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EU Energy Law: Insufficient for the 1.5-Degree Celsius Limit

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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

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1. Problem Statement and Research Issue

Report after report point 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 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 (and subject to large uncertainties) [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 [5,6,7]. A societal transformation is required and effective policy instruments 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 [Error! Bookmark not defined.].

The cornerstone of the EU climate policy is the EU Emissions Trading Scheme (ETS 1) which was adopted in 2003 [9] and has since then been revised multiple times. Besides that, as part of the EU Green Deal [10], the Commission presented a set of legislative proposals to transform the 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 assess how effective the reformed ETS 1 and ETS 2, the SCF and the CBAM are to stay within the 1.5-degree limit of the Paris Agreement. The assessment focusses on the adopted regulations as 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

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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 which aims 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 [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**, [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 on details: [13,14], **Error! Bookmark not defined.**, [15,16], 17]): A qualitative governance analysis "examines the effectiveness of potential or existing governance instruments on the basis of 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" [17].

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 [18], **Error! Bookmark not defined.**, [19,20]. 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 all conceivable costs and benefits of a strategy.

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 [21]. 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) [22] (Section 3.1.2), and a "Social Climate Fund" (SCF) which incorporates a social compensatory mechanism [23] (Section 3.1.3). Besides that, an agreement was achieved on the introduction of a CBAM [24] (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 [25], and two regulations regarding the SCF [26] and CBAM [27] were adopted.

3.1.1. Adaptation of the Established ETS 1

Firstly, Directive (EU) 2023/959 provides amendments of the original EU cap-and-trade system for GHG-emissions ETS 1, which was established by Directive 2003/87/EC [**Error! Bookmark not defined.**] (hereafter: the amended Directive) and has been in force since 2005 [28]. Originally, ETS 1 addressed emissions from power stations and industrial plants and, since 2012, partially from aviation [29]. 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

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stimulates emission reductions [**Error! Bookmark not defined.**, [30,31]. In 2015, more than 11,000 power stations and industrial plants were regulated by ETS 1 [**Error! Bookmark not defined.**]. Overall, ETS 1 covers approximately 40-50 % of the EU's GHG-emissions [**Error! Bookmark not defined.**, [32]. It can therefore be regarded as the centre piece of the EU climate protection policy [**Error! Bookmark not defined.**]. 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 of 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 [**Error! Bookmark not defined.**], 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 [**Error! Bookmark not defined.**]. 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 [33]. 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 to 4.4 % from 2028 [**Error! Bookmark not defined.**]. 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) [**Error! Bookmark not defined.**].

Reviewing and amending the existing ETS 1 was a necessary step to achieve 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 [**Error! Bookmark not defined.**] (Ch. 4.6). Though, since the legally binding 1.5-degree limit of the Paris Agreement [**Error! Bookmark not defined.**] is likely to be failed [34], 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 [**Error! Bookmark not defined.**, [35,36].

Furthermore, the previous design of the ETS suffered from lacking target stringency and loopholes [37]. 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 [**Error! Bookmark not defined.**], the emission reduction target was supposed to be raised to 61 % in 2030 compared to 2005. Against this background, the adopted increase by 62 % is welcome. Still, certain parties in the European Parliament had proposed an increase up to 63 % [38] 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 [39]. Overall, the amended reduction target and the linear reduction factor are still too low to be in line with the 1.5-degree path [40,41]. 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 [**Error! Bookmark not defined.**]. In doing so, the polluter pays principle is being violated and emission decrease is thwarted [42,43,44]. The third issue concerns the shipping sector: Considering the need for a fast transition in the shipping sector [45], the inclusion of maritime transport is an important step to incorporate all GHG-emissions in a cap-and-trade-system [46]. However, this integration urgency faces a slow phase-in and late full applicability in that sector [47] – which again is unfortunate. Also, there are indications that the inclusion of maritime transport entails negative side effects such as carbon leakage [48].

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

Secondly, Directive (EU) 2023/959 [**Error! Bookmark not defined.**] 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) [**Error! Bookmark not defined.**]. This step is based on the fact that these sectors are substantial sources of emissions and pollution. Besides, it is expected that the reform will contribute to innovation and job creating in these sectors [**Error! Bookmark not defined.**, [49]. For instance, in 2017, the transport sector was responsible for 27 % of the total GHG-emissions in the EU [50]. In contrast to ETS 1, ETS 2 is structured as an upstream ETS (Recitals 77 and 89 of Directive (EU) 2023/959) [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. Plants and facilities must acquire allowances and will pass the resulting additional costs on to their customers [**Error! Bookmark not defined.**, [51]. In doing so, ETS 2 will eventually put a financial strain on customers and therefore give them an incentive to reduce emissions [**Error! Bookmark not defined.**]. In line with ETS 1, the underlaying idea of ETS 2 is to reduce the allowances step-by-step and thereby limit the overall emissions of the targeted sectors [**Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**]. As the risk for carbon leakage in the buildings and transport sector is little or non-existent, no allowances will be allocated for free [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. 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 by 5.38 % from 2028. A frontloading mechanism will be used to ensure the functionality of the new system [52,53] (Article 30d para. 2 amended Directive). Even though the newly introduced ETS 2 and the established ETS 1 are adjacent, they operate separately [**Error! Bookmark not defined.**]: 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) [54]. 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 [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. 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 [55]. 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) [**Error! Bookmark not defined.**], which was postponed by a year in the Trilogue Agreement [**Error! Bookmark not defined.**]. Against the backdrop of the very limited remaining GHG emissions budget to stay below 1.5-degree, this delay is critical [56]. In addition, setting a price ceiling of 45 EUR as a trigger for price-dampening measures (Article 30h amended Directive) undermines the target stringency [**Error! Bookmark not defined.**]. 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) [**Error! Bookmark not defined.**]. As much as this measure may be suitable to provide a 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 [**Error! Bookmark not defined.**] (hereafter: SCF Regulation). Its purpose is to contribute to a socially fair transition towards climate neutrality (Article 1) [**Error! Bookmark not defined.**]. 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) [**Error! Bookmark not defined.**]. Precisely, the SCF will provide funds to the Member States to support national policies to address these social impacts (Recital 16 SCF Regulation). Policies will support the vulnerable groups

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by providing a temporary direct income support, and measures and investments intended to increase the energy efficiency of buildings and decarbonise 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) [**Error! Bookmark not defined.**]. To receive funding from the SCF, Member States are obliged to submit Social Climate Plans (hereafter: Plans) to the Commission. These Plans have establish the measures to facilitate a just transition [**Error! Bookmark not defined.**]. 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 [57,58], **Error! Bookmark not defined.** (Ch. 4.7), [59], **Error! Bookmark not defined.**]. In the short term, enhanced climate protection measures tend to raise sustenance costs especially for the most vulnerable in society [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**, [60], **Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**]. Accordingly, it is remarkable that the SCF budget of 72 billion EUR – as envisaged in the Commission's proposal [61] – 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 in 2027 and thus one year 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 [62,63]. 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 [64] (critically on revenue allocation in the SCF [**Error! Bookmark not defined.**, [65]). Lastly, the SCF fails to address the issue that social compensation measures are primarily needed in the global South [**Error! Bookmark not defined.**, [66] (§ 6 E. III.)].

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 [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**] (hereafter: CBAM Regulation). The CBAM aims to mitigate and at best to avoid carbon leakage or shifting effects in the ETS-covered sectors [**Error! Bookmark not defined.**, [67,68]. It also aims to encourage third countries to reduce emissions and create a level playing field for EU producers [**Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**, [69]. 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) [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. In line with that, from an economic perspective, the EU's comparably strict climate protection regulations may cause competitive disadvantages for the local industry [70]. By introducing the CBAM, negative impacts of uneven climate protection efforts between the EU and partners with less strict standards should be compensated [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. Against this background, the CBAM is expected to be an essential element to achieve climate-neutrality in the EU (Recital 10 CBAM Regulation). The targeted sectors will include cement, iron and steel, aluminium, fertilisers and electricity as well as hydrogen (Annex I 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 in parallel to the phasing out of free allowance

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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) [**Error! Bookmark not defined.**].

The introduction of a CBAM is, in principle, a suitable instrument to prevent carbon leakage [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**, **Error! Bookmark not defined.** (§ 6 E.)]. Because the carbon tariff will increase the price of imported goods, foreign producers are given an incentive to reduce emissions [**Error! Bookmark not defined.**]. Furthermore, it is fortunate that some other jurisdictions, such as Canada and Japan, are planning to take similar action [**Error! Bookmark not defined.**]. However, the CBAM enters into force nine months later than originally proposed by the Commission [71], 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 [72] and may cause various effects which could undermine the effectiveness of the CBAM [73]. A clearly 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 [74]. 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 [**Error! Bookmark not defined.**, [75,76,77,78], **Error! Bookmark not defined.**, **Error! Bookmark not defined.**, **Error! Bookmark not defined.**].

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, 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 away from fossil fuels. In that context, using (low-carbon) hydrogen promises to be one suitable approach [79,80,81]. In principle, the ETS is forcing fossil fuels out of the market and thereby making room for new energy sources such as hydrogen. Nevertheless, supplementary regulations and subsidies may be needed [82].

3.2.1. The Ambigous Role of Hydrogen in the Transition towards a Post-Fossil World

Hydrogen is a clean burning molecule [**Error! Bookmark not defined.**], it does not emit CO_2 and causes almost no air pollution when used [**Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**].

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 [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. Since there are many ways to produce hydrogen, the question of whether using hydrogen is beneficial for the energy transition highly depends its production. The hydrogen that is mostly used today (almost 95 %), i.e., "grey hydrogen", is produced by a thermochemical conversion of fossil gas, either Auto-Thermal Reforming (ATR) or Steam Methane Reforming (SMR) [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. Since this production method is

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based on fossil fuels and releases CO_2, its ecological benefits are limited – unless the production, too, becomes fully decarbonised [**Error! Bookmark not defined.**]. In contrast to that, "green hydrogen" [**Error! Bookmark not defined.**] and – serving as a bridging tool – "blue hydrogen" appear to be the most promising materials [**Error! Bookmark not defined.**]. Thus, the following sections discuss these two materials.

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 [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. The products are hydrogen and oxygen [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. Green hydrogen derivatives play a decisive role in transitioning to a post-fossil world [**Error! Bookmark not defined.**, [83,84], **Error! Bookmark not defined.**]. Green hydrogen derivates are discussed as decarbonisation option for sectors in which the direct use of renewable electricity is impossible or difficult [**Error! Bookmark not defined.**]. These sectors include the steel and chemical sector, as well as parts of the transport and heating sector [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. For its ecological benefits, (green) hydrogen has received increasing attention [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. However, the total share of green hydrogen amongst all hydrogen remains minimal [**Error! Bookmark not defined.**].

The small practical significance of green hydrogen is mostly based on: Firstly, the demand for renewable energy in the production process is substantial. The production of various electricity-based energy carriers takes place in complex processes summarised as "Power-to-X" (P2X) [**Error! Bookmark not defined.**]. Due to partially high conversion losses, P2X technologies require much renewable electricity as feedstock for the production of 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 for the production of green hydrogen in the foreseeable future [**Error! Bookmark not defined.**]. According to calculations by the International Energy Agency (IEA), an electrolysis capacity of 3,670 GW is required to achieve climate neutrality by 2050 [85]. This implies an increase of today's capacity by a factor 6,000, and an expansion of renewable energies by a factor ten [86]. Consequently, the demand for renewable energy for the production of green hydrogen within the EU may even surpass the EU's potential [**Error! Bookmark not defined.**]. Secondly, renewable (and low-carbon) hydrogen is not yet cost competitive compared to fossil-based hydrogen [**Error! Bookmark not defined.**].

Green hydrogen is incorporated in several legislative acts:

- On 8th July 2020, the European Commission adopted a "Hydrogen Strategy for a Climate Neutral Europe" [**Error! Bookmark not defined.**] 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) [87], which is one element of "Fit for 55" [88]. In that document, the Commission proposed several incentives for using hydrogen, including binding targets for the industry and transport sector, as well as to raise 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 [89]. REPowerEU was presented by the EU Commission in the wake of the Russian aggression against Ukraine and the resulting efforts to make the EU independent from fossil fuels from Russia [**Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**].

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- Lastly, the Commission supports the hydrogen sector by categorising the sector as "Important Projects of Common European Interest" (IPCEIs) [90] – 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) [**Error! Bookmark not defined.**], defines production criteria for hydrogen based on renewable energies [91]. 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 [92]. The methodology takes into account the GHG-emissions throughout the life cycle of the fuel [93], 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 94g CO_2eq/MJ (Annex A.2.). Taking into account the savings target of at least 70 % results in emissions of max. 28.2g 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 CO2e/MJ (currently only Sweden, although France is close [94]). This favours production in countries with high penetration of nuclear power (as well as RES).

If the above named criteria cannot be fulfilled, the RFNBO producer can enter into a PPA with the RES operator and prove the requirements of additionality, temporal and geographical correlation 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. The intention of this regulation is that mainly additional RES plants are used for hydrogen production. Existing plants, on the other hand, should be used to decarbonise 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 and RES facilities must be located in the same electricity market bidding zone or one that is connected to it.

For climate protection, this regulation appears useful, as the targeted reduction of GHG would be thwarted if the increased demand for electricity is not compensated for 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 regulation, 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" [**Error! Bookmark not defined.**]. Therefore, the temporary use of "blue hydrogen", which is a low carbon solution [**Error! Bookmark not defined.**], has increasingly been discussed. Like grey hydrogen production, the production of blue hydrogen is based on fossil natural gas [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. This makes it an inferior product to green hydrogen [**Error! Bookmark not defined.**]. However, unlike in the grey hydrogen production, CO_2 is not released into the atmosphere but injected into the ground by "carbon capture and storage" technologies (CCS) [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. Therefore, blue hydrogen is ecologically superior to grey hydrogen [**Error! Bookmark not defined.**]. It also offers an advantage by building on existing industrial experience [**Error! Bookmark not defined.**]. Yet, it still is a highly controversial measure for climate protection and is, just as green hydrogen, not cost-competitive against fossil-based hydrogen [**Error! Bookmark not defined.**].

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 [95,96]. In addition, the European Commission established a "European Clean Hydrogen Alliance" in early 2020 [**Error! Bookmark not defined.**]. It aims to create an investment program to support the scaling of the hydrogen value chain across Europe – both for renewable hydrogen and low-carbon hydrogen [**Error! Bookmark not defined.**]. More recently, the European Parliament's Industry and Energy Committee adopted a resolution to support hydrogen produced from "low CO_2" energy sources [97]. 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 [**Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**, **Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**]. 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 the production, storage and transport [**Error! Bookmark not defined.**]. 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 [98].

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 that case, the reduction of upstream emissions until blue hydrogen is produced by reformation leads to a reduction of CO_2 emissions. However, as

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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 [**Error! Bookmark not defined.**].

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.

Only if these requirements are met, should blue hydrogen be considered as a bridging technology towards net-zero economies. To ensure that these requirements are met, a clear regulatory framework, that limits the use of blue hydrogen over time, must be introduced.

4. Discussion and Conclusion: 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 to 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 (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 the human motivations and several governance problems such as shifting effects and lacking target stringency (see above), measured against environmental goals (on the following: [99], **Error! Bookmark not defined.**, **Error! Bookmark not defined.**, **Error! Bookmark not defined.**]). The threat of shifting effects, basic human motives and the transnational character of climate change suggest that purely national approaches to climate change are insufficient, especially since shifting effects can be accompanied by competitive disadvantages and thus declining de facto acceptance for ambitious environmental protection. 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 cleaner environmental media 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 [**Error! Bookmark not defined.**, [100], **Error! Bookmark not defined.**]. While a technology change is underway, a climate law of frugality remains a vision. Overall, the various regulations of energy, agricultural and environmental law are aimed at maintaining lifestyles and economies by technically optimising them, i.e., increasing technical efficiency and consistency.

Above we argued that, measured against the goals of the PA and CBD, past EU climate law 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. The outcome is thus frequently hampered by rebound and 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

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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 [101], **Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**, [102]) 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 take place 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 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 [**Error! Bookmark not defined.**]). This is because the fixed cap prevents redistribution which undermines the ecological effects, as is the case with environmental levies with 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 [**Error! Bookmark not defined.**].

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 that the control variables are easy to enforce and depict – for example, banning peatland drainage [103,104]. 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 address governance and motivational problems in a comparable way (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. Though, the above analysis has also shown, that hydrogen cannot generally be regarded as the "golden solution", as hydrogen can only be viewed as beneficial, when its production is based on sustainable processes. Against this

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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, not only the production of hydrogen, but also the infrastructure for storage and transportation demands a lot of energy [**Error! Bookmark not defined.**]. 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 [**Error! Bookmark not defined.**].

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" as well as the invention of new technologies for production, transport and storage will be necessary. This again will broaden the use cases for "green hydrogen" and "blue hydrogen" and therefore lead industry further away from fossil fuels. The expansion of its use will help mitigating 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 [**Error! Bookmark not defined.**]. To stimulate the crossing over the bridge, one key element will be the reduction of costs of the production of "green hydrogen" and "blue hydrogen". Therefore, one reasonable and effective means will be subsidies because bringing new technologies to the market is the classic use case for subsidies as shown earlier in this chapter [**Error! Bookmark not defined.**, 81].

Secondly, as already mentioned above, the use of 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, environmental impacts that may occur in the production process of hydrogen, always need to be taken into account. Since this article is not intended to focus on an evaluation of the environmental impacts of hydrogen production, it can only be noted that the results of studies focused on the environmental impact show very different results, as illustrated elsewhere [105].

Moreover, the support of the use of hydrogen must be seen in a global perspective, because the production and use of hydrogen is not limited to national scope but enforces an international trade [**Error! Bookmark not defined.**]. 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 [106], blue hydrogen cannot be considered an ecological option in the full sense from the outset). This may not even be due to 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 [**Error! Bookmark not defined.**]. Also in the international perspective, there is a risk, that some countries may produce low carbon hydrogen for export and nationally still rely on fossil fuels. Therefore, there is a need for a clear international legislation that will face such a scenario [**Error! Bookmark not defined.**].

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 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.

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