefore largely stem from these countries, also in hydrogen projects. There is no guarantee that the local population will benefit from this expertise – or that they will be able to contribute their own, local knowledge. It is thus crucial to ensure that expertise related to hydrogen development is shared with stakeholders in the project host country. Here, dialogue is to be established on an equal footing and *via* different formats (e.g. university programs, training of employees, etc.). This is the base, also to promote the (long-term) use of hydrogen and decarbonisation in the project's host country.
For rural populations?	Rural communities, who live far away from (urban) centres of social infrastructure, often have a lower level of formal education. Providing and/or expanding training programs and investing in basic education infrastructure has a significant impact here. Yet, at the same time, rural groups and indigenous groups possess valuable local knowledge about the environment, resources and social dynamics that cannot be found in textbooks. A reciprocal transfer of skills is therefore key.
What are potential effects?	
Negative	• No exchange or content-related involvement of local stakeholders in project management and governance processes nor technical expertise • I.e. mere exploitation of local resources and labour • Perpetuation of unequal qualification levels between foreign employees or decision-makers and local stakeholders
Positive, only if measures are taken	• Investment in training of different target groups (including women and youth, for example) • Creation of exchange platforms for mutual knowledge sharing on e.g. technical or project management expertise • Establishment of a scientific dialogue • Joint research institutions and projects • Joint university programs on hydrogen/derivative production and application potentials in the local context • Programs for continuous learning for employees

What instruments are already specified in the literature? [43]

Quantitative threshold | Minimum hours of employee's participation in training program (provided by the project developer)

- It should be specified what kind of training is targeted (e.g. on specific legal, economic or technical skills relating to the production of RES-e)
- Example: "Required proof that all employees [exact definition needed here] participated at least [x] h in a [specification] training program provided/supported by the project developer."
- Referenced by [i.a.]: H2Global

Quantitative threshold | Minimum amount of investments in training program for employees

- It should be specified what kind of training is targeted (e.g. on specific legal, economic or technical skills relating to the production of RES-e)
- Example: "A minimum amount of [x] [defined currency] must be invested in a training program for employees [exact definition needed here]."
- Referend by [i.a.]: H2Global

Quantitative threshold | Set amount of investments into educational infrastructure in project proximity

- Example: "Investment of minimum of [x] [defined currency] on construction of schools or other educational institutions people either in [x] km radius to the project or in the nearest town"
- Referenced by [i.a.]: H2Global

Other | Proof of women in jobs requiring specific skills

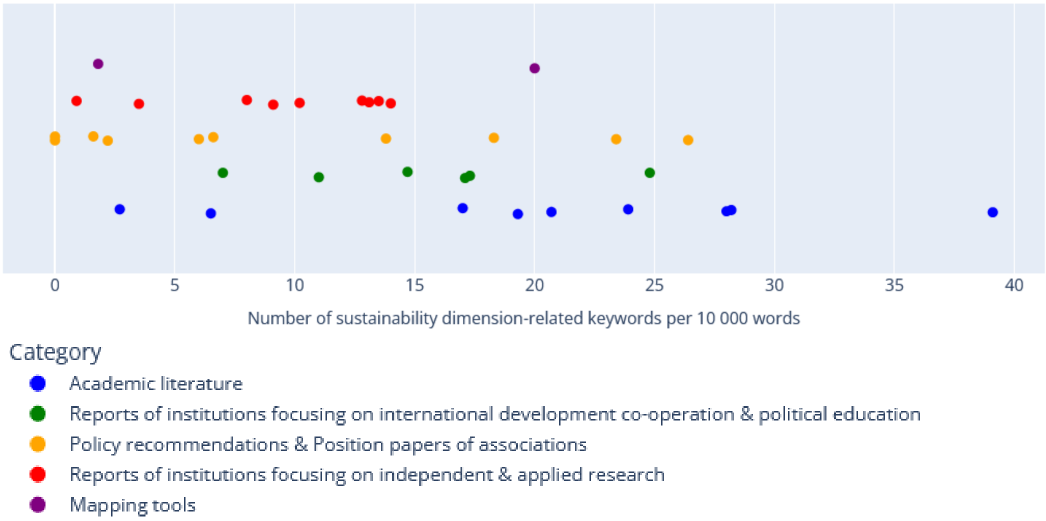
- Via a minimum amount or set share of contracts with women
  - For this instrument to be effective, it should be specified how these contracts are associated with a certain (baseline) skill profile
- Example: "At least [x] contracts with women with at least [x]% of hours spent on construction or operation of value chain assets."
- Referenced by [i.a.] H2Global

[43] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.

How is this sustainability dimension discussed in current publications?

- It is addressed across all publication types;however, the demands are rather general and only a few concrete instruments are mentioned.
  - An exception here is the H2Global mechanism (see above)

Results from the quantitative text analysis



3.3.6 Energy access and infrastructure development in project proximity

The role of energy access and infrastructure development in project proximity	
Sustainability cluster	Socially responsible project development
Key issues	Local energy supply | Energy poverty | Infrastructure investments | Community development
Definition of terms	• **Energy access** refers to the availability of reliable and affordable energy services to meet essential needs such as lighting, heating, cooking. Conversely, energy poverty describes circumstances in which this access is limited or lacking. • In this factsheet, we understand the term **infrastructure** as covering all facilities, institutions, structures and systems that serve the provision of services of general interest for the population in direct project proximity. This encompasses different types of infrastructures, namely social infrastructure such as schools, hospitals, kindergardens, and technical infrastructure, including transport infrastructure, e.g. roads, railways, and energy supply systems, e.g. the electricity grid.
What is the role of infrastructure in hydrogen production?	Technical infrastructure allows the required resources to be delivered to the site of hydrogen production both during the construction phase and during operation. This encompasses transporting materials and machinery, for example by road, rail, pipeline, but also electricity via the grid or direct line as input for electrolysis and other production steps. Further, infrastructure is needed for processes to be carried out on and around the production site premises, including employees travelling to and from work. It is also (technical) infrastructure that allows to transfer the produced hydrogen and derivaties towards domestic user and/or export markets.

Why is this dimension relevant to the sustainability of hydrogen?	
For countries in the Global South?	Many countries and regions of the Global South are impacted by energy poverty. If a hydrogen project is placed in such circumstances and puts additional demands on local infrastructures, there is a high risk that existing constraints in supply can be severely exacerbated. This concerns both the physical infrastructure and the availability of affordable electricity. Especially if RES-e is sourced from the grid without meeting additionality requirements, wholesale electricity prices may rise and limit access to energy for economically constraint end users. "Access to affordable, reliable, sustainable and modern energy for all" is clearly anchored in Sustainable Development Goal 7 [44]. It is therefore crucial to assess what it means to integrate large-scale, centralised and potentially export-oriented hydrogen production into local contexts. This involves addressing adverse impacts, but also identifying positive (spillover) effects. There is high potential to leverage infrastructure development, e.g. by (partially) redirecting infrastructure investments and/or affordable electricity to local communities in project proximity.

[44] https://sdgs.un.org/goals/goal7

For rural populations?	Rural populations are often located in areas which are peripheral to infrastructure development, if at all. This shows both in insufficient social facilities, which are often not available in adequate supply locally, and poorly built technical infrastructure, e.g. unpaved roads, low capacity or no electricity network expansion. This goes hand in hand with rural areas being frequently affected by energy poverty. The use of existing infrastructure, for hydrogen production (for export) may heavily exacerbate such precarious circumstances in rural areas.
What are potential effects?	

Negative	• Competing use of existing infrastructure
	  • Existing structures may be (partially) blocked for local users (e.g. access to certain areas is cut off as solar parks are built for hydrogen production)
	  • Existing structures may be (partially) blocked for other development policy purposes
	• Rise in wholesale electricity prices (if RE power capacity is sourced from the grid, without meeting additionality requirements
	• Limited access to energy due to economic constraints
	  • Exacerbation existing energy poverty

Positive, without further measures	• Spillover effects of infrastructure expansion in project proximity, e.g. access roads to production facilities

Positive, only if measures are taken	• Improvement of common user infrastructure in project proximity
	  • Investments in technical infrastructure (grids, ports, roads)
	  • Investments in social infrastructure (hospitals, schools)
	• Provision of low-cost electricity from RES-e generation for electrolysis

What instruments are already specified in the literature? [45]	
	Evaluation mechanism | Social Impact Assessment (SIA) – SIA or other similar assessment required to help understand the potential impacts of the proposed project – Identified risks shall be addressed and incorporated into a community engagement plan (or similar) – Supporting documents: guidance note on ESIAs by the International Union for Conservation of Nature (IUCN)[46] with detailed information on key elements of an SIA – Referenced by [i.a.]: GH2 Standard, GIZ; ILF Ingeniería Chile Limitada; LBST (2021), Klima-Allianz Deutschland; BUND; WWF Deutschland; DUH; Gegenströmung; Brot für die Welt; Germanwatch; Misereor; Institut für Kirche und Gesellschaft (2024)
	Evaluation mechanism | Preliminary project impact assessment – Assessment of potential impacts of the proposed project via Strategic or Specific EIA or other similar assessment methods (see also SIA) – Identified risks shall be addressed

[45] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.

[46] https://www.iucn.org/sites/default/files/2022-05/esms-social-impact-assessment-sia-guidance-note.pdf

What instruments are already specified in the literature? [45]	
	– Existing guidance documents for EIA: Directive 2011/92/EU [47], International Finance Corporation Performance Standard 1 "Assessment and Management of Environmental and Social Risks and Impacts" [48] – Referenced by [i.a.]: GH2 Standard, NWR (2021), Brot für die Welt; Heinrich-Böll-Stiftung (2022b), GIZ (2022)
	Evaluation mechanism | Grid compatibility test – Technical compatibility test before project commissioning that takes into account the capacity of the system and possible disruptions to the grid – Supporting documents: Note from the German Renewable Energy Sources Act Clearingstelle EGG on the interpretation and application of grid compatibility assessments (in German language) [49] – Referenced by [i.a.]: GIZ (2022)
	Indicator | Share of energy access [%] of urban and rural population – Indicator e.g. reported by the World Bank Group to track SDG 7 "Access to electricity (% of population)" – Example: "No development of projects in countries/regions where the share of energy access ≤ x %" – Referenced by [i.a.]: IEK-3; FZJ (2024), GIZ (2022)
	Indicator | African Index for Development (AIDI) – Indicator [50] developed by the African Development Bank Group to monitor the status and progress of infrastructure development across the continent – Specifically relevant composite indices, e.g.: • Transport Composite Index (Total Paved Roads and Total Road Network) • Electricity Index (Net Generation as of kWh per inhabitant) – Example: "No project development in countries with a rating below [given threshold between 0 points (lowest) and 100 points (highest)]" – Referenced by [i.a.]: IEK-3; FZJ (2024)
	Indicator | Logistics Performance Index – Indicator by World Bank – Evaluation of a country's prevailing logistics situation – Referenced by [i.a.]: IEK-3; FZJ (2024)
	Quantitative threshold | Set share of investments into social infrastructure in project proximity – Example: "Investment of minimum [x] € [currency to be individually adapted] on construction of schools, hospitals, kindergarden or shelter for homeless people either in [x] km radius to the project or in the nearest town" – Referenced by [i.a.]: H2Global

[47] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0092
[48] https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-1-en.pdf
[49] https://www.clearingstelle-eeg-kwkg.de/sites/default/files/Hinweis_2013_20.pdf
[50] https://infrastructureafrica.opendataforafrica.org/pbuerhd/africa-infrastructure-development-index-aidi-2022

What instruments are already specified in the literature? [45]

Other | Public reporting of project's contribution to SDGs
- Reporting of the project's expected (social) impact and contribution to the SDGs
  - Focus on SDG 7 "Affordable and clean energy" and SDG 9 "Industry, Innovation and Infrastructure"
- Referenced by [i.a.]: GH2 Standard

Other | Use of a set share of project profits for infrastructure development
- Mechanism already employe' in the South Africa's independent power producer procurement program (IPPPP) [51]
- Example: "[x] % of the project's profits are set aside to support the local host community's socio-economic development" [52]
- Referenced by [i.a.]: Cremonese et al. (2023)

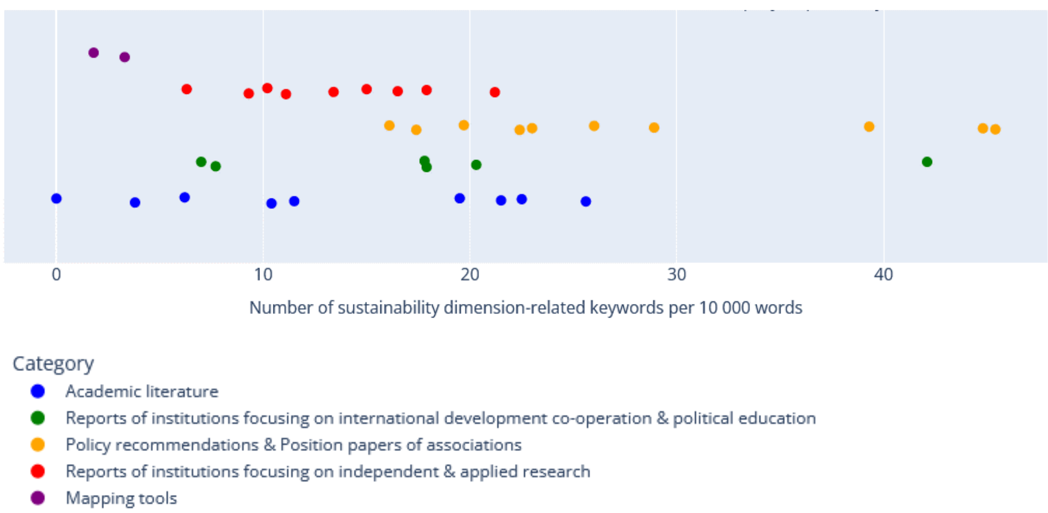
Other | Supply of a share of RES-e generation to local population
- Example: "Provision of surplus electricity from RES-e generation for the population in the [given distance] of the project"

Referenced by [i.a.]: GIZ (2022)

How is this sustainability dimension discussed in the discourse?

- Referred to in almost all publications
  - Mostly addressed in policy papers
- A broad range of instruments (or at least approaches) and especially indicators exists which also address hydrogen-specific issues

Results from the quantitative text analysis



51 https://www.ipp-projects.co.za/Home/About
52 https://scielo.org.za/scielo.php?script=sci_arttext&pid=S1021-447X2018000100004

3.3.7 Labour and working conditions

General information	
Sustainability cluster	Socially responsible project development
Key issues	Safety risks | Health | Contracts
Why is this sustainability dimension relevant?	
For countries in the Global South?	The production, handling and transport of hydrogen and derivatives involves very high health and safety risks. If not managed appropriately, employees are exposed to explosive or toxic substances such as hydrogen itself. Additionally, people living near production sites may also suffer from health impacts. These risks are exacerbated, if health and labour standards are violated – as has been frequently reported across countries of the Global South. And this is not just about health and safety. It also includes other aspects feeding into decent working conditions such as fair pay, effective grievance mechanisms as well as protection against ethnic and sexual discrimination at the workplace. Addressing these issues is therefore essential for promoting fair labour practices and protecting the well-being of both workers and local communities.
For rural populations?	It is not uncommon, that rural groups suffer from highly precarious health conditions, as they are often cut off from health infrastructure such as hospitals in (urban) centres. Therefore, the potential risks on health and safety associated with hydrogen production weigh particularly heavily.
What are potential effects?	

Negative	• Adverse health effects for workers and decreased safety due to inappropriate handling of explosive/toxic substances during production and transport
	• Adverse health effects for people living in proximity to production sites
	• Violation of worker's human and labour rights
	  • Child or forced labour
	  • Inappropriate payments (e.g. below living wage)
	• Instable or untransparent working conditions

Positive, without further measures	• Generally: creation of new work spaces (see 4.3.5) • Generally: potential knowledge transfer (see 4.3.6)

Positive, only if measures are taken	• Creation of fair and safe working conditions
	  • Appropriate payments
	  • High transparency (e.g. full disclosure of any contract)
	  • Stable labour conditions and contracts
	• Monitoring of the employees' state of health

	What instruments are already specified in the literature? [53]
	Standardised framework | International Labour Organisastion (ILO) Declaration on Fundamental Principles and Rights at Work – Declaration [54], adopted in 1998 and amended in 2022 – Commits ILO member states to uphold basic human rights at work: • Freedom of association and the right to collective bargaining, • The elimination of forced or compulsory labor, • The abolition of child labor, • The elimination of discrimination at work, • A safe and healthy working environment – Referenced by [i.a.]: ISCC Plus, EU Taxonomy, GH2 Standard, H2Global, PtX Hub (2022), Müller et al. (2022), GIZ; ILF Ingeniería Chile Limitada; LBST (2021)
	Standardised framework | UN International Bill of Human Rights – Framework [55] that joins the Universal Declaration of Human Rights (UDHR) and the two International Covenants on Economic Social and Cultural Rights and on Civil and Political Rights – Manifests basic human rights that States must refrain from interfering – Guarantees basic rights such as the freedom to choose and accept work, the right to strike or the freedom of children from social and economic exploitation – Referenced by [i.a.]: EU Taxonomy
	Evaluation mechanism | Social Impact Assessment (SIA) – SIA or other similar assessment required to help understand the potential social impacts of the proposed project – Identified risks shall be addressed – Supporting documents: guidance note on ESIAs by the International Union for Conservation of Nature (IUCN) [56] – Referenced by [i.a.]: GH2 Standard
	Evaluation mechanism | Preliminary assessment of human resource and labour management requirements – Including recruitment, project occupational health and safety issues, risks and management measures – Referenced by [i.a.]: GH2 Standard
	Evaluation mechanism | Proof of efficient grievance and refusal mechanisms – Transparent grievance and refusal mechanisms ensure that local communities have the opportunity to enter into dialogue with the project developer to report or refuse unfavourable projects development and proceedings – Existing guidance documents or resources for grievance mechanisms are provided, for instance, in the Grievance Mechanism Toolkit of the Office of the Compliance Advisor/Ombudsman (CAO) (on behalf of Members of the World Bank) [57] and in the International Finance Corporation Performance Standard 1 "Assessment and Management of Environmental and Social Risks and Impacts" [58]

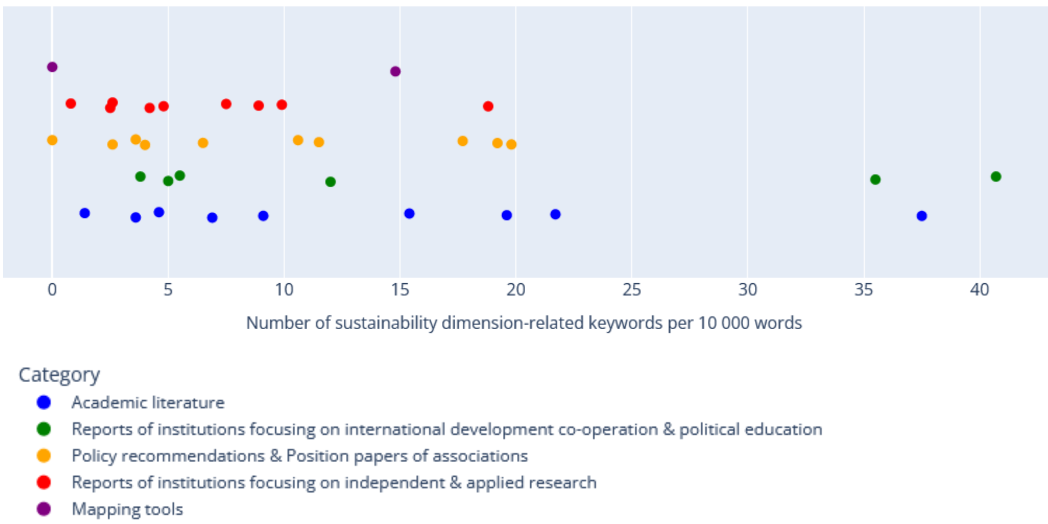
[53] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.
[54] https://www.ilo.org/ilo-declaration-fundamental-principles-and-rights-work
[55] https://www.ohchr.org/en/what-are-human-rights/international-bill-human-rights
[56] https://www.iucn.org/sites/default/files/2022-05/esms-social-impact-assessment-sia-guidance-note.pdf
[57] https://www.cao-grm.org/
[58] https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-1-en.pdf

	– Example: "Project developers have to proof that appropriate grievance mechanisms according to IFC Performance Standards exist or will be established." Referenced by [i.a.]: GH2 Standard, GIZ (2022), Brot für die Welt; Heinrich-Böll-Stiftung (2022b), Brot für die Welt; Heinrich-Böll-Stiftung (2024), PtX Hub (2022), Oeko-Institut, (2021b), NWR (2021)
	Other | Public reporting of project's contribution to SDGs – Reporting of the project's expected contribution to the SDGs • Focus on SDG 3 "Good health and well-being" • Referenced by [i.a.]: GH2 Standard
	Other | Monitoring of potential discrimination through dedicated staff • Proof of activities of an appropriate number of staff dedicated to mnitor potential discrimination within the project business • Activites may include, for instance: evaluation of job advertisements, job interview proceedings and employment decisions, compliation of relevant data on discrimination in a regularly published data format • Example: "An 'equal opportunity officer is to attend at least [x] % of all ob interviews." • Referenced by [i.a.]: H2Global

How is this sustainability dimension discussed in current publications?

- Addressed across all publication types
- Also addressed in regulations (e.g. EU Taxonomy) and certification schemes (e.g. ISCC Plus)
- Common and frequent reference to specific concrete instruments
  - Most importantly the ILO Declaration on Fundamental Principles and Rights at Work
  - However, other specific instruments are also mentioned.

Results from the quantitative text analysis



3.3.8 Local stakeholder participation

General information	
Sustainability cluster	Socially responsible project development
Key issues	Consultation | (Public) Participation
Why is this sustainability dimension relevant?	
For countries in the Global South?	Stakeholder participation involves engaging in dialogue with individuals or groups who have a stake in the project from the very beginning and throughout its implementation. This is crucial in all contexts, whether in the Global North or South, and operates on multiple levels: it helps create transparency in decision-making processes, allows for the early identification and incorporation of local needs into project design and implementation, and thereby helps to prevent land-use conflicts, displacement, and decreased project acceptance. Additionally, it facilitates knowledge exchange – and if done in an effective way – on an equal footing.
For rural populations?	Effective stakeholder participation is particularly important where there are imbalanced negotiating positions, e.g. between economically powerful, often foreign entities and the local communities, including rural and indigenous groups, on whose land projects are to materialise.
What are potential effects?	
Negative	• Neglect of local stakeholders' concerns and needs • Leading to e.g. land-use conflicts, involuntary displacement • Decreased acceptance of or opposition to hydrogen projects
Positive, only if measures are taken	• Adaptation of the project design and processes to local concerns, needs and conditions • Identification of potentials for synergies, e.g. for parallel use of land for PV and agricultural activities • Financial benefits for local stakeholders and municipalities

What instruments are already specified in the literature? [59]	
	Evaluation mechanism | Social Impact Assessment (SIA) – SIA or other similar assessment required to help understand the potential social impacts of the proposed project – Identified risks shall be addressed and incorporated into a community engagement plan (or similar) – Supporting documents: guidance note on ESIAs by the International Union for Conservation of Nature (IUCN) [60] with detailed information on key elements of an SIA – Referenced by [i.a.]: GH2 Standard

[59] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.

[60] https://www.iucn.org/sites/default/files/2022-05/esms-social-impact-assessment-sia-guidance-note.pdf

What instruments are already specified in the literature? [59]

Evaluation mechanism | Preliminary project impact assessment

- Assessment of potential impacts of the proposed project via Strategic or Specific EIA or other similar assessment methods such as SIA (see above) or community-led impact assessments [61]
- Identified risks shall be addressed
- Existing guidance documents for EIA: Directive 2011/92/EU [62], International Finance Corporation Performance Standard 1 "Assessment and Management of Environmental and Social Risks and Impacts" [63]
- Referenced by [i.a.]: ISCC Plus, GH2 Standard, EU Taxonomy, H2Global, GIZ (2022), Oeko-Institut (2021b)

Evaluation mechanism | Proof of efficient grievance and refusal mechanisms

- Transparent grievance and refusal mechanisms ensure that local communities have the opportunity to enter into dialogue with the project developer to report or refuse unfavourable projects development and proceedings
- Existing guidance documents or resources for grievance mechanisms are provided, for instance, in the Grievance Mechanism Toolkit of the Office of the Compliance Advisor/Ombudsman (CAO) (on behalf of Members of the World Bank) [64] and in the International Finance Corporation Performance Standard 1 "Assessment and Management of Environmental and Social Risks and Impacts" [65]
- Example: "Project developers have to proof that appropriate grievance mechanisms according to IFC Performance Standard 1 exist or will be established."
- Referenced by [i.a.]: GH2 Standard, GIZ (2022), Brot für die Welt; Heinrich-Böll-Stiftung (2022b), Brot für die Welt; Heinrich-Böll-Stiftung (2024), PtX Hub (2022), Oeko-Institut (2021b), NWR (2021)

Standardised framework | Free Prior Informed Consent

Note: Mechanism initially designed to ensure the participation of indigenous groups, but can also be extended to other stakeholder groups

- Free, Prior, and Informed Consent (FPIC) is a right granted to Indigenous Peoples recognised in the UN Declaration on the Rights of Indigenous Peoples
  - It ensures that Indigenous Peoples are given the opportunity to withdraw their consent for projects that are planned or being developed on their territories – and this at any phase of project development. This means, that Indigenous Peoples, if they risk being affected by a project, are to be engaged and consulted with throughout project design, implementation and monitoring
- The principle of FPIC is anchored in Convention 169 of the International Labour Organization (ILO) [66] (Articles 6, 7, 16)
- Example: "Project developers are to be provide proof of consultation with relevant stakeholders according to ILO Convention 169"
- Referenced by [i.a.]: Brot für die Welt; Deutsche Umwelthilfe; BUND; Germanwatch; DNR; Heinrich-Böll-Stiftung et al. (2022); ISCC Plus; Brot für die Welt; Heinrich-Böll-Stiftung (2024); Brot für die Welt; Heinrich-Böll-Stiftung (2022b)

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61 Referred to by Gevaert et al. (2023), without further specification.
62 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0092
63 https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-1-en.pdf
64 https://www.cao-grm.org/
65 https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-1-en.pdf
66 https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:55:0::NO::P55_TYPE,P55_LANG,P55_DOCUMENT,P55_NODE:REV,en,C169,/Document

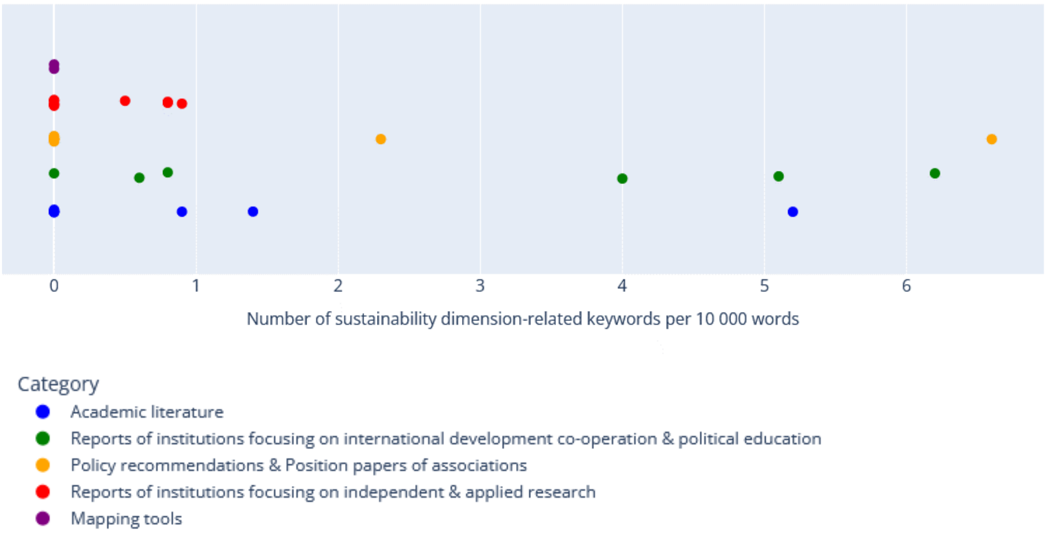
What instruments are already specified in the literature? [59]	
	Evaluation mechanism | Proof of efficient grievance and refusal mechanisms – Transparent grievance and refusal mechanisms ensure that local communities have the opportunity to enter into dialogue with the project developer to report or refuse unfavourable projects development and proceedings – Existing guidance documents or resources for grievance mechanisms are provided, for instance, in the Grievance Mechanism Toolkit of the Office of the Compliance Advisor/Ombudsman (CAO) (on behalf of Members of the World Bank)[67] and in the International Finance Corporation Performance Standard 1 "Assessment and Management of Environmental and Social Risks and Impacts"[68] – Example: "Project developers have to proof that appropriate grievance mechanisms according to IFC Performance Standard 1 exist or will be established." – Referenced by [i.a.]: GH2 Standard, GIZ (2022), Brot für die Welt; Heinrich-Böll-Stiftung (2022b), Brot für die Welt; Heinrich-Böll-Stiftung (2024), PtX Hub (2022), NWR (2021), Oeko-Institut (2021b)
…	**Other |** Proof of regular monitoring of social impacts and stakeholder consultation – Example: "Project developers need to provide proof of consultation, community outreach and engagement during the project's lifetime. This proof needs to be documented in a publicly accessible evaluation of the project and its impacts." – Referenced by [i.a.]: GH2 Standard, Brot für die Welt; Heinrich-Böll-Stiftung (2022b)
…	**Other |** Financial participation of local stakeholders *Note: The analysed literature does not provide further specifications on this topic* – Example: "Local stakeholders shall receive a share of [x] % of the project returns." – Referenced by [i.a.]: Brot für die Welt; Deutsche Umwelthilfe; BUND; Germanwatch; DNR; Heinrich-Böll-Stiftung et al. (2022); NWR (2021)

How is this sustainability dimension discussed in current publications?

- One of the least frequently addressed sustainability dimensions in the literature
  - Primarily targeted in reports of institutions focusing on international development cooperation and political education
  - Not explicitly covered in existing regulations
- Key existing instruments to ensure stakeholder participation are EIAs and SIAs
  - Yet, these mechanisms do not guarantee continuous participation structure

67 https://www.cao-grm.org/
68 https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-1-en.pdf

Results from the quantitative text analysis



3.3.9 Land rights and indigenous rights

The role of land rights and indigenous rights in hydrogen production	
Sustainability cluster	Socially responsible project development
Key issues	Access to land | (Forced) Resettlement | Land-use change | Free Prior and Informed Content
What do you need land – and land rights – for in the hydrogen production process?	Land is a key resource to the hydrogen production process – and so are land rights that regulate access to land. Land is needed at three main steps within the value chain: 1) to provide a ground to build the hydrogen production plant on, which includes electrolysis and peripheral modules, 2) to implement renewable energy sources for electricity production, and 3) to accommodate the direct air capture (DAC) system if the hydrogen is to be converted into other products requiring CO_2. While some of these land requirements are exclusive (e.g. for the construction of the electrolyser plant), other offer potential for parallel use. Land used for RES-e generation such as wind power or photovoltaic systems is potentially still available for other forms of utilisation such as livestock farming if suitable conditions are created – particularly with regard to land rights. Nevertheless, hydrogen export projects are expected to be large-scale projects to ensure their economic viability. Accordingly, each project can be expected to require large areas of land.
Why is this dimension a relevant sustainability criterion?	
For countries in the Global South?	Project-related claims for land and associated land-use changes can interfere with local land rights. This poses major challenges, especially in countries of the Global South, where land rights are often informal, yet closely linked to local livelihoods. When project operators seek to acquire land for their business activities, relocation and loss of shelter or livelihoods for communities or individual households can be the consequence. There is a high risk that this happens involuntarily if no fair dialogue with local landowners takes place. Hydrogen projects are associated with high investment costs and therefore often backed powerful (international) players and/or governments. This may result in imbalanced negotiating positions over suitable land: local communities may see themselves being forced to lease or sell their land for unreasonable prices . Reports from Morocco indicate that such dynamics already show for other large-scale RE projects. [69] In addition to risks associated with land-use change, however, there is also the possibility of developing parallel forms of use. Here, land is used both for RE systems and for agricultural activities, for instance, in the case of PV systems under whose shade crops are grown.
For rural populations?	Land is a key element of rural livelihoods, which are mainly based on agricultural and pastoralist practices. Often, these practices are characterised by common ownership structures and dynamic, mobile land usage patterns.

[69] The Noor Ouarzazate solar project was developed on 3,000 ha of traditional Berber pastoral land. Not only did the project's management restrict herders' access to this land. It also replaced local institutions that managed it as a commons with state and market institutions that commercialised the land, thus significantly altering prevailing land right patterns and livelihoods (Brot für die Welt; Heinrich-Böll-Stiftung 2022a).

	While land use rights are deeply culturally anchored in such structures, in many cases they are not formalised. If the development of a hydrogen project falls within such structures, there is a high risk that negotiating positions between local communities and project developers are unbalanced (see above), which can lead to land grabbing and involuntary resettlement. Associated changes in land ownership and land access may drastically alter prevailing rural livelihoods, stripping communities of their essential resources and limiting their ability to sustain themselves [70]

What are potential effects?	

Negative	• (Forced) Resettlement
	  • Physical displacement
	  • Economic displacement
	• Limited access to land and loss of associated livelihoods
	  • Particularly relevant for rural population whose livelihoods are closely linked with their lands (e.g. for food production)
	  • Ultimately: risk of impoverishment
	• Unfair compensation agreements with local land users
	• Loss of cultural identity linked to lands
	  • Especially relevant for Indigenous People

Positive, without further measures	• In case of fair compensation measures: provision of financial support for resettlement
Positive, only if measures are taken	• Integration of local land use requirements in project design • Synergy effects from parallel land use, e.g. by combining PV and agricultural activities (shading of fields, protection from adverse weather, etc.)

	What instruments are already specified in the literature? [71]
	Standardised framework | Free Prior Informed Consent according to ILO Convention 169 – Free, Prior, and Informed Consent (FPIC) is a right granted to Indigenous Peoples recognised in the UN Declaration on the Rights of Indigenous Peoples • It ensures that Indigenous Peoples are given the opportunity to withdraw their consent to projects that are planned or being developed on their territories – and this at any phase of project development. This means, that Indigenous Peoples, if they risk being affected by a project, are to be engaged and consulted with throughout project design, implementation and monitoring – The principle of FPIC is anchored in Convention 169 of the International Labour Organization (ILO): adopted in 1989, this legally binding international treaty requires governments to consult Indigenous peoples and secure their consent regarding legislative or administrative measures affecting them [72] (Articles 6, 7, 16)

[70] In some regions, this is already the case as researchers from Utrecht University report for instance Gevaert et al. (2023): in Ceará, Brazil, indigenous groups lost control over their territories due to a large-scale wind farm project fencing off areas and restricting access to their land, ultimately threatening their food security.

[71] For references to regulatory mechanisms and certification schemes in this section, see details provided in chapter 5.

[72] https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:55:0::NO::P55_TYPE,P55_LANG,P55_DOCUMENT,P55_NODE:REV,en,C169,/Document

- Example: "In the case of projects that take place in indigenous and traditional communities that are directly affected, prior consultation must be conducted, as provided in ILO Convention 169"
- Referenced by [i.a.]: Brot für die Welt; Deutsche Umwelthilfe; BUND; Germanwatch; DNR; Heinrich-Böll-Stiftung et al. (2022); ISCC Plus

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Standardised framework | International Finance Corporation (IFC) Performance Standard 5

Land acquisition and Involuntary Resettlement

- Specific Performance Standard[73] developed by the IFC (World Bank Group) setting requirements of how their clients (receiving direct investments of the corporation) are to manage project related environmental and social risks and impacts
  - Requirements to avoid or minimise risks associated with land acquisition and involuntary resettlement, e.g. as part of the project design phase, compensation mechanisms, grievance mechanisms, community engagement
- Example: "Project operators are required to avoid involuntary resettlement wherever possible and to minimise its impact on those displaced through mitigation measures in accordance with IFC Performance Standard 5."
- Referenced by [i.a.]: GH2 Standard

Standardised framework | International Finance Corporation (IFC) Performance Standard 5

Indigenous peoples

- Specific Performance Standard[74] developed by the IFC (World Bank Group) setting requirements of how their clients (receiving direct investments of the corporation) are to manage project related environmental and social risks and impacts
  - Requirements to avoid and minimise adverse impacts on Indigenous Peoples in project proximity e.g. by documentation of the efforts made to avoid negative impacts, by obtaining the FPIC of Indigenous Peoples
- Referenced by [i.a.]: GH2 Standard

Indicator | Population density in siting region [inhabitant per km^2]

- Assumption: A low population density, measured in inhabitants per square kilometers in a given area is considered positive for the sustainable production of green hydrogen
  - To be noted, however, that population density can only be a one-dimensional indicator of competition for space and does not represent e.g. the cultural value of (sparsely populated) land
- Example: "No project development in an area/region with > 50 inhabitants per km^2"
- Referenced by [i.a.]: Fraunhofer IEE (2021), GIZ (2022)

Other | Integration of spatial planning practices in national hydrogen strategies

- In order to avoid land use conflicts, a clear zoning of land use forms is beneficial. This allows to exclude potentially more conflict-ridden land use forms such as areas used for traditional grazing or areas of indigenous cultural heritage and to focus on less 'critical' areas such as space already used for industrial purposes or areas, that are available for synergetic approaches (e.g. agrivoltaics)
  - Such zoning can/should be incentivised as part of a national hydrogen strategy

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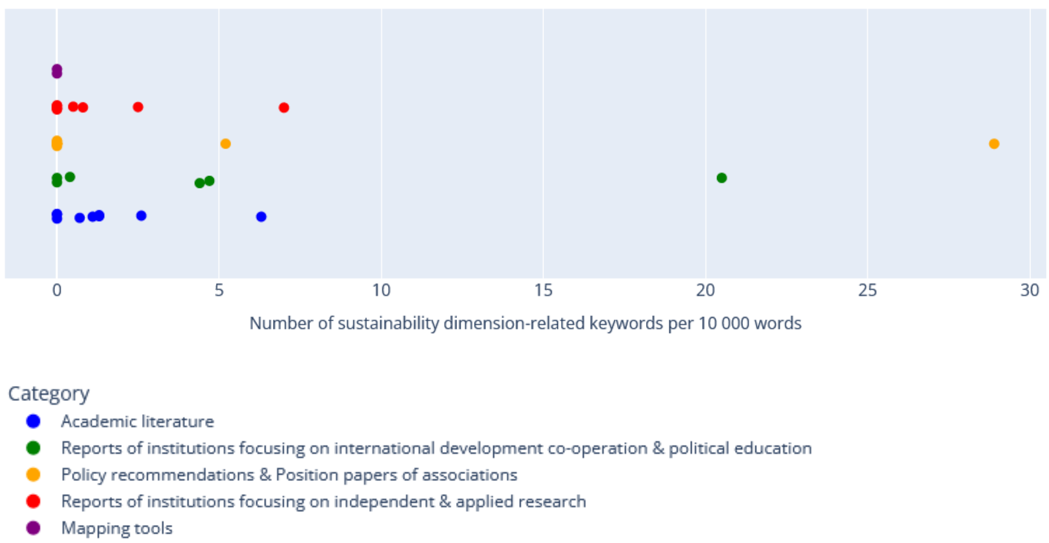
[73] https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-5-en.pdf
[74] https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-7-en.pdf

	– Example: "Project development prioritised on areas that are already impacted, e.g. industrial areas, or in areas with synergy potentials. No project development on conflict-prone areas e.g. with high cultural value." – Referenced by [i.a.]: Brot für die Welt; Deutsche Umwelthilfe; BUND; Germanwatch; DNR; Heinrich-Böll-Stiftung et al. (2022) (IEK-3; FZJ 2024)
...	**Other** | Public reporting of project's potential impact – Reporting of the project's expected impact on local property rights and land-use in a publicly available format – Referenced by [i.a.]: GH2 Standard
...	**Other** | Proof of absence of forced resettlement – Mandatory reporting (initially and on an ongoing, regular basis) to a designated conformity assessment body that the project does not lead to forced resettlement – Seller must ensure that forced resettlement has not taken place at location of value chain activity at least 3 years leading up to project – Referenced by [i.a.]: H2Global
...	**Other** | Exclusion of the use of areas with high agricultural value – Example: "The use of areas which are most suitable for food production is prohibited, particularly with regard to the implementation of open-space PV systems." – Referenced by [i.a.]: Fraunhofer IEE (2021), GIZ (2022), Oeko-Institut (2021b)

How is this sustainability dimension discussed in the discourse?

- Very scarcely addressed in literature (according to this analysis)
  - Especially often referenced in Position papers
- Indicators and instruments exist, especially with regard to FPIC
  - Central, existing mechanism that can be expanded as principle to other areas

Results from the quantitative text analysis



4 References for regulations and certification schemes

Regulatory mechanisms	Country/ region	More information (direct link to website)	Abbreviation [75]
California's Low Carbon Fuel Standard (LCFS)	United States	https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/lcfs-guidance-documents-user-guides-and-faqs	LCFS
Clean Hydrogen Production Standard (CHPS)	United States	https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/clean-hydrogen-production-standard-guidance.pdf?sfvrsn=173e9756_1	CHPS
EU Taxonomy	Europe	https://ec.europa.eu/finance/docs/level-2-measures/taxonomy-regulation-delegated-act-2021-2800-annex-1_en.pdf	EU Taxonomy
Renewable Energy Directive III • Delegated Regulation (EU) 2023/1184 • Delegated Regulation (EU) 2023/1185	Europe	• https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2023.157.01.0011.01.ENG&toc=OJ%3AL%3A2023%3A157%3ATOC • https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1185&qid=1704969410796	RED III
Renewable Portfolio Standards	South Korea	https://dco.energy.or.kr/renew_eng/new/standards.aspx	RPS

Certification scheme	Country/ region	More information (direct link to website)	Abbreviation [76]
CertifHy	Europe	https://www.certifhy.eu/	CertifHy
China Hydrogen Alliance Standard and Evaluation of Low carbon hydrogen, clean hydrogen & renewable hydrogen	China	https://www3.weforum.org/docs/WEF_Green_Hydrogen_in_China_A_Roadmap_for_Progress_2023.pdf	China Hydrogen Alliance Standard & Evaluation

[75] Used for all references to the respective mechanism throughout the report.
[76] Used for all references to the respective scheme throughout the report.

Green Hydrogen Standard	International	• https://gh2.org/sites/default/files/2023-01/GH2_Standard_A5_JAN%202023_1.pdf • https://www.greenhydrogenstandard.org/sites/default/files/2023-12/GH2_Standard_A5_Nov%202023_DIGITAL.pdf	GH2 Standard
H2Global	Germany	https://www.h2-global.org/	H2Global
International Sustainability and Carbon Certification EU Plus	Europe	https://www.iscc-system.org/certification/iscc-documents/iscc-system-documents/	ISCC Plus
TÜV Süd CMS 70	Europe	https://www.tuvsud.com/de-de/-/media/de/industry-service/pdf/broschueren-und-flyer/is/energie/tv-sd-standard-cms-70_grund--und-zusatzanforderungen-deutsch-englisch.pdf	TÜV Süd

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6 Annex

6.1 Quantitative and qualitative text analysis: data base used

Publications that are part of both analyses – i.e. also used in the qualitative text analysis – are marked in italics in the table below.

Category	Authors (year)	Title
Academic literature	*Müller et al. (2022)*	*Hydrogen justice*
Academic literature	Van de Graaf et al. (2020)	The new oil? The geopolitics and international governance of hydrogen
Academic literature	*Cremonese et al. (2023)*	*The sustainability of green hydrogen: An uncertain proposition*
Academic literature	*Gevaert et al. (2023)*	*Green Hydrogen in the Global South: Opportunities & Challenges*
Academic literature	Albert-Ludwigs-Universität Freiburg (2023)	Towards a comprehensive framework for assessing Sustainable Green Hydrogen partnerships
Academic literature	Acar und Dincer (2022)	Selection criteria and ranking for sustainable hydrogen production options
Academic literature	Blohm und Dettner (2023)	Green hydrogen production: Integrating environmental and social criteria to ensure sustainability
Academic literature	Swennenhuis et al. (2022)	Towards a CO2-neutral steel industry: Justice aspects of CO2 capture and storage, biomass- and green hydrogen-based emission reductions
Academic literature	Cheng und Lee (2022)	How Green are the National Hydrogen Strategies?

Category	**Authors (year)**	**Title**
Mapping tools	*Fraunhofer IEE (2021)*	*PTX-ATLAS: Weltweite Potenziale für die Erzeugung von Grünem Wasserstoff und klimaneutralen synthetischen Kraft- und Brennstoffen*
Mapping tools	*IEK-3; FZJ (2024)*	*H2 Atlas Afrika*
Mapping tools	Fraunhofer ISI; Fraunhofer ISE; DIE; GIZ; Ruhr Universität Bochum (RUB) (2022)	HYPAT Working Paper 01/2022
Policy recommendations and position papers of associations	*NWR (2023)*	*Stellungnahme zur Fortschreibung der Nationalen Wasserstoffstrategie*
Policy recommendations and position papers of associations	*NWR (2021)*	*Sustainability criteria for import projects for renewable hydrogen and PtX products*
Policy recommendations and position papers of associations	Germanwatch e.V. (2023)	Policies for a sustainable hydrogen economy in Europe
Policy recommendations and position papers of associations	*Food & Water Action Europe; WSG (2023)*	*Hydrogen: Climate Fix or Fossil Fuelled Fiction?*
Policy recommendations and position papers of associations	*Brot für die Welt; Deutsche Umwelthilfe; BUND; Germanwatch; DNR; Heinrich-Böll-Stiftung et al. (2022)*	*Declaration on Sustainability Criteria for Green Hydrogen*
Policy recommendations and position papers of associations	Sachverständigenrat für Umweltfragen (2021)	Wasserstoff im Klimaschutz: Klasse statt Masse
Policy recommendations and position papers of associations	*Klima-Allianz Deutschland (2021)*	*Wasserstoff-Positionspapier der deutschen Zivilgesellschaft*
Policy recommendations and position papers of associations	*NWR (2024)*	*Stellungnahme zur Erarbeitung der Wasserstoff-Importstrategie der Bundesregierung*

Category	Authors (year)	Title
Policy recommendations and position papers of associations	DWV (2023)	Wasserstoff-Importstrategie für Deutschland
Policy recommendations and position papers of associations	*Klima-Allianz Deutschland; BUND; WWF Deutschland; DUH; Gegenströmung; Brot für die Welt; Germanwatch; Misereor; Institut für Kirche und Gesellschaft (2024)*	*Nachhaltige und gerechte Wasserstoffimporte*
Reports of institutions focusing on international development cooperation and political education	*GIZ (2022)*	*Potenziale für die Produktion von grünem Wasserstoff*
Reports of institutions focusing on international development co-operation and political education	*PtX Hub (2022)*	*PtX.Sustainability: Dimensions and Concerns*
Reports of institutions focusing on international development cooperation and political education	*GIZ; ILF Ingeniería Chile Limitada; LBST (2021)*	*Requirements for the production and export of green-sustainable hydrogen*
Reports of institutions focusing on international development cooperation and political education	*Brot für die Welt; Heinrich-Böll-Stiftung (2022b)*	*Green hydrogen: Key success criteria for sustainable trade & production*
Reports of institutions focusing on international development cooperation and political education	Brot für die Welt; Heinrich-Böll-Stiftung (2022a)	Pastoralism and large-scale Renewable energy and green hydrogen projects
Reports of institutions focusing on international development cooperation and political education	Brot für die Welt; Heinrich Boell Foundation (2022)	Technical potential and challenges of REnewable Hydrogen: Issues in the Global South

Category	**Authors (year)**	**Title**
Reports of institutions focusing on international development cooperation and political education	Sino-German Energy Partnership; GIZ (2022)	Certification of green hydrogen: Recent efforts and developments in the European Union
Reports of institutions focusing on independent and applied research	*Oeko-Institut (2021b)*	*Sustainability dimensions of imported hydrogen*
Reports of institutions focusing on independent and applied research	*SWP (2023)*	*Die Geopolitik des Wasserstoffs*
Reports of institutions focusing on independent and applied research	Oeko-Institut; adelphi (2022)	Comparing sustainability of RES- and methane-based hydrogen
Reports of institutions focusing on independent and applied research	Oeko-Institut (2021a)	Die Wasserstoffstrategie 2.0 für Deutschland
Reports of institutions focusing on independent and applied research	EWI (2023)	H_2 - Geopolitik: Geopolitische Risiken im globalen Wasserstoffhandel
Reports of institutions focusing on independent and applied research	SWP (2020)	Die internationalen Dimensionen deutscher Wasserstoffpolitik
Reports of institutions focusing on independent and applied research	*Brot für die Welt; Heinrich-Böll-Stiftung (2024)*	*Politische Instrumente zur Gewährleistung der Nachhaltigkeit von Wasserstoffimporten*
Reports of institutions focusing on independent and applied research	Corporate Europe Observatory (2023)	Germany's great hydrogen race
Reports of institutions focusing on independent and applied research	Fraunhofer ISI (2020)	Opportunities and challenges when importing green hydrogen and synthesis products

6.2 Quantitative text analysis: methodological approach

Text extraction and pre-processing

For the quantitative analysis, the initial step involved converting PDF documents into plain text to facilitate further processing and analysis using the Python library PyPDF2. The extracted text then underwent preprocessing, with regular expressions (regex) to rectify minor extraction errors, like redundant spaces and line/word breaks, ensuring a clean and uniform text. Literature and references sections were manually removed to focus on the main content relevant to the study. Additionally, single characters, often found in tables and deemed irrelevant to the analysis, were filtered out to enhance the quality of the text for subsequent analysis.

Corpus creation

The creation of the corpus involved several methodical steps. Firstly, we the extracted text was tokenised using the python library nltk (Natural Language Toolkit), breaking down the text into individual tokens (words and punctuation). Metadata, including filenames, categories, and the original language of each document, was then assigned to ensure proper organisation and contextual understanding. Punctuation was removed while preserving alphanumeric characters to maintain the integrity. Word counts were subsequently generated based on these alphanumeric tokens.

Keyword-based text modification

To enhance the specificity of the text analysis, a dictionary of keywords corresponding to the 15 defined sustainability dimensions was imported. A custom function was implemented to link multiple word keywords with underscores (e.g. "upstream emissions" became "upstream_emissions"). This function was applied to modify the text in the corpus, ensuring that keywords were consistently formatted and easily identifiable. This modification resulted in a refined version of the text that facilitated more accurate keyword-based analysis.

Identification of bi-grams and tri-grams

The identification of bi-grams and tri-grams was a critical step in understanding the common word combinations within the text. Initially, stopwords (common words like "and," "then," "that") were filtered out using nltk's stop-words list to ensure the relevance of the identified combinations. The nltk.bigrams() and nltk.trigrams() functions were then employed to generate and identify two-word and three-word combinations, respectively. Bi-grams and tri-grams that appeared more than twice were selected, sorted in descending order of frequency, and organised by dimensions. This step provided insights into prevalent word pairings and triplets within the text. These findings were used to evaluate the original list of keywords, confirming that the manually chosen words were used in significantly. Additionally, new keywords that frequently appeared within each dimension were identified and incorporated into the updated keyword list.

Word frequencies and visualisation

Following the updated list, the appearance of each keyword was counted across all documents, and a broad table of word frequencies was created for each sustainability dimension and category. The results were then plotted with the python library Plotly e.g. as mean and median values.

Limitations

It is important to acknowledge certain limitations in this analysis. The methodology employed, while robust, has some constraints due to limited resources for data clearing, potential inaccuracies arising from translated documents, and a lack of contextual depth by using word frequencies. These limitations were considered acceptable within the scope of this project. Additionally, the word counts used for normalisation are significantly influenced by the extent of data cleansing and normalisation processes (e.g. the number of references or abbreviations in the text) and should not be taken as exact values.

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