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EU Energy Law: Insufficient for the 1.5-Degree Celsius Limit—The Examples of EU Emissions Trading and Hydrogen Policies

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ABSTRACT: This article examines the extent to which the current EU climate protection law fulfils the 1.5-degree limit from Article 2 of the Paris Climate Agreement. To this end, a qualitative governance analysis is applied. On this methodological basis, the main instrument for fossil phasing-out—the emissions trading scheme—and the promotion of hydrogen are discussed as examples. The results show that the EU must further intensify its efforts on its territory and cooperate with other countries since the reformed ETS 1 and ETS 2, the SCF and the CBAM are not sufficiently effective to stay within the 1.5-degree limit of the Paris Agreement. This is also the case with regard to hydrogen policies. The primary focus of energy law on the ETS is therefore fundamentally convincing; however, it should be implemented more consistently, for example, in terms of the breadth of the approach, closing loopholes and the level of ambition.

Keywords: Energy; Climate; EU emissions trading; Paris Agreement; EU law; Hydrogen

1. Problem Statement and Research Issue

Report after report points to the dramatic increase in global temperature. Not surprisingly, these reports also find that emissions achieve ever new record levels [1]. These findings have been published in parallel to the 28th UN Climate Change Conference in the United Arab Emirates in November/December 2023, where negotiators again discussed global climate policy [2]. The backbone of global climate policy is arguably the United Nations Paris Agreement of 2015, which requires its signatories to limit the temperature increase to well below 2-degrees Celsius, aiming for 1.5 degrees Celsius (Article 2 para. 1 (a) PA). Yet, the remaining carbon budget to stay within these limits is very small; taking a per-capita perspective, capacities and historical causation of climate change into account, there is more or less no GHG budget left for industrialised countries, as shown in detail elsewhere [3,4]. The Paris Agreement thus requires net-zero emissions by phasing-out fossil fuels and reducing livestock farming significantly on a global scale by 2035 at the latest [4–7]. A societal transformation is required, and effective policy instruments are needed to induce this transformation. Even though substantial progress has been achieved in the EU, the pace of emission reductions must accelerate even further to remain on track towards its current 2030 and 2050 climate objectives [8]. Against this background, the EU has significantly strengthened its climate policies [8].

The cornerstone of the EU climate policy is the EU Emissions Trading Scheme (ETS 1) which was adopted in 2003 [9] and has since been revised multiple times. Besides that, as part of the EU Green Deal [10], the Commission presented a set of legislative proposals to transform society and address environmental degradation and climate change. The proposals to combat climate change have been summarised as “Fit for 55” legislation. “Fit for 55” includes, among others, a reform of the ETS 1, the adoption of a second ETS (ETS 2) and a Social Climate Fund (SCF), as well as the introduction of a Carbon Border Adjustment Mechanism (CBAM) [11].

The aim of this article and its research question is to evaluate the effectiveness of the reformed ETS 1 and ETS 2, the SCF, and the CBAM in ensuring compliance with the 1.5-degree Celsius target set by the Paris Agreement. The

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assessment focusses on the adopted regulations compared to the original legal proposals. Besides that, loopholes in the previous and revised ETS will be examined as the lack of ambition of the cap. Furthermore, legislation to promote green hydrogen is assessed. Results show that the reforms fail to comply with the goals of the Paris Agreement. Subsequently, this article examines the role of hydrogen in the context of energy transition.

2. Methods

This article applies a qualitative governance analysis to identify effective policy instruments to achieve a policy goal. The present qualitative governance analysis assesses policy instruments against the legally binding goals of the Paris Agreement and the Convention on Biological Diversity (CBD). The Paris Agreement aims to keep global warming "well below 2 °C above pre-industrial levels" and "pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (Article 2 para. 1 (a) PA) (see [4,6,12]). The UN Convention on Biological Diversity aims at stopping biodiversity loss (Article 1 CBD). This and qualitative governance analysis, in general, was explained many times in earlier contributions (see details: [5,12–16]): A qualitative governance analysis "examines the effectiveness of potential or existing governance instruments based on a given objective and takes into account human motivational factors. Behavioral research in various disciplines (sociology, economics, psychology, ethnology, *etc.*) and methods (experiments, surveys, participant observation, *etc.*) identified in particular the following driving factors of human behavior: self-interest, values, conceptions of normality, emotional constraints such as convenience, denial and habits, peer pressure, the tendency to make excuses, difficulties in perceiving distant challenges and structural problems such as path dependencies and problems of collective goods. Based on this knowledge of the motivational factors of consumers, producers, entrepreneurs, politicians, *etc.*, … typical governance problems with respect to sustainability can be identified" [12].

These governance problems limit how effective policy instruments are. In other words, effective instruments have to avoid these governance problems while at the same time achieving the given objectives. These typical governance problems are (spatial and sectoral) shifting and rebound effects, enforcement and depicting problems, and lacking target stringency, measured against the effectiveness of achieving the objective [5,15–17]. Given the qualitative approach of the governance analysis, this includes no quantitative measurement. Effectiveness here refers solely to the actual achievement of objectives. It does not refer to efficiency, *i.e.*, the relationship between a strategy's conceivable costs and benefits.

3. Results

3.1. Far-Reaching Legislative Changes at EU Level

On 18th December 2022, the EU Parliament and Council reached a provisional trilogue agreement on the implementation of the "Fit for 55"-package [18]. Precisely, lawmakers voted for the adaptation of the established emission trading system (ETS 1) (Section 3.1.1), the introduction of a new trading system for emissions of the transport and building sector (ETS 2) [19] (Section 3.1.2), and a "Social Climate Fund" (SCF) which incorporates a social compensatory mechanism [19] (Section 3.1.3). Besides that, an agreement was achieved on the introduction of a CBAM [20] (Section 3.1.4). On 25th April 2023, the agreements were formally adopted by the council. On 10th May 2023, a corresponding directive regarding the adaptation of the existing ETS 1 and the introduction of the new ETS 2 [21], and two regulations regarding the SCF [22] and CBAM [23] were adopted.

3.1.1. Adaptation of the Established ETS 1

Firstly, Directive (EU) 2023/959 provides amendments to the original EU cap-and-trade system for GHG-emissions ETS 1, which was established by Directive 2003/87/EC [9] (hereafter: the amended Directive) and has been in force since 2005 [24]. Originally, ETS 1 addressed emissions from power stations and industrial plants and, since 2012, partially from aviation [25]. It is designed as a downstream ETS, in which power stations and industrial plants with direct emissions are obliged to acquire allowances. Mainly, this mechanism provides an incentive for emitters to invest in energy efficiency measures and renewable energy technology and, therefore stimulates emission reductions [22,26,27]. In 2015, more than 11,000 power stations and industrial plants were regulated by ETS 1 [22]. Overall, the ETS 1 covers approximately 40–50% of the European Union's greenhouse gas (GHG) emissions. [22,28]. It can, therefore, be regarded as the centre piece of the EU climate protection policy [25]. With the adoption of the new Directive (EU) 2023/959, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme, Regulation (EU) 2015/757 and the Decision of the European Parliament and the Council amending Decision (EU) 2015/1814 as regards the amount of allowances to be placed in the market stability reserve for the Union greenhouse gas emission trading scheme until 2030 [17], the ETS 1 was amended extensively.

To achieve the Union's emission reduction targets for 2030, the new Directive requires an emission decrease by 62% in the sectors covered by ETS 1—compared to 2005 [17]. Moreover, maritime transport will be incorporated into ETS 1 by amending Article 3b of Directive 2003/87/EC and thus extending the overall emission coverage of the trading system (see also Article 3g ff. of the amended Directive). According to Article 3ga, the maritime sector will be phased in in 2024 and 2025 and be fully included by 2026 [29]. At the same time, according to Article 9 of the amended Directive, the total number of allowances will be decreased by 90 million in 2024 and by 27 million in 2026. The linear reduction factor will be raised to 4.3% from 2024 to 2027 and 4.4% from 2028 [17]. Lastly, according to Article 10a para. 1 (a) of the amended Directive, and in accordance with the upcoming CBAM Directive, the allocation of free allowances will be phased out by 2034 (see below) [17].

Reviewing and amending the existing ETS 1 was a necessary step towards achieving climate neutrality. In principle, the establishment of a rigorous emissions trading system with a tight cap and an efficient linear reduction factor is a feasible and preferable approach to reaching net-zero emissions. It offers advantages over e.g., regulatory law instruments which has been extensively argued elsewhere [5] (Ch. 4.6). Though, since the legally binding 1.5-degree limit of the Paris Agreement (see in detail [4,6]) is likely to fail [4,30], an additional cap-and-trade system for greenhouse gas emissions from livestock farming (combined with a livestock-to-land ratio at farm level) must accompany ETS 1 and ETS 2 [7,31,32].

Furthermore, the previous design of the ETS suffered from lacking target stringency and loopholes [33]. And indeed, some of these issues are addressed in the reform. The first issue is the reduction target: In the original reform proposal for the ETS 1 from 14th July 2021 [26], the emission reduction target was supposed to be raised to 61% in 2030 compared to 2005. Against this background, the adopted increase of 62% is welcome. Certain parties in the European Parliament had proposed an increase of up to 63% [34], which, however, was not adopted. Besides, it remains widely unclear how the path to climate neutrality subsequent to the 2030 objective is going to be designed [35]. Overall, the amended reduction target and the linear reduction factor are still too low to be in line with the 1.5-degree path [36,37]. The second issue is free allowances: The original proposal foresaw the expiration of free allowance allocation by 2032. However, this deadline has been postponed by two years [17]. In doing so, the polluter pays principle is being violated, and emission decrease is thwarted [38–40]. The third issue concerns the shipping sector: Considering the need for a fast transition in the shipping sector [41], the inclusion of maritime transport is an important step to incorporate all GHG-emissions in a cap-and-trade-system [42]. However, this integration urgency faces a slow phase-in and late full applicability in that sector [43]—which again is unfortunate. Also, there are indications that the inclusion of maritime transport entails negative side effects such as carbon leakage [44].

3.1.2. Introduction of the ETS 2 for the Transport and Building Sector and Additional Sectors

Secondly, Directive (EU) 2023/959 [18] introduced a new chapter "IVa" in the amended Directive 2003/87/EC: the Articles 30a ff. of the amended Directive now contain the provisions for the new emissions trading system for buildings, road transport and additional sectors, which include industrial activities not yet covered by Annex I of the amended Directive (ETS 2) [17]. This step is based on the fact that these sectors are substantial sources of emissions and pollution. Besides, the reform is expected to contribute to innovation and job creation in these sectors [26,45]. For instance, in 2017, the transport sector was responsible for 27% of the total GHG-emissions in the EU [46]. In contrast to ETS 1, ETS 2 is structured as an upstream ETS (Recitals 77 and 89 of Directive (EU) 2023/959) [17,26]. Plants and facilities must acquire allowances and will pass the resulting additional costs on to their customers [26,47]. In doing so, ETS 2 will eventually place a financial strain on customers, thereby providing them with an incentive to reduce emissions [44]. In line with ETS 1, the underlying idea of ETS 2 is to reduce the allowances step-by-step and thereby limit the overall emissions of the targeted sectors [44]. The reduction target of ETS 2 requires emission reductions in the buildings and road transport sector by 43% by 2030 compared to 2005 and by 42% in the other sectors [17]. As the risk for carbon leakage in the buildings and transport sector is little or non-existent, no allowances will be allocated for free [17,44]. The emissions trading under ETS 2 will effectively enter into force by 2027 (Article 30d amended Directive). According to Article 30c para. 1 and 2 of the amended Directive, the linear reduction factor for the yearly decrease of total emission allowances will be 5.10% from 2024 and 5.38% from 2028. A frontloading mechanism will be used to ensure the functionality of the new system [48,49] (Article 30d para. 2 amended Directive). Even though the newly introduced ETS 2 and the established ETS 1 are adjacent, they operate separately [17]: The Market Stability Reserve, as established by Decision (EU) 2015/1814, will also apply to ETS 2. The auctioning of the allowances is separated (Article 30d para. 1 amended Directive) [50]. Article 30h of the amended Directive establishes measures for excessive price increases, *i.e.*, measures to regulate the conditions under which allowances from the Market Stability Reserve will be released. Under certain circumstances, emissions trading of ETS 2 can be postponed until 2028 (Article 30k amended Directive).

The establishment of an ETS for the road transport and buildings sector is an important step towards climate neutrality [32,46]. A positive aspect is that it is designed as an upstream ETS, which does not provide any free allowance allocation. Another positive aspect is that fuel for manufacturing has also been included—as requested by the European Parliament. Moreover, extending the scope of ETS 2 to sectors not included in the ETS 1 increases its environmental effectiveness [51]. A negative aspect is that the proposal by the Commission foresaw an entering into force only in 2026 (Article 30d para. 2 of the original proposal) [26], which was postponed by a year in the Trilogue Agreement [48]. Against the backdrop of the very limited remaining GHG emissions budget to stay below 1.5-degree, this delay is critical [52]. In addition, setting a price ceiling of 45 EUR as a trigger for price-dampening measures (Article 30h amended Directive) undermines the target stringency [44]. The same applies to the possibility of postponing the entry into force until 2028 in case of exceptionally high energy prices (Article 30k amended Directive) [48]. As much as this measure may be suitable to provide short-term protection for citizens from increasing energy prices, it waters down the effectiveness of the ETS 2 to combat climate change (in the long run).

3.1.3. Establishment of a Social Climate Fund

Thirdly, a Social Climate Fund (SCF) is established by Regulation (EU) 2023/955 [19] (hereafter: SCF Regulation). Its purpose is contributing to a socially fair transition towards climate neutrality (Article 1) [15]. To this end, the fund aims to address the expected social impacts. The inclusion of the buildings and road transport sector into Directive 2003/87/EC and the upstream design will primarily impact vulnerable households, micro-enterprises and transport users (Recitals 10 ff. SCF Regulation) [44]. Precisely, the SCF will provide funds to Member States to support national policies aimed at addressing these social impacts (Recital 16 of the SCF Regulation). Policies will support the vulnerable groups by providing temporary direct income support and measures and investments intended to increase the energy efficiency of buildings and decarbonise the heating and cooling of buildings (Recital 16 SCF Regulation). According to Article 10 para. 1 of the SCF Regulation, the resources for the SCF shall amount to 65 billion EUR (2026 to 2032). The SCF will be funded by allowance auctioning of the ETS 2 (Article 30d para. 3a amended Directive) [17]. To receive funding from the SCF, Member States are obliged to submit Social Climate Plans (hereafter: Plans) to the Commission. These Plans have established the measures to facilitate a just transition [15]. Article 4 of the SCF Regulation details the content of these Plans. Lastly, according to Article 15 of the SCF Regulation, the Member States will have to contribute at least 25% of the total estimated costs of their Plans.

In principle, the establishment of an SCF is a suitable measure to mitigate the social effects of enhanced climate protection measures ([5] (Ch. 4.7), [44,53–55]). In the short term, enhanced climate protection measures tend to raise sustenance costs, especially for the most vulnerable in society [45,50,51,56]. In the long term, these measures are necessary to protect these groups as they are the ones most affected by climate change. This is true on a national and global scale [50]. Accordingly, it is remarkable that the SCF budget of 72 billion EUR—as envisaged in the Commission's proposal [57]—has been reduced to 65 billion EUR in the Trilogue Agreement. In addition, the original proposal foresaw a 50% contribution of the Member States (Article 14 original proposal). According to Article 1 of the SCF Regulation, the SCF will enter into force before ETS 2 (Article 30d amended Directive). On the one hand, one year may be considered too little time to adopt effective compensatory measures from SCF funds [58,59]. On the other hand, time is pressing to establish the new ETS 2. Overall, instead of cutting the SCF budget to 65 billion EUR, more or all revenues from ETS 2 could have been used to fund the SCF [60] (critically on revenue allocation in the SCF [46,61]). Lastly, the SCF fails to address the issue that social compensation measures are primarily needed in the global South and not in the EU [50,62].

3.1.4. Introduction of a Border Carbon Adjustment Mechanism

Fourthly, a carbon tariff on imports in emission-intensive sectors, which currently benefit from free allowance allocation under ETS 1 (CBAM), has been established by Regulation (EU) 2023/956 [16,19] (hereafter: CBAM Regulation). The CBAM aims to mitigate and, at best to, avoid carbon leakage or shifting effects in the ETS-covered sectors [19,63,64]. It also aims to encourage third countries to reduce emissions and create a level playing field for EU producers [60]. Carbon leakage occurs if businesses transfer production to other countries—or imports from those countries replace equivalent products that are less GHG-emission intensive of inland production [16,65]. Since climate change is a global issue, EU efforts to reduce GHG-emissions are undermined if GHGs are emitted in third countries (Recital 9 CBAM Regulation) [16,41]. In line with that, from an economic perspective, the EU's comparably strict climate protection regulations may cause competitive disadvantages for the local industry [66]. By introducing the CBAM, the negative impacts of uneven climate protection efforts between the EU and partners with less strict standards should be compensated [19,63]. Against this background, the CBAM is expected to be an essential element in achieving climate neutrality in the EU (Recital 10 of the CBAM Regulation). The targeted sectors include cement, iron and steel, aluminum, fertilizers, electricity, and hydrogen (Annex I of the CBAM Regulation). Over time, the scope of the CBAM is going to be amplified to include all emissions by 2030 (Article 30 CBAM Regulation). It entered into force on 1st October 2023 and, in a transitional period until 31st December 2025, imposes reporting requirements on importers (Article 32 CBAM Regulation). From 2026 onwards, EU importers will be required to purchase and surrender CBAM certificates (Article 22 CBAM Regulation). These certificates will be phased in parallel to the phasing out of free allowance allocation (Article 10a para. 1a amended Directive 2003/87/EC and Article 31 CBAM Regulation). In order to preserve its effectiveness, *i.e.*, to prevent carbon leakage, the CBAM is supposed to reflect the EU ETS price (Recital 23 CBAM Regulation). Therefore, the carbon tariff will be equal to the weekly average ETS carbon price paid by EU producers (Recital 23 CBAM Regulation) [16].

The introduction of a CBAM is, in principle, a suitable instrument to prevent carbon leakage [5], [59] (§ 6 E.), [61]. Because the carbon tariff will increase the price of imported goods, foreign producers are incentivized to reduce emissions [61]. Furthermore, it is fortunate that some other jurisdictions, such as Canada and Japan, are planning to take similar action [63]. However, the CBAM enters into force nine months later than originally proposed by the Commission [67], and the transition period will be shortened by nine months. It will not apply comprehensively until the allocation of free allowances is fully phased out, which has been postponed to 2034—once again thwarting the polluter-pays principle (see above).

An ambivalent aspect is that export rebates are not introduced. These rebates could weaken the price signals in relation to emissions [68] and may cause various effects that could undermine the effectiveness of the CBAM [69]. A positive aspect is that—unlike in the Commission's original proposal—emissions from hydrogen are also covered by the CBAM (on hydrogen, see further below). The same applies to the (preliminary partial) inclusion of indirect emissions, *i.e.*, emissions from the electricity generation used to produce goods covered by the CBAM (Recital 19 CBAM Regulation). A negative aspect is that no agreement could be reached on using the revenues from the CBAM for climate protection measures in third countries. Such a provision would have been urgently needed to address the global nature of climate change [70]. Also, if the revenues are not used to combat climate change in third countries, it remains unclear if the CBAM is in line with World Trade Organization law [61,63,65,66,71–74].

3.2. Hydrogen and Power-to-X in the Context of Energy Transition—Supporting Measure at EU Level

With the revision and adaptation of ETS 1 and its clearer target stringency, the introduction of ETS 2, and the accompanying establishment of an SCF and the CBAM, the EU is pursuing a necessary and desirable path for climate protection. However, the original drafts have been watered down in many places. The polluter-pays principle is still not sufficiently adhered to. In addition, most of the measures have been adopted too late. With little time left to meet the 1.5-degree goal of the Paris Agreement, the EU cannot adopt weak compromises. Against this background, additional actions must be taken to accelerate the transition from fossil fuels. In that context, using (low-carbon) hydrogen may promise to be one suitable approach [75–77]. In principle, the ETS is forcing fossil fuels out of the market, making room for new energy sources such as hydrogen. Nevertheless, supplementary regulations and subsidies may be needed, for example concerning special energy sources [78]. In order to react to the very broad discussion on hydrogen, we analyse this need for additional regulatory and subsidizing instruments with regard to hydrogen. In a first step, a short analysis on the technological background makes sense.

3.2.1. The Ambiguous Role of Hydrogen in the Transition Towards a Post-Fossil World

Hydrogen is a clean burning molecule [74]; it does not emit CO_2 and causes almost no air pollution when used [72]. It is very versatile so it can be used for all kinds of transportation and power production, as a heat source and feedstock for artificial goods production [72,74].

Nevertheless, using hydrogen for transitioning to a post-fossil era also bears challenges. Hydrogen is not naturally available as an energy source but is an energy carrier that needs to be produced from other elements [73,74]. Since there are many ways to produce hydrogen, the question of whether using hydrogen is beneficial for the energy transition highly depends on its method of production. The hydrogen that is mostly used today (almost 95%), *i.e.*, "grey hydrogen," is produced by thermochemical conversion of fossil gas, either Auto-Thermal Reforming (ATR) or Steam Methane Reforming (SMR) [72–74]. Since this production method is based on fossil fuels and releases CO_2, its ecological benefits are limited [72]. In contrast to that "green hydrogen" [74] and—serving as a bridging tool—"blue hydrogen" appears to be the most promising material [73]. Thus, the following sections discuss these two production methods.

3.2.2. Green Hydrogen and Power-to-X

Green hydrogen is produced by electrolyzers powered with renewable electricity (or other processes using bioenergy) and water [72–74]. The products are hydrogen and oxygen [73,74]. Green hydrogen derivatives play a decisive role in transitioning to a post-fossil world [72,74,79,80]. Green hydrogen derivatives are discussed as a decarbonization option for sectors where the direct use of renewable electricity is impossible or challenging. [74]. These sectors include the steel and chemical sector, and small parts of the transport and heating sector [72,74]. For its ecological benefits, (green) hydrogen has received increasing attention [72–74]. However, the current total share of green hydrogen amongst all hydrogen remains minimal [74].

The small practical significance of green hydrogen is mostly based on: Firstly, the demand for renewable energy in the production process (and the inefficiency of hydrogen production) is substantial. The production of various electricity-based energy carriers takes place in complex processes summarised as "Power-to-X" (P2X) [74]. Due to partially high conversion losses, P2X technologies require much renewable electricity as feedstock to produce the electricity-based energy carriers. However, since renewable energy is mostly used to replace carbon-based electricity, renewable electricity is not expected to be available in sufficient quantities to produce green hydrogen in the foreseeable future [73]. According to calculations by the International Energy Agency (IEA), an electrolysis capacity of 3670 GW is required to achieve climate neutrality by 2050 [81]. This implies an increase of today's capacity by a factor of 6000, and an expansion of renewable energies by a factor of ten [82]. Consequently, the demand for renewable energy for the production of green hydrogen within the EU may even surpass the EU's potential [80]. Secondly, renewable (and low-carbon) hydrogen is not yet cost-competitive compared to fossil-based hydrogen [72].

Green hydrogen is incorporated in several legislative acts:

- On 8th July 2020, the European Commission adopted a "Hydrogen Strategy for a Climate Neutral Europe" [72] aiming to "harness all the opportunities associated with hydrogen". The Strategy contains a vision for the creation of a European hydrogen infrastructure.
- Concrete measures were adopted one year later. The Commission published a proposal to amend the Renewable Energy Directive (hereafter: RED II) [83], which is one element of "Fit for 55" [84]. In that document, the Commission proposed several incentives for using hydrogen, including binding targets for the industry and transport sectors, as well as increasing the share of hydrogen-based energy sources to 2.6% by 2030 (Article 1, para. 14: new Article 25). At the same time, Member States should ensure that the contribution of renewable fuels of non-biogenic origin (RFNBOs) used for final energy consumption and non-energy purposes in industry accounts for 50% of the hydrogen used for final energy consumption and non-energy purposes by 2030 at the latest (Article 1 para. 11: newly inserted Article 22a).
- Hydrogen-based energy sources are incorporated in the REPowerEU plan as a supporting pillar of the future energy system [85]. REPowerEU was presented by the EU Commission in response to the Russian aggression against Ukraine and the resulting efforts to make the EU independent of fossil fuels from Russia [82]. The REPowerEU plan aims to produce 10 million tons of renewable hydrogen within the EU by 2030 and to import a further 10 million tons [82].
- Lastly, the Commission supports the hydrogen sector by categorising the sector as "Important Projects of Common European Interest" (IPCEIs) [86]—*i.e.*, "IPCEI hydrogen". The project consists of four sub-projects: "IPCEI Hy2Tech" (technology), "IPCEI Hy2Use" (industry), "IPCEI Hy2Infra" (infrastructure) and "IPCEI Hy2Move" (mobility).

The ramp-up of hydrogen for climate protection requires a definition of production criteria and the development of a reliable certification scheme. The former has been adopted on 10th February 2023 and formally published by the EU Commission with two Delegated Acts on 20th June 2023: The first Delegated Act (hereafter: DA I), based on Article 27 para. 3 Renewable Energy Directive (hereafter: RED II) [80], defines production criteria for hydrogen based on renewable energies [87]. The second Delegated Act (hereafter: DA II), based on Article 25 para. 2 und 28 para. 5 RED

II sets out a methodology for calculating the life-cycle GHG-emissions from RFNBOs [88]. The methodology takes into account the GHG-emissions throughout the life cycle of the fuel [89], including upstream emissions, emissions related to the withdrawal of electricity from the grid, and emissions related to the processing and transport of the fuel to the final consumer. Article 25 para. 2 RED II requires GHG-savings for RFNBOs of at least 70% from 1st January 2021 compared to the replaced fuels. The fossil benchmark for RFNBOs is set at 94 g CO_2eq/MJ (Annex A.2.). Taking into account the savings target of at least 70% results in emissions of max. 28.2 g CO_2eq/MJ for RFNBOs.

According to the DA I, green hydrogen can be produced either directly from a Renewable Energy Source (RES). In this case, two requirements need to be fulfilled: Firstly, RFNBO facility and RES plant need to be connected through a direct connection. Secondly, the RES facility is no older than 36 months at start-up of the RFNBO facility (with extended periods for certain expansions).

Also the production of green hydrogen from grid-sourced electricity is possible if the RES plant would otherwise be curtailed without the RFNBO production (proof of this needs to be obtained from the national TSO), the share of RES production exceeds 90% in the relevant electricity market "bidding zone" as an average of all consumption in the previous calendar year or the grid average GHG emissions intensity is below 18 g CO_2e/MJ (currently only Sweden, although France is close [90]). This favours production in countries with high penetration of nuclear power (as well as RES).

If the above-mentioned criteria cannot be met, the RFNBO producer can sign a Power Purchase Agreement (PPA) with a renewable energy source (RES) operator. They must then demonstrate that the requirements for additionality and temporal and geographical correlation are fulfilled as described above. In this case the produced hydrogen also counts as green.

- Additionality: The RES generation facility is no older than 36 months than the RFNBO facility and has so far not received any State aid (*i.e.*, this restricts a broad category of subsidies and state support, subject to certain exceptions). These two requirements will apply from 1 January 2028, except for RFNBO facilities commencing operations before that date. In this case, the criteria will only apply from 1 January 2038. They will, though, then apply in full even to pre-existing RFNBO producers. This raises the possibility that, in certain cases, a RFNBO facility may need to change its RES power supply solution in the middle of operations once these rules kick-in. This regulation intends that mainly additional RES plants are used for hydrogen production. Existing plants, on the other hand, should be utilized to support the decarbonisation of the electricity system.
- Temporal and geographical correlation: Temporal correlation means that until January 1, 2030, RFNBO output must occur during the same calendar month. If this cannot be realised, it must occur within the same hour as energy produced from the contracted RES generation sources. In terms of geographical correlation, RFNBO production facilities and RES facilities must be located within the same electricity market bidding zone or in a zone directly connected to it.

For climate protection, this regulation seems useful, as the targeted reduction of GHG emissions would be undermined if the increased demand for electricity is not offset by additional plants. Still, it is clear that without a massive expansion of wind and solar power, which is unlikely to happen under the existing regulations, there will not be enough renewable energy as feedstock for green hydrogen production. Thus, the additionality criterion requires further instruments to accelerate and increase the expansion of renewable energies.

3.2.3. Blue Hydrogen in the Context of Energy Transition

Against the background of an impending shortage of green hydrogen, the European Hydrogen Strategy states that, in the short and medium term, "other forms of low-carbon hydrogen are needed, primarily to rapidly reduce emissions from existing hydrogen production and support the parallel and future uptake of renewable hydrogen" [72]. Therefore, the temporary use of "blue hydrogen", which is a low carbon solution [73], has increasingly been discussed. Like grey hydrogen production, the production of blue hydrogen is based on fossil natural gas [73,74]. This makes it an inferior product to green hydrogen [74]. However, unlike in grey hydrogen production, CO_2 is not released into the atmosphere but injected into the ground by "carbon capture and storage" technologies (CCS) [74,77]. Therefore, blue hydrogen is ecologically superior to grey hydrogen [74]. It also offers an advantage by building on existing industrial experience [73]. Yet, it still is a highly controversial measure for climate protection and is, just as green hydrogen, not cost-competitive against fossil-based hydrogen [72].

According to the EU Innovation Fund, 10 billion EUR shall be invested between 2020 and 2030 in, among others, low greenhouse gas ("low CO_2") technologies and Carbon Capture Storage and Carbon Capture Utilization (CCU) processes [91,92]. In addition, the European Commission established a "European Clean Hydrogen Alliance" in early 2020 [72]. The program aims to establish an investment initiative to support the expansion of the hydrogen value chain across Europe, covering both renewable hydrogen and low-carbon hydrogen [72]. Recently, the European Parliament's

Industry and Energy Committee adopted a resolution supporting the use of hydrogen produced from "low-carbon" energy sources [93]. However, whether blue hydrogen contributes added value for the energy transition is controversial. The two main positions for and against the temporary use of blue hydrogen are discussed below.

Grey hydrogen production is a well-established technology that has been used for decades, *i.e.*, industrial infrastructure is available and would (in some cases) only require the construction of a CCS to provide the benefits of blue hydrogen [73]. Therefore, blue hydrogen could increase the amount of hydrogen and "fill the gap" in the short- and mid-term—until sufficient green hydrogen is available [72,73]. More precisely, blue hydrogen can, on the short run, rapidly reduce emissions from existing hydrogen production and, on the long run, stimulate the demand for hydrogen and support the development of a transport and distribution infrastructure. This infrastructure could also be used for green hydrogen [72]. Thus, blue hydrogen could support the subsequent switch to green hydrogen and contribute to the energy transition as a "systemic stimulus". However, as the production requires fossil fuels, using low-carbon hydrogen is not an end in itself, but must only serve the transition of the energy system [73]. Therefore, the hydrogen ramp-up should not be stimulated for its own sake. Instead, the primary goal is to provide the hydrogen and derivatives needed to decarbonise non-electrified areas in the shortest possible time [72]. Hence, the usefulness of blue hydrogen consequently stands or falls with its decarbonisation level.

The decarbonisation level of blue hydrogen depends on numerous factors of production, storage and transport [73]. Even though blue hydrogen can—in some cases—achieve an overall better GHG-balance than grey hydrogen, certain residual emissions remain—depending on the CCS maturity. Because of remaining CO_2 emissions, blue hydrogen—contrary to the National Hydrogen Strategy—cannot be described CO_2-neutral. However, far more critical than the CO_2 emissions are methane emissions that are released during the production and transport of natural gas. Over a period of 20 years, methane has 86 times the GHG-impact of CO_2 [94].

In addition, CO_2 capture plants have a very high energy demand. If this demand is covered by natural gas, blue hydrogen has no relevant emission advantage over grey hydrogen. The picture looks different if renewable electricity is used. In this context, reducing upstream emissions during the production process of blue hydrogen through reformation contributes to an overall reduction in CO_2 emissions. However, as discussed above, the availability of renewable energy is limited. Moreover, techniques such as CCS and CCU have higher sustainability risks compared to other mitigation pathways such as energy efficiency improvements and direct electrification. Therefore, hydrogen and bioenergy should be better targeted towards applications with no or very limited other mitigation options [8].

Bearing in mind the decisive role of hydrogen for the energy transition, the following requirements have to be met so that blue hydrogen can be considered a climate-friendly bridging technology:

- Firstly, methane leaks along the entire supply chain need to be minimised.
- Secondly, low-carbon electricity should be used for all processes.
- Thirdly, reforming technology with consistently high CO_2 capture rates must be employed.

Blue hydrogen should only be considered a bridging technology towards net-zero economies if these requirements are fully met. To ensure that these requirements are met, a clear regulatory framework that limits the use of blue hydrogen over time must be introduced. Consequently, a new delegated act on low-carbon hydrogen is currently in the making.

4. Discussion and Conclusions: Optimising Governance Options

The analysis found that the EU does not take sufficient measures to comply with the 1.5-degree limit from Article 2 PA. The analysis focused on the main instrument for post-fossilisation, the EU ETS, and supplementary instruments to promote a new green technology, *i.e.*, hydrogen. The current EU emissions trading (1) has an insufficient cap, measured against the environmental goals, (2) contains distorting factors such as large quantities of old certificates from an oversupply of certificates in the early years of the ETS in the market, (3) does not cover livestock farming (and focuses too much on carbon emission while neglecting other GHG emissions) and (4) is only slowly creating sufficient protection against shifting effects outside the EU. Against this background, optimising governance options—measured against the 1.5-degree limit—are discussed below. The aim is to show that emissions trading is the most effective governance instrument—but certain elements need to be taken into account and improvements adopted.

Climate governance instruments must do justice to human motivations and several governance problems such as shifting effects and lacking target stringency (see above), measured against environmental goals (on the following: [5,7,75,95]). The threat of shifting effects, basic human motives, and the transnational nature of climate change indicate that purely national approaches to addressing it are insufficient. This is particularly true because shifting effects can lead to competitive disadvantages, which in turn may reduce the actual acceptance of ambitious environmental protection measures. If a limited group of states still improves its environmental protection provisions, these provisions have to be combined with border adjustments. World trade law allows the adoption of border adjustments under certain conditions. Ultimately, the combination of these measures avoids shifting effects. Thus, by extending ETS 1 and introducing ETS 2 in combination with the CBAM, the EU takes an effective step point in the right direction.

Climate, biodiversity and other environmental goals such as closed resource cycles and overcoming the contamination crisis demand two core strategies: a complete phase-out of fossil fuels in all sectors and replacement by renewable energies, more energy efficiency and frugality—alongside a drastic reduction in livestock farming [4,7]. While a technology change is underway, a climate law of frugality remains a vision. Overall, the various regulations in energy, agricultural, and environmental law aim to sustain current lifestyles and economies by focusing on technical optimization, specifically through improving technical efficiency and consistency. As discussed above, when evaluated against the goals of the Paris Agreement (PA) and the Convention on Biological Diversity (CBD), past EU climate legislation has not been successful. EU climate governance, thus must be optimised. To this end, either regulatory law or quantity instruments can be implemented. Regulatory law governs individual products, activities or installations. Thus, The outcome is frequently hampered by rebound, shifting effects, and enforcement problems. In some cases, even opposing effects may be caused. A more effective approach instead appears to be quantity governance instruments such as an ETS. Cap-and-trade systems offer particular advantages to achieve environmental goals, such as the 1.5-degree limit of the PA:

Cap-and-trade approaches can comprehensively address the motivational situation of norm addressees as described elsewhere [5,96]. They not only target monetary self-interest, but also, for example, conceptions of normality and emotional factors such as denial. Besides, if quantity control approaches set ambitious caps, address easily graspable governance units (such as fossil fuels or animal products at the level of slaughterhouses and dairies [7,97]) on a sectorally and geographically broad scale (*i.e.*, at the EU level plus climate clubs with other countries plus border adjustments), they can avoid governance problems such as problems of enforcement, rebound, shifting and depicting. The orientation towards absolute quantities prevents rebound effects; the less small-scale perspective prevents enforcement problems; the factually and spatially broad approach prevents shifting effects; the use of easily comprehensible governance units prevents issues of depicting with which, for example, a building regulatory law may struggle. Compared to the current ETS 1 and ETS 2, however, this requires a more ambitious cap, the closing of loopholes and the extension to livestock farming. Furthermore, quantity control encourages more consistency, resource efficiency and frugality. For if the cap is not achievable by purely technical solutions, the norm addressees inevitably switch to frugality measures. This shift will occur without public authorities having to establish comprehensive control knowledge and a more or less comprehensive monitoring apparatus for a large number of individual actions, as in the case of regulatory law.

Quantity control is also particularly compatible with the basic principles of liberal democracies because it leaves the greatest possible degrees of freedom while effectively defending the physical preconditions of freedom. Furthermore, quantity control can be combined well with—national or transnational—social redistributive measures (as compensation for distributional effects of climate change on the one hand and climate law on the other; see in detail [51]). This is because the fixed cap prevents redistribution, which could undermine its ecological impact, as often occurs with environmental levies that involve revenue redistribution.Hence, the SCF points precisely in the right direction.

The best-known advantage of cap-and-trade systems (without direct ecological relevance) is that these approaches promise to achieve an environmental goal particularly efficiently in the sense of “at particularly low cost”. In contrast, subsidies, which in some aspects have a similar effect as quantity control, generate much higher costs [75].

If central drivers of diverse environmental problems (climate change, loss of biodiversity, disturbed nutrient cycles, environmental media pollution) such as fossil fuels and animal products are chosen as the governance unit of cap and trade, an integrated solution to most environmental problems can be found, namely in a combination of various strategies including frugality. Still, such a comprehensive approach would require supplementary subsidy and regulatory law. Subsidies, for example, can promote research and development and bring new—not yet cost-efficient—products on to the market. Regulatory law can prohibit certain actions, provided the control variables are easy to enforce and depict—for example, banning peatland drainage [98,99]. However, the approach presented probably as an overall approach to solving modern environmental problems (which are quantity problems) cannot be replaced by those other instruments that cannot comparably address governance and motivational problems (e.g., cannot protect themselves comparably against rebound and shifting effects), are less liberal, are less cost-efficient, can be combined less well with social compensation, *etc.* In general, however, a distinction must be made between the best possible design of an instrument and the real (deliberately or inadvertently ecologically ineffective) design of an instrument.

As the above analysis has shown, hydrogen has the potential to support achieving the goals of the PA as a very versatile tool, especially as an energy carrier. For this reason, the interest in the use of hydrogen has experienced several boosts in the past and again today. However, the analysis above also demonstrates that hydrogen cannot universally be regarded as the "golden solution". Its benefits are contingent on its production being based on sustainable processes. Against this background, the benefits of hydrogen on the pathway to climate neutrality can only be viewed with modesty: On the one hand "grey hydrogen", which is mainly used today and is predominantly based on fossil fuels, cannot provide any benefits on the pathway to climate neutrality. On the other hand, especially "green hydrogen" and in some cases "blue hydrogen" can be viewed as beneficial on this pathway. Then again, it is most likely that "green hydrogen" and "blue hydrogen" will only play a minor part in the foreseeable future. As of today, its overall market share is still marginal and its overall cost structure is rather expensive. Also, the production of hydrogen and the infrastructure for storage and transportation demands a lot of energy [73]. So, along the chain, there are numerous potential gateways for the use of fossil-based energy and therefore there is a risk of undermining the benefits of "green hydrogen" and "blue hydrogen" along the way. Moreover, the storage and transportation of hydrogen is comparably complex and, therefore, causes high costs. For these reasons, "green hydrogen" and "blue hydrogen" now and may also in the foreseeable future will only play a role in special use cases in which other green energy sources are not at hand [73].

To develop its undeniable potential on the pathway to a post-fossil world, the improvement of already existing technologies, such as CCU in the context of "blue hydrogen" and the invention of new technologies for production, transport and storage will be necessary. This, in turn, will expand the use cases for "green hydrogen" and "blue hydrogen," further steering industry away from reliance on fossil fuels. The expansion of its use will help to mitigate emissions. In this sense, low-carbon hydrogen can be viewed as a "low-carbon-energy-bridge" between fossil fuels on the one side and climate-neutral sources on the other side. Against this background, the action that has recently been taken and that has been analyzed above, such as the "Hydrogen Strategy for A Climate Neutral Europe," the more concrete RED II and its Delegated Acts and the REPowerEU are welcomed. They depict meaningful steps in recognizing the potential of and supporting the use of hydrogen. Also, they already address some of the upcoming questions and issues such as the "additionality" criterion in Article 5 DA I addresses the risk of a "lock-in" in the fossil power supply (see above). Nonetheless, the development of the use of hydrogen is an ongoing process, which has only been started. Further action needs to be taken.

First of all, the cost structure is not yet competitive [73]. To stimulate the crossing over the bridge, one key element will be the reduction of costs for producing "green hydrogen" and "blue hydrogen". Therefore, subsidies will be one reasonable and effective means because bringing new technologies to the market is the classic use case for subsidies, as shown earlier in this chapter [75,77].

Secondly, as already mentioned above, using hydrogen cannot generally be regarded as merely ecologically beneficial. Just as the use of fossil-based energy sources has impacts on the environment, the production of hydrogen has, depending on the method of production, varying impacts on the environment—such as its production consumes vast amounts of fresh water. Therefore, the environmental impacts that may arise during the hydrogen production process must always be carefully considered. Since this article does not aim to provide a comprehensive evaluation of all environmental impacts of hydrogen production (including its effects on the Global South), it should be noted that studies on this topic present widely varying findings, as discussed in other sources [100].

Moreover, support for the use of hydrogen must be viewed from a global perspective, as its production and utilization extend beyond national boundaries and drive international trade [73]. Naturally, there is a risk at hand that sustainability standards in the production, transportation and storage differ between nations and therefore, the benefits of "green hydrogen" and "blue hydrogen" may be undermined (and because of the serious challenges of CCS discussed elsewhere [101], blue hydrogen cannot be considered an ecological option in the full sense from the outset). This may not even be due to the bad faith of some actors but more so because the categories of hydrogen and the requirements of categorization as "grey", "green", "blue" (and even more categories) are not (yet) legally regulated. As long as there is no legal clarity about the sustainability standards on the international level, there is no practical security in the matter of which hydrogen can be regarded as environmentally beneficial. Against this background, clear international legislation is vital to create equal standards [74]. From an international perspective, there is a risk that some countries may produce low-carbon hydrogen for export while continuing to rely on fossil fuels domestically. Therefore, there is a need for clear international legislation that will face such a scenario [73].

All in all, we have seen that the EU must further intensify its efforts on its territory and cooperate with other countries since the reformed ETS 1 and ETS 2, the SCF and the CBAM—as well as hydrogen policies—are not sufficiently effective to stay within the 1.5-degree limit of the Paris Agreement. The primary focus of energy law on the ETS is fundamentally sound; however, its implementation should be more consistent. This includes broadening the scope of the approach, closing existing loopholes, and raising the level of ambition.

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Writing—original draft preparation F.E., T.R., C.G.; additional research and editing P.C.K.; review and editing K.H. and F.E.; methodology F.E., K.H.; supervision F.E. All authors have read and agreed to the published version of the manuscript.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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