

Translating climate science into legal standards: lessons from the *Milieudefensie v. Shell* case

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Abstract: The landmark case of *Milieudefensie v. Shell* highlights a critical issue: while Courts have relied on scientific models to determine climate obligations for nation states, they appear reluctant to do the same for corporations. This article examines the difficulties Courts encounter in integrating scientific evidence -- particularly emissions reduction pathways -- into legal rulings on corporate responsibility. We show how the scientific foundations of corporate pathways are the same as global pathways used for states' emissions targets, but that the evidence base is currently less robust. We suggest several ways forward, and argue that interdisciplinary collaboration among scientists, legal experts, and policymakers is essential to refine the role of scientific models in corporate climate litigation.

Main Text:

As the world struggles to meet the Paris Agreement’s temperature goals, climate litigation has become a powerful tool to translate science into enforceable legal obligations. Among its most significant milestones, *Milieudefensie v. Shell* (“the *Milieudefensie* case”) stands out – not only for its ambitious claims and the first landmark ruling by the Hague District Court, but also because its 2024 appeal judgment raises important questions about the future of corporate climate accountability.

A central issue emerging from the ruling is that Courts appear to struggle with applying the results of Integrated Assessment Models (IAMs) to individual companies. IAMs, computer models that combine climate science, energy systems, and economics to assess climate change impacts and responses, provide globally recognized emissions reduction pathways. These pathways have been successfully used by litigants to underpin legally binding obligations for governments, as in *Urgenda Foundation v. State of the Netherlands*, *Neubauer et al. v. Germany*, and *Notre Affaire à Tous v France*. Yet, in the *Milieudefensie* case, the Dutch Court of Appeal hesitated to apply IAM-derived sectoral emissions pathways to Shell, citing a lack of scientific consensus on the precise level of required reductions (para 7.73). This might seem contradictory, since the same modelling approaches and models had been accepted by the same court in the *Urgenda* case when assessing the Dutch government’s obligations, but were deemed insufficient for establishing corporate responsibilities in this case.

This issue extends beyond the *Milieudefensie* case. As courts increasingly face climate litigation that seeks to change future corporate behaviour, the application of scientific models to corporate actors must be clarified to avoid inconsistent rulings that undermine legal certainty. The problem is all the more pressing as regulatory frameworks globally are starting to incorporate corporate transition planning requirements (e.g., in the European Union, Australia, UK, Switzerland and Singapore) (1). The appeal judgment exposes a key challenge for these frameworks: the translation of global climate goals into specific, enforceable corporate obligations. Understanding the challenges in translating climate science into legal standards is critical not only for future litigation but also for the broader development of regulatory norms and standards. By closely examining the scientific evidence available, particularly the application of IAMs to corporate emissions pathways, we provide guidance for litigators and experts, as well as courts and policymakers as they navigate the evolving legal landscape of corporate climate responsibility.

Translating global temperature goals into legal obligations

The decade since the Paris Agreement was signed in 2015 has seen a surge in attention on corporate responsibility for the transition to net zero, leading to a plethora of standards, campaigns, advice, and guidance for companies (2). These range from initiatives led by non-governmental organisations and investors to campaigns and standards adopted by more authoritative intergovernmental bodies.

One of the clearest articulations of corporate climate responsibilities is found in the 2023 update to the OECD Guidelines for Multinational Enterprises. The Guidelines are not directly binding on companies, but member states are required to “promote and support” their implementation (3). In the commentary to the Environment Chapter, the updated Guidelines state that “enterprises should ensure that their greenhouse gas emissions and impact on carbon sinks are consistent with internationally agreed global temperature goals based on best available science” (4). The means for achieving this is through “the introduction and implementation of

science-based policies, strategies and *transition plans* on climate change mitigation” (emphasis added), as well as the adoption of emissions targets which should be science based and include Scope 1, 2, and 3 greenhouse gas (GHG) emissions. This shows that transition plans – structured frameworks that outline how companies intend to reduce their emissions over time – have become a central mechanism for ensuring corporate accountability in the low-carbon transition.

The integration of such obligations into the Guidelines can be seen as part of a broader process by which voluntary and soft law norms have started to “harden” into more legally binding ones (5). Recent analyses document a surge in regulatory instruments concerned with company net zero targets and transition plans in the years from 2015 to 2024 (6). Such instruments demonstrate significant variance in their form, scope, and level of stringency, however at least in certain regions we can see a trend towards binding requirements for corporate transition plans (7). This trend builds on older legislation that established corporate obligations to conduct mandatory human rights and environmental due diligence (e.g., France’s 2017 duty of vigilance law). In the absence of mandatory climate due diligence standards, litigants brought claims that framed climate-related harms as a human rights and environmental issue, and thus mitigation forms part of responsible business practices (e.g., *Notre Affaire à Tous and others v. Total*).

At present, the most significant piece of corporate transition plan legislation is the European Union’s Corporate Sustainability Due Diligence Directive (CSDDD), which forms part of a broader suite of legislation aimed at aligning firm activity with the goals of the European Green Deal (8). The CSDDD requires companies that meet certain threshold criteria to “adopt and put into effect a transition plan for climate change mitigation which aims to ensure, through best efforts, that the business model and strategy of the company are compatible with ... the limiting of global warming to 1,5°C in line with the Paris Agreement and the objective of achieving climate neutrality as established in Regulation (EU) 2021/1119” (8). Companies’ plans shall include “time-bound targets” based on “conclusive scientific evidence” and “where appropriate” may include absolute emissions targets for Scope 1, 2, and 3 GHGs.

For legislation to work effectively, guidance needs to be formulated for companies on how to translate overarching temperature or time-bound climate neutrality objectives into emissions pathways in practice. In developing guidance that is as clear and concrete as possible, policymakers will be presented with similar challenges in translating state-of-the-art research and science to those faced by the judges in the *Milieudefensie* case. Studying this case and other examples of corporate climate litigation provides an opportunity to inform the practical application of emerging regulatory norms, as well as to learn lessons for future litigation cases.

When existing regulatory mechanisms do not produce sufficiently climate-aligned outcomes, litigation can compel governments and corporations to take more ambitious action (5). Historically, most climate-related legal claims, both overall and in terms of success, have been against governments, but an expanding category of cases targets corporations (9). These claims require robust scientific evidence on how corporate behaviour affects climate change and climate policy outcomes. The type of evidence required depends on whether the claimants seek to hold corporations responsible for past conduct, known as ‘backward-looking’ cases, or to change future corporate behaviour in line with climate targets; ‘forward-looking’ cases (9). *Milieudefensie* is a forward-looking case.

While academic discussions about the use of climate science in litigation have burgeoned in recent years, much of this has focused on backward-looking corporate claims (10). In those

cases, attribution science often plays a critical role in linking companies' GHG emissions to global climate change and local impacts (11-13). Forward-looking cases typically require evidence about what levels of emissions reduction is required for corporations to stay in line with global and national targets. While the *Milieudefensie* case is the most high-profile case in this category – and the only one resulting in a successful court judgment until the Hague District Court's initial decision was overturned in 2024 – there are more than 20 other forward-looking cases pending around the world (14). A key question for courts is to determine whether and how global or sectoral pathways should be applied to individual companies. Unlike with backward-looking cases and attribution science, there has been little academic discussion about how this type of science can be applied in litigation. The recent *Milieudefensie* appeal judgment reflects the challenges of developing legal norms based on interdisciplinary scientific research.

The Milieudefensie case

In May 2021, the Hague District Court ordered Shell to reduce its GHG emissions by 45% below 2019 levels by 2030, drawing on standards such as the earlier iteration of the OECD Guidelines mentioned above. The reduction obligation applied to Shell's entire energy portfolio, covering Scope 1, 2 and 3 emissions. Shell appealed this decision. On 12 November 2024, the Court of Appeal diverged, in part, from the District Court's decision (15). Although the Court confirmed that under Dutch law, Shell has an obligation to limit its emissions to combat climate change, crucially it determined that it cannot impose a specific absolute emissions reduction obligation on the company, at least as regards Scope 3. However, the Court separately noted that to comply with legal obligations, oil and gas (O&G) companies may need to consider evidence that suggests no new investments in O&G are compatible with the Paris Agreement temperature goals.

The appeal judgment turned heavily on the Court's finding that based on available studies of emissions pathways provided to it, there is no "sufficiently unequivocal conclusion" (para 7.91) that can be drawn on to determine a sectoral standard, to then order a Scope 3 reduction target against a specific company. The Court engages with several other important issues, such as whether imposing a reduction obligation on just one O&G company would even be effective, given the presence of other players in the market for O&G. However, we focus this article on whether the Court made a fair assessment of the state of science on sectoral and corporate pathways.

At the global level, the Court and the litigants agreed that there is "broad consensus" that to limit global warming to 1.5°C, emissions must reduce by a net 45% by the end of 2030 relative to 2019 and be net zero by 2050 (para 7.73). Courts have previously imposed minimum reduction targets on states, based on global and national pathways, most notably in the decision of *Urgenda Foundation v. State of the Netherlands*, where the Dutch Supreme Court ordered the Dutch government to reduce emissions by at least 25% by 2020 (16). However, in the *Milieudefensie* case, the Court felt that the global pathway could not be directly translated into an obligation on Shell, as different countries and sectors will need to reduce emissions at different rates. In the next section, we explain the scientific foundations of corporate pathways, highlighting that the methodological approach behind global pathways used for setting emissions targets for states is, in fact, the same as the approach used for corporate target-setting.

Understanding the state of the art: sectoral emissions pathways

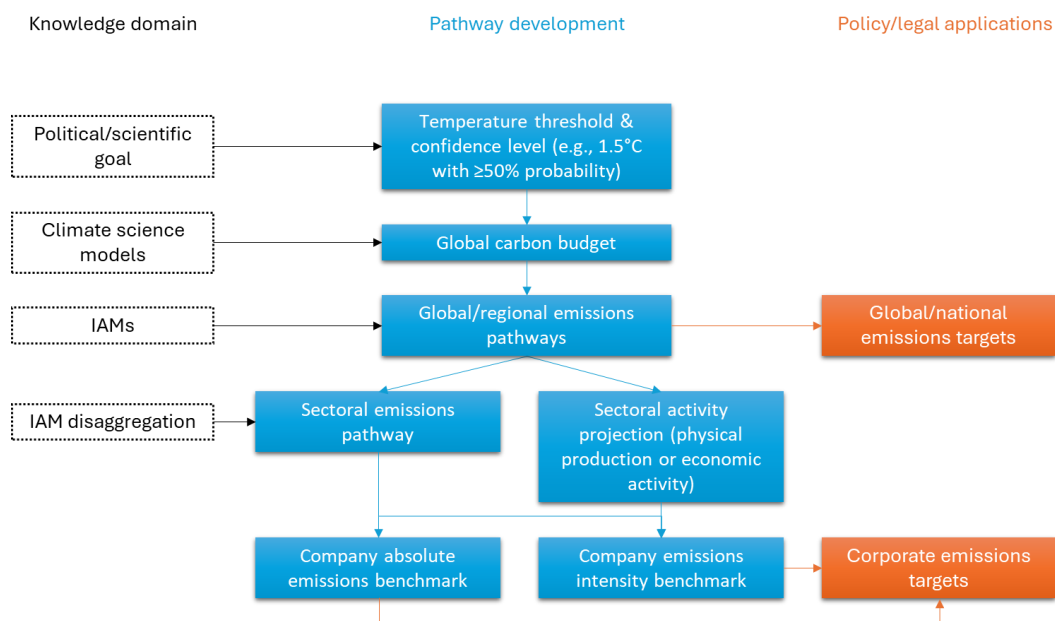
While there is a long tradition of setting emissions targets at the international and national levels, the science of corporate target-setting is less developed (17). A fundamental challenge is

translating global climate targets into actionable corporate commitments (i.e., from global temperatures to company emissions of different scopes). A primary concern is ensuring targets are meaningful, especially because corporate targets tend to be voluntary.

Several methodologies exist to facilitate this process. Simpler approaches apply global or regional emissions reduction rates uniformly across all companies (18, 19). This logic was partially followed in the *Milieudéfense* case, indeed. Milieudéfense presented the global emissions target as a baseline minimum that Shell should meet or exceed on the basis that Shell, as one of the largest contributors to climate change, bears a greater legal duty to reduce emissions than other entities.

More sophisticated methodologies account for variations in mitigation potential and economic costs across companies, typically by differentiating between the economic sectors that companies belong to (20). Decarbonization challenges can vary strongly across sectors such as aviation, electricity and steel. Fig. 1 illustrates how top-down methodologies utilize the outputs of IAMs to derive company emissions pathways on either an absolute or intensity basis.

Fig. 1 Flow chart depicting how to derive company emissions pathways from global climate goals (centre), major inputs to the method (left) and major policy/legal applications (right).



A prominent example of a methodology like this is the Sectoral Decarbonization Approach (SDA). The Science-Based Targets initiative (SBTi) has operationalized the SDA and now validated over 4,000 corporate emissions targets using this methodology as a core benchmark (21). The Transition Pathway Initiative (TPI) similarly applies a variant of the SDA to independently assess whether companies' emissions pathways align with sector-specific benchmarks (22). TPI's analysis is among other things an input to the Net Zero Company Benchmark of Climate Action 100+, the world's largest investor-led engagement initiative on climate change.

The SDA has been applied to the O&G sector using a scope of emissions that includes not only Scopes 1 and 2, which most methods of calibrating corporate emissions targets have

been restricted to, but also Scope 3, category 11, use of sold products (i.e., customers' burning O&G), which is the dominant share of lifecycle emissions from the sector (23). These emissions can be normalized by energy sales to create a production-based intensity measure or used directly as an absolute emissions measure. With the former measure, O&G companies are benchmarked against the emissions intensity of the whole energy sector. O&G companies can reduce their emissions intensities by diversifying away from fossil fuels towards renewables, which is indeed the strategy being followed by O&G companies that are most advanced on climate change (23). Absolute emissions would be an appropriate way to benchmark companies whose climate strategy is instead to manage decline (24), noting that no company has so far set such a strategy. (25) take a similar approach to this, using IAM output to derive pathways for fossil-fuel companies' absolute production.

The key point is that methods exist, which have been published in peer-reviewed academic journals, to derive sectoral pathways for O&G companies like Shell. So, why was the Court of Appeal reluctant to draw on these methods, compared to global and national pathways? The Court's decision might be considered surprising given that global/national and sectoral pathways draw on the same kind of evidence – IAMs run to comply with global temperature targets. The origin of the net zero by 2050 goal, for example, is the representative time at which IAMs synthesized by the 2018 IPCC Special Report on 1.5°C reached net zero CO₂ emissions (26).

It is fair to say, however, that sectoral pathways currently command less confidence than global pathways. Pathways at all levels must contend with the fact that different assumptions (e.g., on socio-economic pathways, deployment of carbon capture and storage, etc.) can lead to very different projections, with the range reflecting not just technical uncertainty but also competing normative visions of a low-carbon world (27). However, this is currently a more acute problem for corporate pathways, because few IAMs produce emissions scenarios at the sector level (at least that are publicly available). So, while the aforementioned goal of net zero by 2050 was established by looking across a wide range of IAMs, sectoral pathways are typically based on a more limited set of IAMs, and some sectors benefit from more IAM data than others (O&G, as part of the energy sector, is relatively well off in this regard). With fewer models, the analysis is less robust. There is also fundamentally more uncertainty about sectoral than economy-wide pathways, because forecasting errors in each sector will be at least to some extent idiosyncratic (as they relate to, e.g., sector-specific technologies).

In addition, the emerging literature on corporate pathways has identified further contestable assumptions in how IAM outputs are used by methods like the SDA. It can be difficult to ensure the aggregate of corporate commitments is consistent with global climate goals even for top-down methodologies that focus on this challenge (20). Selecting a pathway for one sector has implications for other sectors given economic and emissions inter-dependencies. (28) emphasise that existing frameworks such as SBTi effectively allocate emissions to companies based on grandfathering and thereby ignore historical exceedance of benchmarks. Instead, it might be considered fair to hold companies accountable for historical emissions in excess of their benchmark, in which case company and benchmark pathways should start in the same base year (e.g., 2015 to coincide with the Paris Agreement), and, logically, future excess company emissions would also lead to a readjustment of their benchmarks. More broadly, IAMs are optimization models, meaning they seek a cost-minimizing distribution of emissions reductions across sectors. While this ensures that mitigation efforts are allocated where they are most cost-effective, it does not inherently account for principles of fairness, equity, or historical

responsibility in the distribution of emissions reductions. In theory, the cost-minimizing distribution of emissions reductions can be accompanied by climate finance and transfer payments to reconcile economic efficiency with more equitable cost-sharing. However, in practice, the political and economic feasibility of such transfers remains highly uncertain. As a result, IAM-derived pathways may not align with all stakeholders' expectations of fairness in corporate or national climate commitments. Ultimately, there is as of yet no repository of corporate climate benchmarks which is underpinned by the same body of peer-reviewed scientific evidence and meets the same standards of transparency as the IPCC's global scenarios.

The path forward

In this section, we review three alternative approaches that could help strengthen “forward-looking” cases seeking to improve corporate accountability for climate harms. Understanding ways forward is relevant both for national courts that interpret companies' duty of care under relevant legal regimes in their jurisdiction (e.g., domestic tort law, interpreted in line with human rights law and soft law, as in the *Milieudefensie* case; or in company law or sustainability regulation like CSDDD) – as well as policymakers seeking to impose transition plan requirements on companies within their jurisdiction or control.

Sectoral emissions pathways

IAMs are built around varying assumptions about future social, economic and technological developments. It cannot be reasonably expected that scientists will agree on a specific reduction figure as different approaches and models lead to different results. However, all emissions pathways put forward as evidence in the case – even those proposed by Shell's experts – point to a reduction. Rather than requiring fixed figures, courts could establish emissions reduction obligations based on reasonable ranges derived from existing models and pathways.

Milieudefensie put forward evidence for necessary sectoral emissions reductions ranging from 28.5% to 51.7% for oil and 30.1% to 50.5% for gas (15). While for the Court this range pointed to a lack of scientific consensus, it could have alternatively found that the lower percentages constituted a minimum reduction requirement. The Dutch Supreme Court took a similar approach in *Urgenda*, when plaintiffs demanded an emissions reduction obligation for the Dutch government of 25-40% by 2020 and the Court set the lower percentage as the legal standard. The latter figures came from IPCC AR4's Summary for Policymakers. While evidence presented in future cases may not always have the IPCC's implicit endorsement, similar scientific approaches can provide a solid foundation for applying emissions reduction ranges to corporations.

Going forward, it would be helpful for scientists to produce more sectoral model-based pathways based on a larger set of IAMs. This could make it possible to calculate multi-model averages akin to the basis for the IPCC's net zero by 2050 finding, applied to individual sectors and corporations. This requires funding and urgency.

An approach based on marginal abatement costs

One way to judge whether a company is doing enough to cut emissions is to look at the cost of those cuts. Economists call this the “marginal abatement cost” (MAC) – essentially, the cost of eliminating one extra tonne of CO₂. If reducing emissions is cheaper than a certain threshold, it makes economic sense to do it. IAMs minimize the cost of meeting a given temperature target. They do this by identifying all emissions reductions that can be made at or

below a certain cost per tonne and assuming that these are implemented first. The MAC must be equal across countries, sectors and companies (the “equimarginal principle”), meaning the cost of cutting the last tonne of CO₂ should be the same everywhere. The MAC is often reported as the “carbon price”. This is not necessarily a tax or trading price that already exists, but the price per tonne of CO₂ that would give companies and consumers the incentive to cut emissions to the required level. For example, the scenario database of IPCC AR6 contains 230 scenarios that limit global temperatures to below 2°C in 2100 (29). These scenarios have a median MAC of US\$73/tCO₂ (interquartile range \$24-127) in 2020 and \$119/tCO₂ (interquartile range \$46-197) in 2030, further increasing over time to reach net zero.

For a company to be aligned with 1.5°C or well below 2°C on a MAC basis, all investments with a MAC below the corresponding representative scenario value should be made each year. There would be two main advantages to a MAC/price-based approach. The first is that MACs are available for all IAMs, not only the subset of models which report sectoral emissions paths. Thus, representative MACs (medians or means) will be more robust. The second is that applying a uniform MAC to all companies still accounts for sectoral differences in abatement potential and costs – and is still consistent with economic efficiency – unlike the approach of applying a uniform emissions reduction rate to all companies. MACs could be presented as another evidence base in litigation, and courts could consider MACs when determining whether a company is complying with its duty of care. They can help courts understand the thresholds at which companies could easily reduce emissions (relative to cost) and what should be considered a reasonable standard of conduct in the context of climate change.

Minimum standards

Lastly, courts can play an important role in clarifying how existing legal duties apply in the climate context. Judges cannot create new standards that have no basis in existing statutes, regulations or common law principles. Their role is interpretive: to apply established legal norms to new factual circumstances. In the *Milieudefensie* case, the Court of Appeal interpreted Dutch tort law and confirmed that companies like Shell have a general obligation to mitigate climate change. While unable to impose entirely new obligations, the Court could have elaborated, within the framework of that duty of care, on what constitutes “reasonable steps” to meet it. This could have included, for instance, indicating that companies need to develop and implement emissions pathways based on credible methodologies aligned with specified temperature targets (i.e., without prescribing the specific emissions pathway that each company must follow). Such clarification of minimum standards of conduct would remain anchored in existing law, yet provide practical guidance for corporate climate accountability.

This interpretative approach resonates with the emerging concept of corporate “transition planning”, whereby companies are expected to set out credible, detailed strategies for aligning their operations and investments with net zero or other specified climate targets. Such plans typically include short- and medium-term milestones, governance arrangements, and disclosure obligations – elements increasingly reflected in guidance from bodies such as the UK Transition Plan Taskforce and the International Sustainability Standards Board. An automotive company, for example, might translate these milestones into the percentage of electric vehicles sold per year as opposed to internal combustion engine vehicles. As others have argued, such “transition-specific alignment targets” can be a useful complement to more abstract emissions-reduction goals (31). While caution is needed to avoid over-prescription or locking in particular technologies, requiring companies to produce a plan with interim indicators would still leave

them flexibility to choose the most effective means to achieve their transition goals, while creating a reasonable, enforceable standard of conduct.

A parallel for this approach of setting minimum standards can be found in cases against governments. In *Verein Klimaseniorinnen v. Switzerland*, for example, the European Court of Human Rights outlined a clear set of minimum actions that state parties to the European Convention on Human Rights must undertake to fulfil their obligations, without dictating a specific emissions pathway for each state (e.g., setting carbon budgets and interim targets) (30). States and companies are evidently subject to different legal obligations, but this parallel illustrates how courts may approach cases, in the absence of public laws regulation specific to climate transition plans.

Conclusion

The recent *Milieudefensie v. Shell* appeal judgment illustrates the difficulties in applying IAM-derived sectoral pathways to individual companies, but it also highlights an opportunity: with further refinement and standardisation, these methodologies can provide a stronger foundation for legal decision-making. We have shown that global/national emissions pathways and sectoral/corporate emissions pathways are both based on the same IAMs, albeit currently less evidence is available, and more assumptions are required, to produce the latter.

Further interdisciplinary collaboration between scientists, modellers, legal scholars, and policymakers can facilitate the integration of IAMs in corporate climate litigation. Enhancing the robustness of sectoral pathways through broader model comparisons, refining methodologies for corporate emissions benchmarking, and developing clearer regulatory guidance will help bridge the gap between IAMs and legal enforcement. In parallel, courts can adopt pragmatic approaches, such as setting minimum legal standards for corporate transition plans.

Ultimately, science, litigation and regulation must work in tandem to ensure corporate accountability in the transition to a net-zero future. As companies increasingly face legal scrutiny over their climate commitments, a more coherent and science-based approach to setting corporate climate obligations will be critical. The way forward requires balancing legal certainty with scientific rigor, ensuring that courts, policymakers, and businesses alike contribute to meaningful climate action in line with the urgency of the climate crisis.

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