GO4Industry

Fundamentals – Report G4

Sectoral, legal and transnational interfaces in renewable energy verification systems

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About the project

GO4Industry

Much of industrial production will soon have to be climate-neutral. This requires an immense increase in the use of renewable energy at all stages of the production process. These efforts require proper emissions accounting along the supply chain, which in turn requires a reliable, transnational verification system for renewable energy across all sectors: electricity, gas, heating/cooling. In the Renewable Energy Directive 2018/2001, the EU has instructed the member states to implement this system at the national level. In the "GO4Industry" project, funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the Hamburg Institut and GreenGasAdvisors are developing the basis for a comprehensive national verification concept for renewable energy. This includes an analysis of how guarantees of origin and other verification concepts for renewable energy could interact across all sectors concerned. The project results are available at https://go4industry.com.

Content

List of abbreviations

AIB	Association of Issuing Bodies
BEHG	Fuel Emissions Trading Act (Brennstoffemissionshandelsgesetz)
BImSchG	Federal Immission Control Act (Bundesimmissionsschutzgesetz)
EEG	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
EnWG	Energy Industry Act (Energiewirtschaftsgesetz)
EU	European Union
EU ETS	EU Emissions Trading System
GEG	Building Energy Act (Gebäudeenergiegesetz)
GO(s)	guarantee(s) of origin
MW	Megawatt
PtX	Power-to-X
RED I	Renewable Energy Directive I (2009/28/EC)
RED II	Renewable Energy Directive II (2018/2001/EU)
RE(S)	renewable energy (sources)
REGATRACE	Renewable Gas Trade Centre in Europe
RFNBO	Renewable Fuels of Non-Biological Origin

1. Introduction

The increasing use of renewable energy sources (RES) places high demands on the verification of their "renewable attribute". Especially when energy is converted from one form to another (e.g., for cross-sectoral use), preserving the original renewable energy attribute is a challenge. Accordingly, the comprehensive and transparent verification of RES using different verification systems necessitates dealing with various types of interfaces. These interfaces need to be analysed in more detail in order to avoid any incompatibilities in their regulatory and technical design, to enable efficient processing and to minimise friction and transaction costs. As in any verification system, the most important guiding criteria for interface management are the prevention of double marketing of the renewable energy attribute and the strengthening of credibility vis-à-vis the energy consumers.

The interfaces addressed in this report include both the potential **links between national RE verification systems for a specific energy carrier and those between different energy carriers**. These links are gaining importance, firstly, because the various types of verification (e.g., guarantees of origin (GOs) and mass balancing) have so far been managed largely independently of each other and, secondly, due to the increasing volume and complexity of energy conversion (Sections 2.2and 2.3), particularly in the context of sector coupling applications (especially power-to-X), which aim to make the energy system more flexible and less emission-intensive. In all cases, the reliable and fraud-proof traceability of the RE attribute – potentially across several conversion stages – is indispensable, both for meeting regulatory requirements and building trust with consumers.

Another set of **interfaces exist between verification and regulation**, since verified energy production from RES may count towards various policy measures, both at the EU level and the national level (Section 3). Finally, **interfaces with the verification systems of other European countries** and, in the future, of non-European countries must be taken into account, since the broad recognition of RE requires the standardization and harmonization of thus far disparate systems (Section 4).

This topic is increasingly relevant for **companies** that are obliged to deal with the interfaces between various national and international verification systems, for example when **energy conversion** is an integral part of their business processes and when the renewable attribute must be traced across several forms of energy. Furthermore, when hydrogen is used in industrial processes and imported from non-EU countries, companies increasingly face **cross-EU verification**. Finally, companies, be they generators, processors or consumers of energy, must clearly define the **purpose to be served by RES verification systems** in order to use them appropriately. In the industrial context, verification may be required for example in disclosing the climate protection contribution of a product (e.g., to consumers), in emissions accounting, when applying for subsidies, or to meet regulatory obligations.

The next section takes an in-depth look at such sectoral, legal and cross-country interfaces and highlights particular challenges associated with linking different verification systems within and across countries.

2. Interfaces between national RE verification systems

The growing number of RE verification systems and sector coupling applications, in particular the increasing "non-traditional" use of electricity in the heating and transport sectors, means that the number of interfaces between verification systems of one energy carrier (e.g., gas GOs and gas mass balancing in the future) and between the verification systems of different energy carriers (e.g., mass balancing for gas and GO for electricity, gas and heating/cooling) also grows. This section provides an overview of the existing and – in the light of new regulations and energy conversion technologies – potential future verification pathways for RE and presents the challenges in dealing with the emerging interfaces.

2.1 Overview of current and future RES verification schemes

Figure 1provides a schematic overview of existing and potential future verification paths of renewable energy attributes that may result from new regulations (including Art. Article 19 of the EU's recast Renewable Energy Directive (RED II). In addition to existing mass balancing schemes for biogas, bioliquids and biofuels, and GOs for renewable electricity, pursuant to Art. Art. 19 RED II, GOs will in the future also be issued for renewable gas and heat/cold and transferred to downstream actors where appropriate. The principles of the GO system as already applicable in the electricity sector will be retained for the new GO use cases for heating/cooling and gas (Styles et al. 2021). A RES GO is generally issued when the RE is marketed, [1] i.e., when the energy is fed into a grid or otherwise transmitted (e.g., by road transport in the case of renewable gas) – at which point renewable and non-renewable energy may be mixed. Further requirements for the verification of renewable electricity are currently being prepared (cf. Art. Art. 27(3) RED II).

The possibility of issuing **GOs for self-consumption is** also being discussed. For example, GOs could potentially be issued for self-supply with self-generated energy. Such certificates could be used, for example, as proof in corporate sustainability reporting. However, it would be advisable to stipulate that self-supply GOs cannot be transferred or used in the context of energy labelling vis-à-vis third parties, as the associated energy is not available to the market (cf. Verwimp et al. 2020: 58).

[1] Mass balancing in the sustainability certification of biofuels already begins with the production of the biomass and continues along the entire value chain (see Figure 6in Section 5).

In the field of **biogenic gas and liquid fuels**, sustainability criteria are in place which are monitored by "voluntary systems" such as REDcert or International Sustainability and Carbon Certification "ISCC". The traceability and enforcement of these criteria and the renewable energy attribute of the respective energy carrier is ensured by mass balancing systems (e.g., nabisy, dena Biogasregister, European Renewable Gas Registry "ERGaR"). These systems enable the substances to be counted towards the RES targets of the EU (e.g., in the transport sector in accordance with Art. 25 and Art. 31 RED II), in EU emissions trading (EU ETS) and for national regulation (e.g., remuneration under the German Renewable Energy Sources Act (EEG)). In the area of (power-based) **renewable liquid fuels,** it would be conceivable to issue GOs for the output of power-to-liquid plants; however, GOs for liquid fuels are currently envisaged neither in RED II nor in expert discussions. This is because liquid fuels are transported by tank rather than through grids, which requires more complex tracking (of the material itself, not just of the renewable energy attribute), which cannot currently be achieved by a book & claim system. The situation is different in the case of **renewable gas**. As the RED II extends the scope of GO to renewable gas, this energy carrier too can now be traded separately from the physical energy in a legally secure manner. Efforts are already underway, for example by the EU project REGATRACE (Renewable Gas Trade Centre in Europe)[2] and ERGaR,[3] to create a system that, besides providing for standardised mass balancing across the EU, also enables the standardised issuance and trading of GOs for biomethane/renewable gas.

Art. 19 RED II also provides for the issuance of GOs for **renewable hydrogen**. The CertifHy project has already developed a proposal for an EU-wide hydrogen GO system, including a definition for green and low emissions hydrogen.[4] Yet it is still unclear whether the member states will implement the requirements of Art. 19 RED II using uniform GOs for all renewable gases or with separate GOs for hydrogen. Furthermore, the recognition of renewable hydrogen by EU and national regulation requires a verification system that goes beyond the requirements for GOs in accordance with Art. 19 RED II. This is because RED II already requires mass balancing to document the fulfilment of greenhouse gas (GHG) saving criteria (similar to bioliquids and gas) for non-biogenic gas and liquid fuels (including hydrogen) to be counted towards RES targets. It is conceivable that in the future, sustainability criteria for the water used in electrolysis (e.g., considering potential local scarcity, etc.) may also be introduced.

Due to the upscaling of the production of electricity-based gas and liquid fuels, there will also have to be new or modified procedures for proving the **renewable energy attributes of electricity**, in addition to the GO systems that are already well established in Europe (in

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[2] See www.regatrace.eu.

[3] See press release, 07/15/2021, www.ergar.org/wp-content/uploads/2021/07/210715_press-release-on-ERGaR-CoO-scheme_final.pdf.

[4] See https://www.certifhy.eu.

accordance with Art. 19 RED II). At least without supplementary information or types of verification, these systems are not in a position to meet new regulatory requirements, in particular for the grid purchase of electricity (see also Section 5). At the national level, for example, there is discussion about what should be required of the production of renewable hydrogen for it to be exempt from the EEG surcharge (Art. 69b EEG 2021). The amended Renewable Energy Ordinance (EEV) stipulates that electrolysers must cancel GOs that meet certain criteria (e.g., regarding the price zone in which the plants are located and optional coupling, see Art. 3b EEV) if electricity is purchased from the grid.[5] At the EU level, Recital 90 and Art. 27(3) RED II define certain conditions for the eligibility of electricity-based synthetic gases and liquid fuels for use in the transport sector (so-called Renewable Fuels of Non-Biological Origin "RFNBO") under which electricity from the grid used in fuel production can be considered renewable. Besides a bilateral contract between the power generator and the RFNBO producer, the requirements include a contribution to the security of supply, spatial and temporal correlation between the production of the power and the fuel, and the creation of additional RE generation capacity. The requirements will be specified in more detail in a Delegated Act of the EU Commission, which is to be published by the end of 2021 (see Hoffmann and Antoni 2021 on the current state of the discussion). It is already foreseeable that such requirements will go beyond the verification function of the current GO in accordance with Art. 19 RED II. A new verification scheme or a further development of the existing power GO would therefore have to enable the designation of additional criteria.

In the **heating/cooling sector,** the previous version of the RED II (the RED I) also already provided for issuing GOs for heating/cooling on an optional basis, but this has not yet been implemented in German law. In other European countries, there are so far only isolated examples of heating/cooling GO systems, particularly in the Netherlands and Flanders (Verwimp et al. 2020, p. 15). In Germany, the environmental quality of heating/cooling supplied within an interconnected network has so far been documented by the primary energy factor. The introduction of GOs in this sector would for the first time permit the legally secure tracking and allocation of the renewable attribute of the heat/cold transported via grids to individual consumers. In the future, this could enable the separate marketing of green district or local heating/cooling products, which could generate additional financial contributions for investment in RES plants. Such products are not only interesting for climate-conscious private customers but also for building owners and industrial customers. Whether it will be possible for labelling purposes to use GO that do not originate from the heating/cooling network in which a consumer is located has not yet been conclusively determined.

Figure 1illustrates the multiple verification paths and the resulting multiplicity of verification interfaces, which primarily accrue in two areas: **between the verification systems of one**

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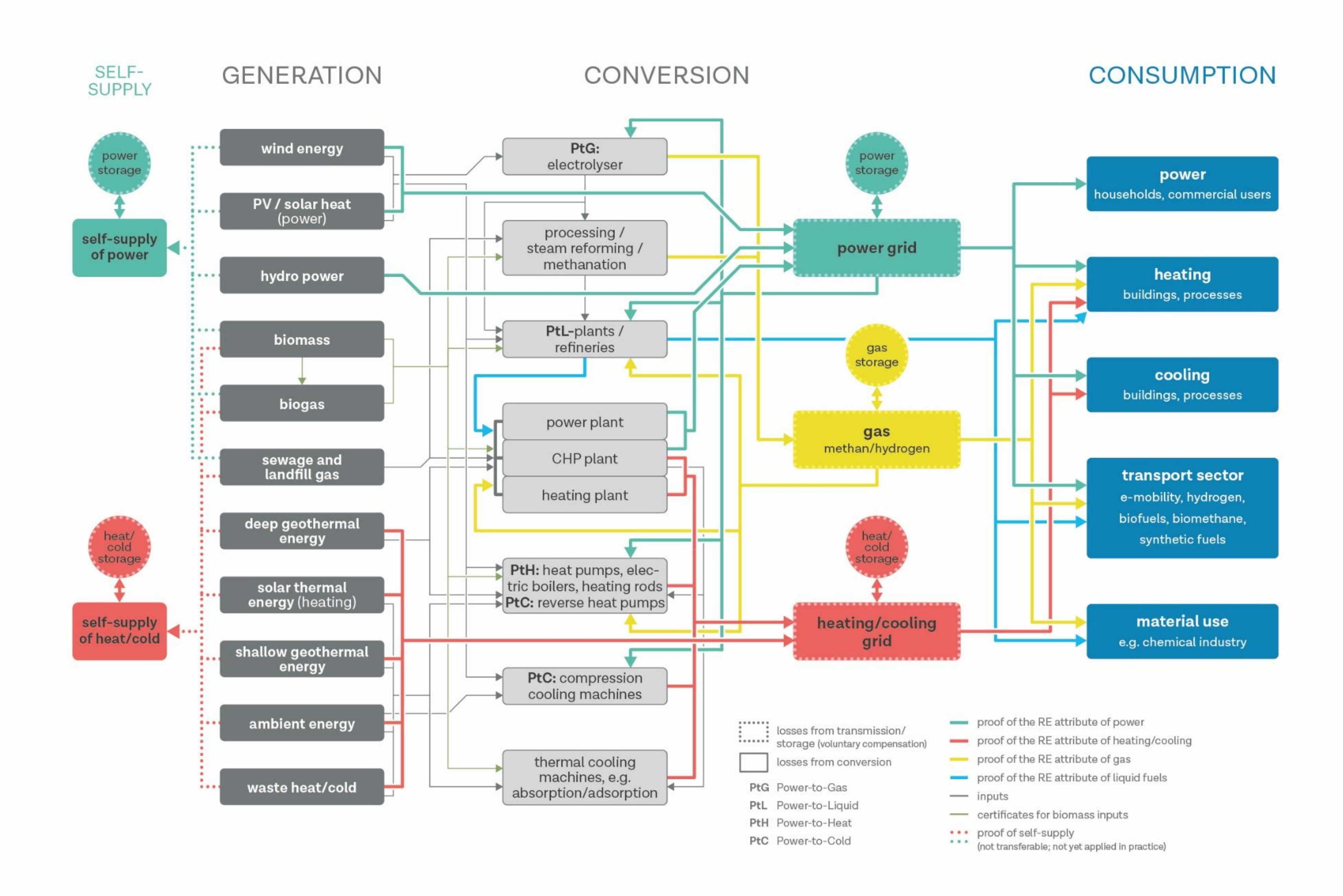
[5] Renewable Energy Ordinance of 17 February 2015 (Federal Law Gazette I p. 146), last amended by Art. 87 of the Act of 10 August 2021 (Federal Law Gazette I p. 3436).

energy carrier and **between the verification systems of several energy carriers**. These interface categories are examined in more detail in the following two sections.

Figure 1: Existing and future RE attribute verification pathways in Germany



Note: The mass balancing of fuels of biogenic origin already begins at the production of the biomass and continues along the entire value chain, while the figure only shows the verification paths of the RE attribute from the conversion of biomass into a usable form of energy, i.e. after conversion into liquid fuels or gas. Generally, the figure only shows realistic paths, rather than all technically feasible paths. © Hamburg Institut Consulting GmbH.

2.2 Interfaces between verification systems for a specific energy carrier

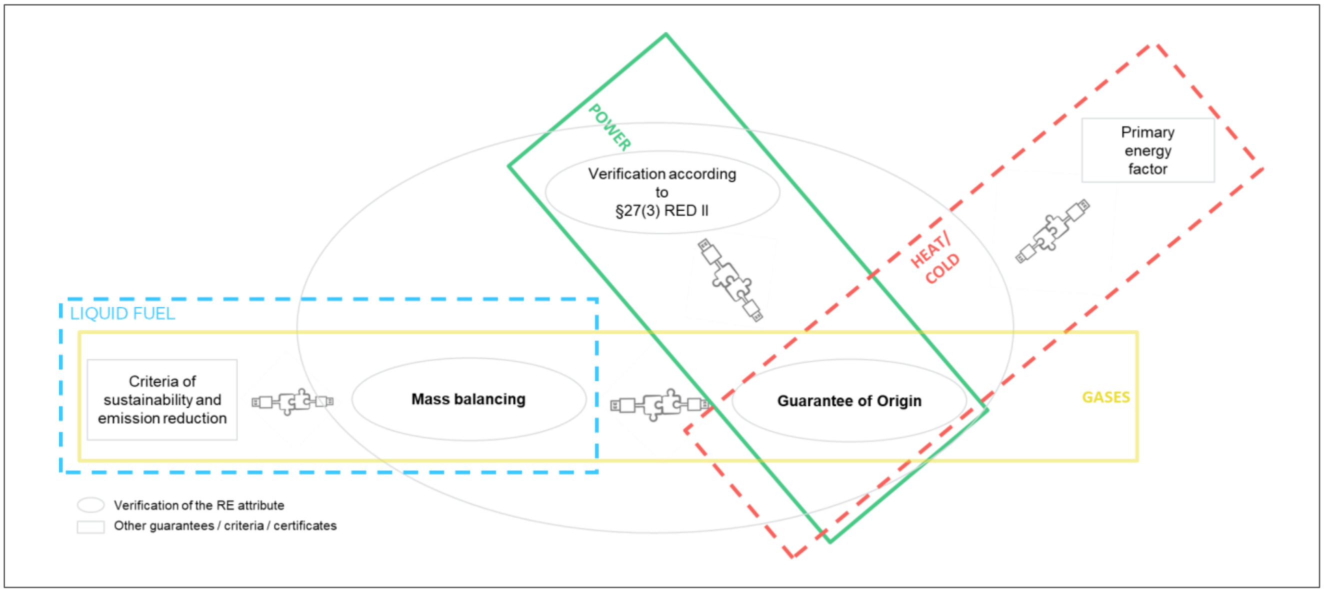
The regulation of RED II regarding the compulsory issuance of GOs for other energy sources besides electricity means that there can now be several types of proof for the legally secure verification of the renewable attributes of an energy source (see Figure 2). In the **biogas and biomethane sector, existing interfaces between the mass balancing and sustainability certification systems may be supplemented by interfaces with the future GO systems for gas**. Such interfaces could contribute to implementing all forms of marketing or eligibility for policy measures at reasonable administrative effort while avoiding double marketing of the RE attribute. Especially in the German context, it is also desirable to reconcile the multiple mass balancing systems that currently exist in parallel to rule out any double marketing of biogas (Bowe and Girbig 2021).

As outlined in the previous section, **multiple verification pathways are also likely to arise in the case of hydrogen**, where concrete discussions are already underway. As already mentioned, similarly to the handling of biogenic gas, mass balancing is likely to be required for the verification of green hydrogen to meet regulatory requirements/RE targets, especially when used as RFNBO in the transport sector. Interfaces between GO and mass balancing systems would thus also play a role for green hydrogen. The extent to which the existing **electricity GO** in accordance with Art. 19 RED II will become part of the verification process to prove the requirements of Art. 27(3) RED II for the power-based production of green hydrogen, or whether a separate, new verification process will be created for this purpose, currently remains open due to the still unclear legal situation. However, some reconciliation between the two makes sense to avoid double marketing.

In the case of **heat/cold and liquid fuels, the introduction of further forms of verification beyond those currently stipulated by law is currently not in sight,** which also means that there will be no interfaces with other types of verification of the RE attributes of the same energy carrier. In the case of liquid fuels, mass balancing will initially remain the only dominant form of verification. Here, the interfaces with the (mass balancing) systems of other countries within and outside of the EU are crucial. For the time being, the heating/cooling GOs to be established in the member states are also the only forms of verification of the RE attribute for this energy source. Interfaces across regions or countries will only become relevant if the GOs can also be cancelled for labelling purposes outside of a coherent heating/cooling network. In addition, it may become possible in the future to use heat/cold GOs to determine primary energy factors that are specific to an individual heat product or building. The design of this would depend on the general handling of GOs (e.g., cancellation and labelling rules) and the calculation rules of the primary energy factor (e.g., whether the established “one network, one factor” principle will continue to apply).[6]

[6] This topic is elaborated in more detail in a dedicated report on "Heating/Cooling".

Figure 2: Potential interfaces between verification systems for an energy carrier



Note: It is not yet clear whether power GOs and verification pursuant to Art. 27(3) RED II constitute two completely independent systems. For liquid fuels and heat/cold, there is only one system of verifying the renewable energy attribute.

2.3 Interfaces between verification systems for different energy sources

In addition to the interfaces mentioned in the previous section, **energy conversions in which the input energy carriers have already been transported through a grid or by some other infrastructure (e.g., by tanker) in which fossil and renewable energy are mixed** (referred to hereafter as "transported energy") require the verification of the RE attribute at interfaces between verification systems of different energy carriers.[7] This section focuses on such energy conversions.

[7] This excludes, for example, the direct use of power in electromobility. Power that is used to generate kinetic energy is also converted and must be verified if it is to count towards the RE transport sector target of the RED II. However, this use case entails no interface between different verification systems, as the verification ends when the electricity is fed into the car battery.

Table 1presents the details.

Renewable Energy source		Output			
		Power	Gas	Heat/Cold	Liquid Fuels
Input	Power		**Power-to-Gas** production of hydrogen (methane) by electrolysis (+methanation)	**Power-to-Heat/Cold** heat generation by heat pump, electric boiler or heating rod; cold recovery by reverse heat pump or compression cooling machine	**Power-to-Liquid** production of synthetic liquid fuels (e.g., methanol) by electrolysis/synthetic gas production and liquefaction (e.g., Fischer-Tropsch/ alcohol/methanol synthesis)
	Gas	**Power generation** e.g., in gas CHP plants; possibly reconversion of electricity-based gas into electricity	**Processing or conversion of gas** hydrogen ⇔ methane by various processes (e.g., methanation, steam reforming)	**Heat/cold generation** e.g., in gas CHP plants, heat pumps, thermal cooling machines; possibly using electricity-based gas	**Gas liquefaction** of synthetic or biogas by various processes (e.g., Fischer-Tropsch/ alcohol/methanol synthesis, etc.)
	Heat/ Cold	*		**Temperature increase,** e.g., by heat pump, solar heat **Temperature reduction,** e.g., by reverse heat pump	
	Liquid Fuels	**Power generation** e.g., in an oil CHP plant; possibly reconversion of electricity-based liquid fuels into electricity		**Heat/cold generation** e.g., in an oil CHP plant or boiler; possibly using power-based liquid fuels	

2.3.1 Conversions of transported energy where RE verification matters

For our purposes, energy conversion refers to the **use of a transported form or carrier of energy (input energy) to generate another form or carrier of energy (output energy).** Such conversions and the associated verification paths occur particularly in the context of sector coupling applications. In broad terms, **sector coupling applications** refer to the steadily increasing substitution of fossil energy sources with renewable electricity, other RES (e.g., biomass) and sustainable forms of energy use (e.g., waste heat) in new and existing cross-sector applications with the primary goal of decarbonisation (Wietschel et al. 2018). The innovative linking of established consumption sectors (households, industry, transport, etc.) using grid infrastructure can also be subsumed sector coupling (Wietschel et al. 2018). In sum, sector coupling is also referred to as the "linking of electricity, heat, transport and industrial sectors in terms of energy technology and energy economics" (BDEW 2017).

More specifically, the term "sector coupling" often refers to power-to-X (PtX) applications, where power is converted into other forms of energy in various sectors. Besides the direct use of electricity for e-mobility and heating/cooling (power-to-heat; power-to-cold), PtX also means the use of electricity to generate electricity-based gas and liquid fuels (power-to-gas; power-to-liquid; hereafter: PtX fuels), as well as their conversion back into electricity.

While the direct use of electricity in transport, heat and industry, without any prior conversion steps, is considered to have a large technical and economic potential, estimates of the potential of **PtX fuels** (electricity-based gas and liquid fuels) vary widely (cf. e.g., Pfluger et al. 2017, Henning and Palzer 2015, Hydrogen Council 2017, Acatech/Leopoldina/ Akademienunion 2017). PtX fuels are an option to achieve the long-term storage and thus flexibility necessitated by the expansion of fluctuating RES. They also enable the large-scale use of RE in freight transport, aviation, shipping, and industry. At the same time, however, such conversions may entail large energy losses, making PtX fuels significantly less efficient than the direct use of electricity and thus greatly increasing the demand for electricity, which is already rising due to the electrification of the heat/cold and transport secors. Since the production of PtX fuels involves various steps and requires considerably more inputs than the mere generation of electricity, compliance with clearly defined sustainability and climate protection criteria is even more important here (cf. dena 2017, ESYS 2017, Gerhardt et al. 2015, Öko-Institut/Fraunhofer ISI 2015). The losses associated with the various conversion steps also require greater effort in proving the RE attribute, which is less of an issue when the transported energy is used directly.

Table 1: Conversions of transported RE carriers where verification matters

Renewable Energy source		Output			
		Power	*Gas*	*Heat/Cold*	*Liquid Fuels*
Input	*Power*		**Power-to-Gas** production of hydrogen (methane) by electrolysis (+methanation)	**Power-to-Heat/Cold** heat generation by heat pump, electric boiler or heating rod; cold recovery by reverse heat pump or compression cooling machine	**Power-to-Liquid** production of synthetic liquid fuels (e.g., methanol) by electrolysis/synthetic gas production and liquefaction (e.g., Fischer-Tropsch/ alcohol/methanol synthesis)
	Gas	**Power generation** e.g., in gas CHP plants; possibly reconversion of electricity-based gas into electricity	**Processing or conversion of gas** hydrogen ⇔ methane by various processes (e.g., methanation, steam reforming)	**Heat/cold generation** e.g., in gas CHP plants, heat pumps, thermal cooling machines; possibly using electricity-based gas	**Gas liquefaction** of synthetic or biogas by various processes (e.g., Fischer-Tropsch/ alcohol/methanol synthesis, etc.)
	Heat/ Cold	*		**Temperature increase,** e.g., by heat pump, solar heat **Temperature reduction,** e.g., by reverse heat pump	
	Liquid Fuels	**Power generation** e.g., in an oil CHP plant; possibly reconversion of electricity-based liquid fuels into electricity		**Heat/cold generation** e.g., in an oil CHP plant or boiler; possibly using power-based liquid fuels	

Source: Hamburg Institut and GreenGasAdvisors.
The table only includes fully renewable energy sources and widely applied processes.
*** Power generation from heat is not listed as it does not usually involve a transport of energy through a grid, i.e., no mixing of attributes, and verification would only be necessary for the output electricity. Feasible conversions that are not widely applied include geothermal/solar thermal with heat recovery (e.g., by a turbine/generator) and waste heat with ORC plants/thermoelectric generators (Hoffmann et al. 2017).**

2.3.2 Challenges of verification in the conversion of transported energy

Conversion processes may pose special challenges for the verification of the RE attribute. These challenges arise when using transported RE inputs (e.g., grid sourcing, transportation in a tank, etc.) to produce a green energy output. Since energy inputs with different attributes (fossil and renewable) are mixed during transport, these transported inputs can no longer be assigned to one energy source, so they can only be called renewable on a balance-sheet basis using verification. This also applies to potential downstream products, which particularly complicates the regulatory eligibility of that output.

Table 2: Demonstrating the RE attribute in on-site vs. off-site production

	On site	***Off site***
PRODUCTION PROCESS	In the production of a green energy output, all production units are connected to each other via a direct line (e.g., the electrolyser is directly connected to the power plant).	To produce a green energy output, input energy that is green on a balance-sheet basis is obtained from a transport infrastructure that absorbs (also fossil) energy from multiple production units (e.g., the electrolyser draws power from the grid).
VERIFICATION	Simple: - The certificates are issued just before the product is made available for “final usage”. - The RE attribute needs not to be passed on across several verification systems.	Complicated: - There can be multiple interfaces between the verification systems of different energy carriers. - The RE attribute must be passed on across several verification systems.

Source: Hamburg Institut.

Difficulties of verification and thus also of regulatory creditability are reduced if the renewable input energy for the generation of the renewable output energy that is to be certified is procured via a direct line ("on site") from a homogeneous energy generation plant at the same location or in the vicinity, **rather than via a heterogeneous transport system**. If the RE certificates are then issued just before the "final use"[8] of the output product, they need not be passed on across multiple certificate systems, which greatly simplifies the verification process.[9] This applies, for example, to solar electricity that is transported by a direct line to an electrolyser that produces hydrogen from it. In this case, only one form of verification is required for the renewable hydrogen (GO or mass balancing, depending on the purpose) – to verify the RE attribute of the electricity obtained via direct line, a plant audit would suffice, for example.[10]

By contrast, e.g., for the production of hydrogen and other electricity-based fuels, in addition to on-site production, the regulatory efforts at the EU level (e.g., Art. 27(3)

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[8] "Final use" means the production of useful energy (such as the conversion of electricity into kinetic energy) and includes the final energy use on site (e.g., private consumption) as well as the final energy use, which directly takes place after transportation (e.g., through a grid) without intermediary conversions.

[9] On-site power generation from biogas constitutes a special case because mass balancing must be maintained all the way from the use of the biomass to power generation in order to meet the sustainability and GHG reduction criteria. By contrast, the RE property of the end product (in this case electricity) only requires a certificate (e.g., a GO) if it is consumed without further conversion.

[10] However, if electricity GOs were issued for the corresponding electricity production, these would have to be cancelled to prevent double marketing of the renewable attribute.

RED II) are intended to also enable off-site production to count towards RE targets. In other words, it shall be possible to use transported (heterogeneous) renewable input energy (in this case electricity from the public grid) to produce "green" energy outputs such as hydrogen that are eligible in terms of regulation (see Table 2). Similarly, Art. 3b EEV formulates requirements at the German national level for hydrogen produced from electricity drawn from the grid to qualify as "green" and claim an EEG levy exemption. The background to these efforts is that although the power generation unit and the processing unit often cannot be connected by a direct line in practice, emerging technologies such as hydrogen electrolysis shall be promoted. Also, the flexibility of the energy system is to be increased for it to better handle fluctuating RES. For example, buying power from the grid allows decisions on the location of renewable power plants and electrolysers to be optimised independently of each other. Nevertheless, to integrate fluctuating RE generation into the system, sufficient grid capacity (i.e., absence of grid bottlenecks) and the system-serving operation of electrolysers must be ensured.

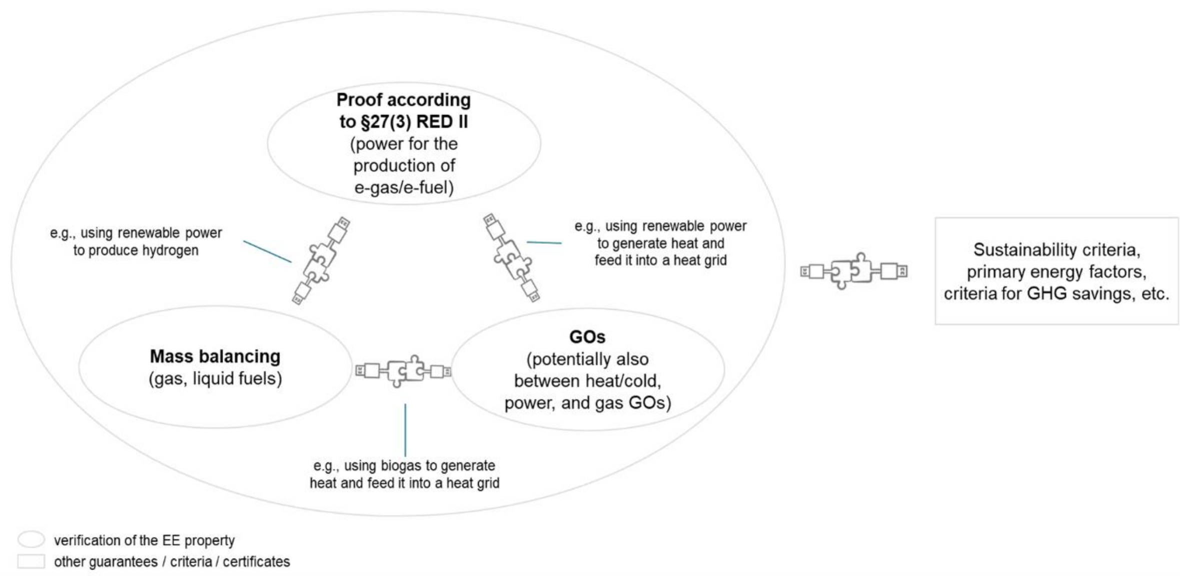
Energy conversions based on transported input energy take place in particular in PtX applications, such as the conversion of power from the grid into hydrogen, liquid fuels and heat or cold, the combustion of gas for heat and cold generation, and the (re)conversion of gas into electricity (see Figure 1and

Table 1).[11]

Renewable Energy source		Output			
		Power	*Gas*	*Heat/Cold*	*Liquid Fuels*
Input	*Power*		**Power-to-Gas** production of hydrogen (methane) by electrolysis (+methanation)	**Power-to-Heat/Cold** heat generation by heat pump, electric boiler or heating rod; cold recovery by reverse heat pump or compression cooling machine	**Power-to-Liquid** production of synthetic liquid fuels (e.g., methanol) by electrolysis/synthetic gas production and liquefaction (e.g., Fischer-Tropsch/ alcohol/methanol synthesis)
	Gas	**Power generation** e.g., in gas CHP plants; possibly reconversion of electricity-based gas into electricity	**Processing or conversion of gas** hydrogen ⇔ methane by various processes (e.g., methanation, steam reforming)	**Heat/cold generation** e.g., in gas CHP plants, heat pumps, thermal cooling machines; possibly using electricity-based gas	**Gas liquefaction** of synthetic or biogas by various processes (e.g., Fischer-Tropsch/ alcohol/methanol synthesis, etc.)
	Heat/ Cold	*		**Temperature increase,** e.g., by heat pump, solar heat **Temperature reduction,** e.g., by reverse heat pump	
	Liquid Fuels	**Power generation** e.g., in an oil CHP plant; possibly reconversion of electricity-based liquid fuels into electricity		**Heat/cold generation** e.g., in an oil CHP plant or boiler; possibly using power-based liquid fuels	

[11] A detailed analysis of the individual energy sources is provided in further project reports.

Figure 3: Potential interfaces between verification systems for different energy carriers



Source: Hamburg Institut.
Note that it is not yet clear whether electricity GO and verification acc. to Art. 27(3) RED II constitute independent systems.

Regarding the procurement of transported input energy for the generation of renewable outputs, the **question** arises in particular as **to what extent different types of verification for RE** – mass balancing, GO, and possibly other systems to be established in the future – **can be meaningfully linked with each other so as to securely pass on the RE attribute** (see Figure 3). This requires proper interface management, both between the different types of verification systems (e.g., between GO systems and mass balancing systems including sustainability certifications)[12] and between the GO systems of different energy carriers (GO systems for electricity, gas, and heat/cold) (see Table 3).

[12] Such an interface or reconciliation already exists to a certain extent between the mass balancing system for biomethane and the GO system for power if biomethane is used to generate renewable electricity for which GO are to be issued (verification of feedstock logs by environmental auditors, etc., cf. Art. 42 HkRNDV on assessment obligations for biomass plants listed in the GO register or Art. 4b(5) EEG 2021 on the conditions under which gas taken from the gas grid can be regarded as biomethane).

Table 3: Possible interfaces between RE verification systems in using transported input energy to generate output energy

Renewable Energy source		*Output*			
		Power	*Gas*	*Heat/Cold*	*Liquid Fuels*
Input	*Power*		GOs for power and/or verification acc. to Art. 27(3) RED II → *GOs for gas/hydrogen and/or mass balancing*	GOs for power and/or verification acc. to Art. 27(3) RED II → *GOs for heat/cold*	GOs for power and/or verification acc. to Art. 27(3) RED II → *Mass balancing*
	Gas	GOs for gas or hydrogen and/or mass balancing → *GOs for power*	Hydrogen GO and/or mass balancing, if applicable → *GOs for gas and/or mass balancing**	Gas or hydrogen GOs and/or mass balancing → *GOs for heat/cold*	Gas GO and/or mass balancing → *Mass balancing*
	Heat/Cold			GO for heating → *GO for cold** GO for cooling → *GO for heat**	
	Liquid Fuels	Mass balancing → *GO for power*		Mass balancing → *GO for heat/cold*	

The verification system above / below each arrow applies prior to / after the energy conversion, respectively. The table includes only fully renewable energy sources and widely applied processes. Sustainability certification is required in accordance with Art. 29(1) RED II in the case of solid biofuel plants with a rated thermal capacity ≥ 20 MW and gaseous biofuel plants with a rated thermal capacity ≥ 2 MW. Art. 27(3) RED II initially only formulates requirements for the grid procurement of power used for the production of electricity-based fuels. However, the announced methodology may be extended to other PtX applications.
*** To the extent that labelling rules distinguish between heat and cold or hydrogen and other gases, respectively.**

In RED II, such interfaces or the linking of different verification systems in conversion processes are neither explicitly defined nor prohibited. As a result, **experts are currently discussing whether, how, and under what conditions a transfer of the green attribute can take place during the conversion of transported energy inputs into corresponding outputs** (e.g., Verwimp et al. 2020: 35 ff.). Besides the options of linking different verification systems (e.g., mass balancing and GOs), the discussions also focus on the **passing on of attributes between GOs for the input energy carrier and the output energy carrier**. Verwimp et al. 2020 propose to develop a "**GO cancellation methodology**", which they call "conversion issuance". For example, they suggest cancelling GOs for energy inputs used in conversion processes (e.g., electricity GOs for electricity inputs) and issuing GOs for outputs (e.g., GOs for heat from power-to-heat plants), with the latter "inheriting" the energy source attribute of the cancelled GOs (e.g., wind). No direct conversion of GOs takes place in this process. This "cancellation methodology" takes account of conversion losses since GOs are not issued on a one-for-one basis but only for the measured amount of output energy.

There would be several options for **passing on RE attributes in the issuance of GOs for conversion plants** that obtain their input from a heterogeneous transport system. Firstly, the attribute could be transferred to the output energy without any requirements regarding the cancelled input GOs. Alternatively, depending on the purpose of the new verification, additional requirements could be imposed. For example, if power was procured from the grid, requirements could be placed on the location or support status of the renewable power plants, or a coupling of power and GO supply could be required (Werner 2021). Then conversion plants that use externally sourced input energy could only receive output GOs if GOs with corresponding attributes are cancelled for the input energy. In addition, GOs for energy used in conversion could be required to contain further information that makes certain attributes of the energy traceable. For example, hourly or quarter-hourly time stamps on GOs could be used to prove a temporal correlation between the generation of input and output energy (EnergyTag 2021).[13] Alternatively, conversion plants could be issued GOs if their purchase of RE is verified by other systems (e.g., mass balancing for gas inputs).

Ultimately, the **EU legislator or, given sufficient flexibility by the member states, national or regional verification system operators would have to clearly specify the requirements for issuing renewable certificates for conversion plants.** Yet other requirements may be imposed for energy output from conversion plants to be deemed to be produced entirely from RE for the purpose of support programmes or regulatory instruments. As outlined above, this applies for example to the transport sector, where additional conditions are set for electricity drawn from the grid and electricity-based fuels to count towards RED II targets. This necessitates new modes of verification in the electricity sector or at least some further development of power GOs (Bowe and Girbig 2021, Styles et al. 2021), including greater granularity with respect to volume and time, e.g., hourly GOs per kilowatt-hour. Another challenge is to define requirements and ways to prove that plants producing electricity-based fuels are located and operated in a manner that promotes the overall efficiency of the energy system (BT-Drucksache 19/29793, p. 19).

In sum, buying transported input energy for conversion into renewable output energy involves more numerous verification interfaces and thus more complexity than obtaining the input energy from a direct line. This requires **meaningful interconnection options between the different verification systems** that facilitate the implementation of all possible applications (e.g., regulatory purposes and consumer information purposes).

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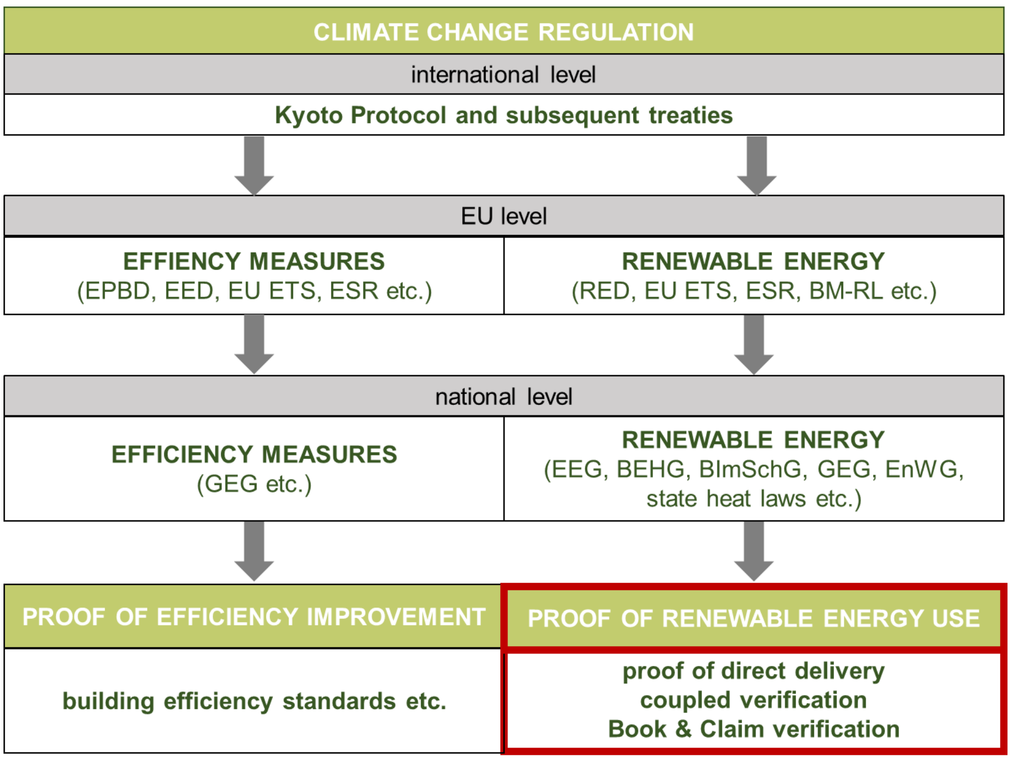
[13] The EnergyTag initiative (www.energytag.org) is developing a control system for hourly power certificates.

3. Proof of the RE attribute as a regulatory compliance option

Besides the interfaces between different verification systems for a given energy carrier and across several energy carriers, we also need to consider interfaces between the above-mentioned RE verification systems and various political and legal frameworks. Figure 4provides an overview of central climate protection regulations at the EU level and the national level. In the following, we focus on the question of which verification systems can be used to prove the fulfilment of which regulatory requirements (RE shares, etc.).

Figure 4: European and national regulation and proof of the RE attribute



BEHG = Fuel Emissions Trading Act, BImSchG = Federal Immission Control Act, BM-RL = Internal Market Directive, EED = Energy Efficiency Directive, EEG = Renewable Energy Sources Act, EnWG = Energy Industry Act, EPBD = Energy Performance of Buildings Directive, ESR = Effort Sharing Regulation, EU ETS = European Emissions Trading Scheme, GEG = Building Energy Act, RED = Renewable Energy Directive.

3.1 EU regulations

At the EU level, the **targets set by RED II (regarding overall RE use and the transport sector), emissions trading (EU ETS), and the Effort Sharing Regulation (ESR), which are implemented by national regulation at the member state level, are particularly relevant for the use of RE**.

Art. 3 RED II states that the **share of energy from RES in the EU's gross final energy consumption** should be at least 32% in 2030.[14] This target is monitored by national statistics on RES shares, which do not rely on any of the discussed means of proving the RE attribute.

The **transport sector target** specified in Art. 25 RED II obliges the member states to ensure a RE share in final energy consumption in the transport sector of at least 14% by 2030. This target is independent of the overall Art. 3 target and subject to a different calculation method (Hoffmann 2020). To calculate the power sector's contributions to the Art. 3 target, all renewable power production is attributed to the electricity sector. At the same time, renewable power used in transport, power-based fuels, biofuels and upstream emission reductions can count towards the Art. 25 target. The transport sector target is implemented in German law by the Federal Immission Control Act (BImSchG), which has required fuel providers to meet a GHG reduction quota since 2015. From 2020, the GHG emissions that result from using the fuel must be reduced by 6 percent (Art. 37a (4) BImSchG).[15] While, to count towards the target, the measurement of renewable power used in transport currently relies on e-vehicle registration statistics and the national electricity mix. For liquid and gaseous biofuels (with an emission factor of zero), the RE attribute must be proven by mass balancing. In addition, most biomass inputs used for fuel production must meet certain sustainability and GHG savings criteria (Art. 29 RED II). For electricity-based fuels, proof is required that only electricity from renewable and non-biogenic sources was used for production. Furthermore, for electricity drawn from the grid, an ordinance is to define more precisely how proof of the RE status is to be provided as soon as the relevant delegated act of the EU Commission on the basis of Art. 27(3) RED II has been published (BT-Drucksache 19/27435; see Table 5below).

The **EU ETS,** on the other hand, which regulates emissions of carbon dioxide and other GHG, concerns the energy industry and other emission-intensive industries (chemicals, steel, etc.). Here RE certificates are required to confirm the renewable nature of biofuels. Any power generated from it can then be assigned an emission factor of zero, so that no emission certificates have to be bought. According to Art. 39 of the Implementing Regulation (EU) 2018/2066 on the monitoring and reporting of GHG emissions (in short: Monitoring Regulation), analytical or estimation methods (e.g., based on mass balancing) must be used for this purpose. An exception is biogas taken from the gas grid. According to the amendment to the Monitoring Regulation published in late 2020 (Implementing Regulation (EU) 2020/ 2085), the biomass share can be determined on the basis of invoice documents for the purchase of biogas with the same energy content, provided that double counting of the biogas is credibly prevented, e.g., by submitting GOs. In addition, a network connection

[14] Changes result from the EU Commission's proposal to adapt RED II to the stricter GHG reduction target of 2030 (EU Commission 2021). Among other things, the use of RE in industry is to be strengthened. Proposals on this will be examined in more detail in subsequent reports, while this section focuses on the status quo.

[15] The Act on the Further Development of the Greenhouse Gas Reduction Quota passed in May 2021 lays down further steps: from 7% from 2022 to 25% in 2030.

between feed-in and exit must be demonstrated, e.g., by mass balancing. Again, most biomass inputs must meet certain sustainability GHG savings criteria. In the previous version of the Monitoring Regulation (Art. 39(3) Implementing Regulation (EU) 2018/2066), only the submission of GOs was required for the balancing of biogas from the gas grid. However, the German implementation always contained additional requirements, such as proof of a supply contract between the operator of the plant that is subject to emissions trading and the biogas supplier or intermediary, as well as the use of a mass balancing system (DEHSt 2018: 37 f.).

The counterpart to the EU ETS (in sectors where it does not apply) is the **Effort Sharing Regulation (ESR) of 2018** (formerly the Effort Sharing Decision of 2009). It covers emissions from the transport, buildings, agriculture, waste, and some energy and industrial sectors – which together account for approximately half of total emissions in Germany. The common goal of the member states is to reduce GHG emissions in these sectors by ten percent by 2020 compared to 2005. The Regulation is implemented in Germany (in addition to building efficiency standards, renovation rates, etc.) partly by the **Fuel Emissions Trading Act (BEHG)**, which came into force on 20 December 2019 and whose first trading period runs from 1 January 2021 to 31 December 2030. The BEHG induces a carbon price, which is paid by suppliers, wholesalers and refineries (if they market their fuels) of natural gas, heating oils and fuels, who pass it on to their customers. Here, too, biofuels, liquid fuels and biomass fuels (biogas), and in the future also synthetic (PtX) fuels, can be assigned an emission factor of zero and are therefore exempt from the price. However, the conditions for this “zero-rating” have not yet been conclusively clarified as an ordinance is currently still pending, but they will likely be based on those of the EU, comprising for example mass balancing and sustainability and GHG reduction criteria for biomass inputs. Additional cancellation of GOs to exclude double marketing would be conceivable in the gas sector (but not for fuels such as biodiesel and alcohols, where no introduction of book & claim GOs is planned).

Finally, the **Electricity Directive (EU) 2019/944** (as the successor to Directive 2009/72/EC) requires the national implementation of an **electricity labelling obligation**. Consumers must be provided with information on the composition of an energy supplier’s electricity mix and any product mixes. The declaration of RE shares or volumes must be substantiated by cancelling GOs.[16] Exceptions apply according to Art. 19 RED II if member states do not issue GOs to financially supported RE producers, and in the case of untraced commercial offers for which the residual energy mix can be used. At the national level, the electricity labelling obligation is implemented by Art. 42 of the Energy Industry Act (EnWG) (Styles et al. 2021).

3.2 National regulation

Apart from the EU regulation and its implementation at the national level, several other national laws require proof of renewable attributes. For example, **EEG-subsidised plants**

[16] For more detail on current and proposed electricity labelling rules, see Maaß 2021.

that generate power from biomass must document in feedstock diaries the type, quantity, unit and origin of the substances they use. If converted biomethane or landfill, sewage, mine or storage gas is withdrawn from the gas grid, the transport and distribution of the gas from production to withdrawal must be traced by mass balancing (Art. 44b(4) EEG 2021). In addition, compliance with the requirements of the **Biomass Sustainability Ordinance** regarding liquid biomass must be demonstrated by mass balancing (Art. Art. 15-17 BioSt-NachV). A new version of the ordinance to implement RED II is currently being prepared (BMU 2021).

The **Building Energy Act** also requires verification by mass balancing if biomethane from the gas grid is to be counted towards the RE requirements (Art. 40(3) GEG). Given suitable verification, a primary energy factor below that of natural gas may be used (Art. 22(1) no. 2 GEG). Analogous provisions apply to biogenic liquefied petroleum gas (Art. 22(1) no. 3 and Art. 40(4) GEG). Balance-sheet procurement of green electricity from the grid, on the other hand, is not a compliance option. Regarding annual primary energy consumption and eligibility for RE usage requirements, renewable power can only be deducted if it is generated in the immediate vicinity of the building and is primarily used in the building itself (Art. 23(1) and Art. 36 GEG). For liquid biomass used in heat generation, the GEG also refers to the requirements of the Biomass Electricity Sustainability Ordinance (Art. 39 GEG).[17]

Requirements for balance-sheet energy purchase can also be found in the **renewable heat laws of the German federal states**, which in some cases even require a certain share of RE in existing buildings when heating systems are replaced or retrofitted. For example, the Renewable Heat Act (EWärmeG) of Baden-Württemberg or the Hamburg Climate Protection Implementation Ordinance (HmbKliSchUmsVO) require mass balancing as proof in the case of a balance-sheet purchase of biomethane via the gas grid or reference is made to corresponding provisions of the GEG (Art. 5(3) EWärmeG; Art. 6(6) HmbKliSchUmsVO).

Finally, for green hydrogen production, the amended **Renewable Energy Ordinance (EEV)** defines when electricity inputs can be considered completely renewable – initially, however, only for the comparatively narrowly defined application case of the EEG surcharge exemption of Art. 69b EEG 2021. Table 5summarises the corresponding requirements for green hydrogen production (see Section 5).

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[17] Furthermore, the GEG provides for the possibility to buy district heating/cooling as a substitute measure for the proportional coverage of the heating/cooling energy demand in buildings. Art. 44 GEG establishes conditions for the heat or cold distributed in the network as a whole.

Table 4: Regulatory eligibility of RE and required verification

Renewable Energy Source	*Regulation (required proof)*	
	EU level	*German federal level*
Power	**EU ETS, Implementing Regulation (EU) 2020/2085** *(plant audits; for biogas inputs: GOs + grid connection between feed-in and consumer, e.g., via mass balancing)* *** **RED II, transport sector target, Art. Art. 25-31** *(RE share of transport, registration data of battery electric vehicles + national electricity mix)* **RED II, overall RE target, Art. 3** *(national RE shares in electricity)* **Electricity Internal Market Directive (EU) 2019/944, electricity labelling** *(usually GOs)*	**EEG subsidies** *(plant audits; for biogas input from the gas grid: mass balancing)* **BImSchG, Art. 37a(4),** implementation of the transport sector target of RED II in German law *(see EU legal requirements for transport sector target, Art. Art. 25-31 RED II)* **Energy sector target,** part of the implementation of the overall RE target of Art. 3 RED II **Art. 42 EnWG**, national implementation of the electricity labelling obligation *(usually GOs)*
Biogas Hydrogen	**RED II, transport sector objective, Art. Art. 25-31** (*mass balancing; proof according to Art. 27(3) RED II for (grid-bound) electricity for the production of hydrogen)* *** **RED II, overall RE target, Art. 3** *(national RE shares, renewable gas statistics)* **EU ETS, Implementing Regulation (EU) 2020/2085** *(GOs + grid connection between biogas feed-in and consumers for power generated from biogas, e.g., via mass balancing)* *** **ESR** *(see BEHG)*	**EEG subsidies** *(plant audits or mass balancing for electricity generated from biogas)* **BEHG,** part of the implementation of the ESR in German law *(mass balancing)* *** **BImSchG, Art. 37a(4),** implementation of the transport sector target of RED II in German law *(see EU legal requirements for transport sector target, Art. Art. 25-31 RED II)* **Sectoral targets for buildings/industry/transport,** part of the implementation of the overall RE target of Art. 3 RED II **Art. 3b EEV**, requirements for green hydrogen for the purpose of EEG levy exemption
Heat Cold	**ESR** *(see BEHG)* **RED II, overall RES target, Art. 3** *(national RES shares heat/cold, statistics)*	**GEG, support and proof of RE used** *(mass balancing for renewable gas)* **Sectoral target for buildings,** part of the implementation of the overall RE target of Art. 3 RED II
Liquid fuels	**ESR** *(see BEHG)* **RED II, transport sector target, Art. Art. 25-31** *(mass balancing)*** **RED II, overall RES target, Art. 3** *(national RE shares of liquid fuels, statistics)* **EU ETS, Implementing Regulation (EU) 2020/2085** *(GOs + grid connection between feed-in and consumers for power generated from biomass)* ***	**BEHG,** part of the implementation of the ESR in German law *(mass balancing)* *** **BImSchG**, implementation of the transport sector target according to RED II in German law *(see EU legal requirements for transport sector target, Art. Art. 25-31 RED II)* **Sectoral target for transport/industry,** part of the implementation of the overall RE target of Art. 3 RED II

Source: Hamburg Institut and GreenGasAdvisors.
BImSchG = Federal Immission Control Act, BEHG = Fuel Emissions Trading Act, EEG = Renewable Energy Sources Act, EEV = Renewable Energy Ordinance, EnWG = Energy Industry Act, ESR = Effort Sharing Regulation, EU ETS = European Emissions Trading Scheme, GEG = Building Energy Act, RED II = European Renewable Energy Directive II.
*** exact design not yet finalised / legislation pending**
**** incl. sustainability criteria for biomass, in the future potentially also for water used in electrolysis**

4. Interfaces between verification systems of different countries

Both book-and-claim (such as GOs under Art. 19 RED II) and coupled verification (such as mass balancing) for RE currently operate across national borders. We must therefore consider not only national verification interfaces but also interfaces with the verification systems of other European countries and, given the growing demand for electricity-based fuels such as hydrogen and ammonia, also interfaces with third-country systems or their integration into existing international systems. Two factors in particular must be considered regarding the cross-border transfers of certificates. First, it must be ensured that the quality of the certificates or the energy they represent is uniform in order to prevent the procurement of cheap certificates from countries with lower quality standards. A comprehensive approach already exists within CEN standardisation to define minimum standards for certificates to facilitate transnational trade within the EU (and beyond, in the case of mass-balanced gas). For example, the European GO standard EN 16325 is currently being revised to reflect standardised requirements for gas and heat/cold GO systems, in addition to the electricity sector. The German Federal Environment Agency is currently examining the eligibility of GOs from other countries on a case-by-case basis (see Fouquet et al. 2014). In the future, the relevance of international standards for the verification of RE attributes will also increase in order to support transnational trade in energy carriers such as hydrogen. Second, as in the case of energy conversions (Section 2.3), the creation of suitable IT infrastructure and interfaces is necessary for cross-border transfers to avoid both double marketing and double reporting of the RE attribute and to thereby strengthen consumer confidence. The next section presents in more detail the existing institutions, actors and infrastructures that are already involved in the transnational linking of RE verification systems, as well as various further linking options.

4.1 Existing actors and infrastructure for transnational RE verification

Within the EU, various actors and infrastructures already exist to facilitate the transnational transfer of proof of RE properties. **For electricity GOs (in accordance with Art. 19 RED II), the Association of Issuing Bodies (AIB) is the leading institution** for communication and the transfer of GOs between national actors/registries. GO transfers are processed by the AIB-led European Energy Certificate System (EECS), whose rules provide a common standardised framework for the GO systems of the AIB member countries or regions. Its experience is also incorporated into the further development of the CEN standard EN 16325. The AIB operates a central one-to-many- IT hub for its members, which is connected to each of the national electronic registers that hold GOs in the accounts of their owners. This enables the automated processing of cross-border transfers between the participating countries or registries.[18] Trading of GOs takes place independently of the technical transfer and is carried out on various digital marketplaces, through exchange and over-the-counter trading. However, neither these transactions nor the resulting GO pricing are transparent to the public.

Mass balancing systems already allow transfers within the EU as well as imports from all over the world into the EU (Bowe and Girbig 2021), which can be important for any future imports of electricity-based fuels since interfaces to non-EU countries already exist here. **For renewable gas, ERGaR**, an association of national RE gas registries, **has established a documentation system for the cross-border transfer of renewable gas certificates** to replace previous bilateral agreements. The ERGaR Hub connects biomethane registries in Europe, thereby enabling the transfer of proof for biomethane and other renewable gas distributed through the European gas grid, with the aim of avoiding double sales and counting. To facilitate the transmission of certificates, ERGaR develops and operates a central hub for the transmission of certificates to which national registries can connect. In the future, the hub should enable both mass balancing and the transmission of book-and-claim certificates such as gas GOs.[19] Furthermore, two earlier described EU projects, REGATRACE[20] and CertifHy, also aim to create standardised mass balancing and GO systems for biomethane/renewable gas and hydrogen at the European level and thus seek to enable standardised issuance and simple and secure transfer.

4.2 Infrastructure design options for transnational RE verification

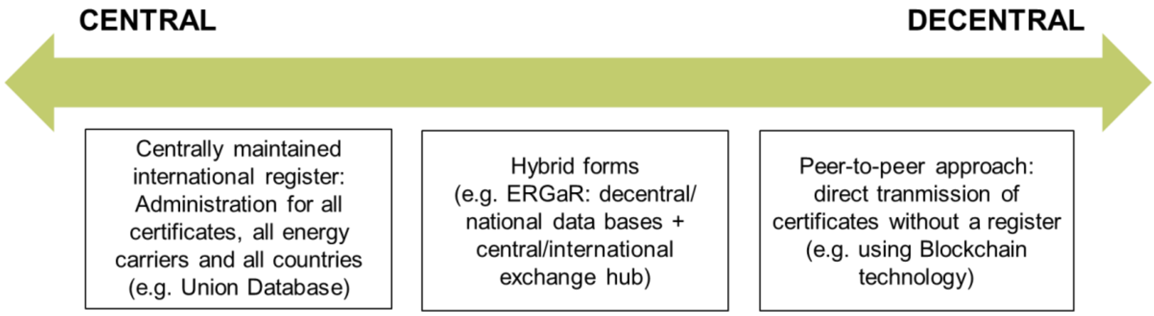
In addition to the existing infrastructure for cross-border transfers of RE certificates, detailed approaches to further design options have already been worked out (Moody et al. 2020). They can be depicted as a continuum (see Figure 5).

[18] See www.aib-net.org/aib.

[19] See www.ergar.org.

[20] Besides the AIB and ERGaR, national registers for renewable gases also participate in REGATRACE.

Figure 5: Design options for the cross-border[21] transfers of RE certificates



Source: Based on Moody et al. 2020.

The most centralised option, which requires the fewest external interfaces, is the establishment of a **central register or database** that manages all types of proofs for each energy carrier in all EU (and non-EU) countries. Such an all-encompassing register does not exist at present and is not planned for the foreseeable future. However, there are already plans at the EU level to establish an **EU-wide system or register, the "Union Database", for the central issuing and cancellation of certificates for gas and liquid energy carriers, initially for use in transport** and later to be extended to other applications (EU Commission 2021, RED III draft 15 July; Alberici et al. 2020). The Union Database is primarily intended to complement existing traceability requirements for sustainable biofuels (liquid and gaseous) and to facilitate transnational trade in these fuels and biomethane, but prospectively also in other renewable gases, RFNBOs and recycled carbon fuels for use in transport, heat/cold and electricity. The database will most likely serve as an EU-wide mass balancing database, which will enable the documentation of various pieces of information, such as GHG emissions and sustainability criteria in order to allow fuels to count towards Art. 25 RED II (the transport sector target). The aim of introducing such a central register is to ensure consistent reporting across member states and to exclude double marketing of renewable gas and liquid fuels in the future. The Union Database also promises to more efficiently prevent the multiple registration of the same fuel quantity in several mass balancing systems, which so far has been possible (Bowe and Girbig 2021). If registration in the Union Database, and thus mass balancing, were to be a prerequisite for eligibility for regulatory targets and for financial support, mass balancing would become even more established as the dominant form of verification for renewable gas, hydrogen and liquid fuels. GOs for renewable gas would then fulfil a complementary role. As GO systems are not envisaged to be maintained within the Union Database at this stage, the Union Database should at least be linked or reconciled with the GO systems. This is indicated by a draft revision of RED II, which requires the cancellation of any gas GO issued when a delivery of gas is registered in

[21] Such a continuum also applies to the design of national transfers.

the database in order to prevent the double reporting of that volume of gas (EU Commission 2021).

Most other linkage options are a **mix of central, international and decentralized, national registers** of the type that already exist today. One of these is the establishment of a central, transnational coordination office through which certificates for all energy carriers can be transferred among the national registers. It would be up to the member states to manage the national registers and thus also to decide whether a national register should manage several types of certificates (e.g., mass balancing and GOs) or certificates for different energy carriers (e.g., gas and liquid fuels), or whether different registers should each manage one type of certificate/energy carrier. A similar but less centralised administration of certificates would be achieved by setting up transnational administrative offices for each certificate type or energy carrier in combination with the national registers. Another variant would allow each member state to participate in a central body that assumes certain functions, while other functions remain at the national level. Historically grown hybrid forms currently prevail in practice.

The **most decentralised form of coordination of the cross-border transfer of certificates would be achieved through peer-to-peer approaches.** For example, there could be a dedicated link from one register to every other register. An even more granular solution would be the direct transfer of certificates between actors without any involvement of registers. In principle, it should be noted that greater decentralisation can offer efficiency benefits in some cases but can also increase the complexity of a system. Decisions on design options and IT solutions to be used (e.g., blockchain) require a balanced cost-benefit analysis in advance. Recent efforts in the context of planning a Union Database for renewable gas and liquid fuels at the EU level indicate that more centralised approaches are favoured by the EU for harmonisation, fraud-proofing and settlement reasons. Operational design options for registers will be considered in other reports on individual energy carriers.

5. Challenges in dealing with RE verification system interfaces

The verification of the RE attribute at the verification system interfaces poses a number of **technical and administrative challenges**. Important criteria that must be met or observed include (cf. Verwimp et al. 2020; Van Stein Callenfels et al. 2020)

- avoiding double marketing of the RE attribute (i.e., the double or multiple issuance and marketing of the RE attribute of a given amount of energy),
- avoiding duplication in the registration, transmission, and cancellation of proof due to technical errors or misuse,
- avoiding multiple use of a cancelled certificate (applies in particular to GOs),

- avoiding multiple claiming of RE attributes (e.g., using the RE attribute of a given volume of energy for several purposes),
- building user confidence,
- and ensuring the climate protection effect of the system.

To meet these criteria, the **reliable, correct, and transparent recording of all transactions is essential**, both at the national level and for the transnational interconnection of systems within the EU and between the EU and third countries (e.g., when importing hydrogen). In **particular, in the absence of a central register** for the administration of different types of certificates across national borders, correct accounting requires the **proper management of the interfaces** between the certificate systems for different energy carriers and between the interfaces of the certificate systems for a given energy carrier by the registers both within a country and across national borders. This is an **extremely complex task**. For example, when linking systems of different energy carriers – i.e. when transported energy is converted, such as between electricity GOs and gas GOs/mass balancing, etc. – defining rules for the transfer of green attributes is a key challenge.[22] Interfaces between multiple verification systems of an energy carrier (e.g., future gas GOs and gas mass balancing, several independently operated mass balancing systems, etc.) are also relevant in this context.[23] For example, when issuing a certificate for renewable gas, it must be ensured in future that mass balancing systems and GO systems (and especially in Germany also various independent mass balancing systems) are reconciled with each other so as to be able to track exactly which certificate was issued or cancelled and thus to avoid the double marketing of the RE attribute (via GOs and via mass balancing). **Suitable technical interfaces, in particular IT solutions**, must be established to ensure secure and reliable communication between the different verification systems or the associated registers within a country and across borders. Furthermore, **uniform verification mechanisms** (e.g., by independent experts) must be established to ensure, among other things, that input and output energy are measured correctly.[24]

In transactions between countries with diverging regulations, establishing standards based on uniform ideas and definitions[25] is particularly important in order to harmonise the quality level of certificates or the RE behind them, respectively, and to ensure this in the long term. Only in this way can the cheaper procurement of certificates from countries with lower quality standards be avoided. RED II sets minimum standards for the GO systems in Europe

[22] For example, the form in which information on the cancellation of a certificate for energy inputs (e.g., electricity) is transmitted to the register that issues certificates for energy outputs (e.g., gas) must be specified.

[23] In Germany, several mass balancing systems are operated by different agencies; thus, double marketing of RE attributes cannot currently be ruled out without reconciliation between different registers (Bowe and Girbig 2021).

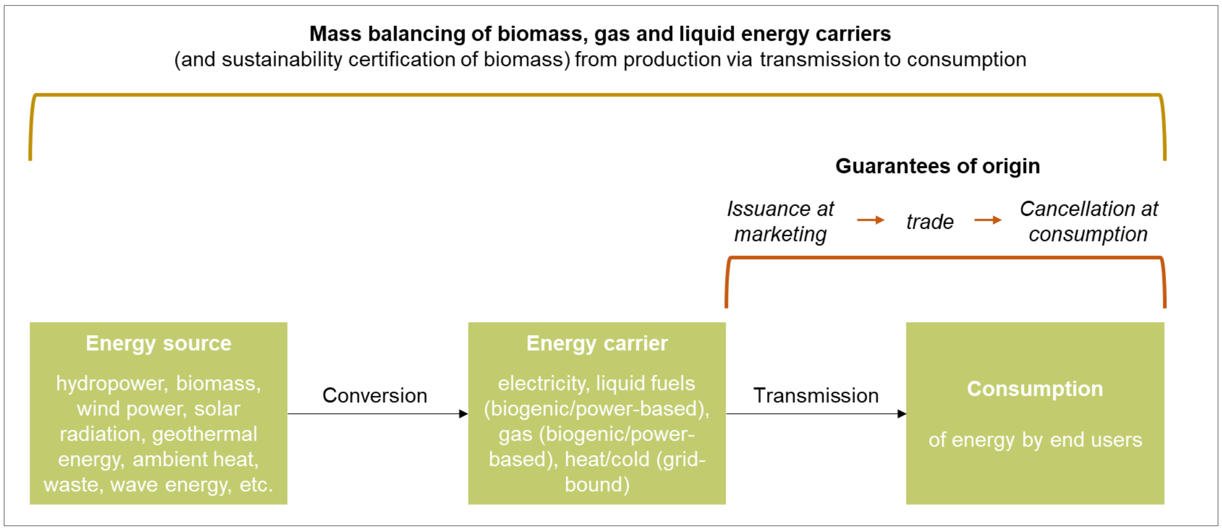
[24] The challenges presented here are analysed in more depth in e.g., Verwimp et al. 2020 and in REGATRACE work packages 4.3 and 4.4 (www.regatrace.eu/work-packages), which focus in particular on the interface between electricity and gas certificates.

[25] The definition of renewable energy is already an example of this.

and thus creates the basis for the EU-wide market for these certificates. In addition, the DIN EN 16325 standard facilitates the transfer of GOs through uniform data sets. However, the definition of these standards requires corresponding coordination processes and test mechanisms.

Another challenge is the **selection of the required proof**. As described in Section 3, different forms of verification serve different regulatory requirements. In this context, the **balance-sheet limits of the different forms of verification must be observed** (Figure 6).

Figure 6: Balance-sheet limits of verification systems of the RE attribute



Source: Hamburg Institut.

Depending on the purpose for which the RE attribute is verified, verification must already begin with the extraction of the energy source (e.g., mass balancing for RED II requirements), or it can only take place once the energy source has been marketed (e.g., GOs for labelling). Accordingly, the energy producers' fixing of a certain start of verification creates some inflexibility regarding the purpose that such verification can serve. The (regulatory) fulfilment options must therefore be considered when selecting a particular type of verification.

Finally, a further difficulty lies in **ensuring that using the verification has a positive – or at least non-negative – climate impact** (Werner 2021). This applies in particular to the case of energy conversions that use transported input energy, where it may be necessary to ascertain not only the RE attribute of the energy input but also further qualitative requirements in order to prevent fossil plants connected to the transport grid from operating profitably for an "artificially" extended period of time.

Excursus on additionality: The example of electrolysis using power drawn from the grid

Without qualitative requirements for the required proof, the following exemplary case could arise: A hydrogen electrolyser could draw electricity from the grid when power production from fluctuating RES is low so that at that point in time, the share of fossil energy sources in the grid is high. This would have an impact on the revenues of fossil power plants if the additional power demand suffices to increase the electricity price they achieve. A problem of credibility would arise if the green credentials of the electricity and hydrogen produced were proven by presenting certificates whose underlying electricity was unrelated in space and time to electricity consumption. Furthermore, in order to avoid a mere redistribution of green attributes among the sectors, e.g., from electricity to transport, it should be ensured that the additional demand for RE for cross-sectoral applications stimulates the expansion of renewable electricity generation.

Art. 27(3) and Recital 90 RED II formulate requirements for the temporal and spatial correlation of, on the one hand, electricity generation and, on the other hand, consumption for the production of electricity-based fuels as well as the **additionality of the RE used**. The verification methodology is to be specified in more detail by the end of 2021 by a delegated act. Table 5provides an overview of the criteria that are being discussed (see also Hoffmann and Antoni 2021). The focus is on liquid and gaseous electricity-based fuels that can be counted towards the RED II transport sector target for RE. Proving the temporal and spatial connection aims to show that a corresponding demand could have been met from RE in balance-sheet terms. For example, regarding plant location, the discussion holds that electricity and hydrogen production plants should be located in the same price zone or in neighbouring price zones without a systemic grid bottleneck. Since all of Germany is a single price zone, a broad notion of spatial connection would have to apply here. As proof of the temporal connection, a quarter-hourly balance of renewable electricity generation and consumption is being discussed. To ensure additionality, it is suggested that the electricity should come from an unsubsidised RE plant that was commissioned no more than twelve months before the electrolyser. In addition, a requirement for PPAs between the RE plant and the electrolyser is being considered. Note, however, that PPAs can take many forms (Hilpert 2018), so more specific requirements would be called for.

At the national level, the amended **EEV** formulates requirements for the production of green hydrogen to be exempt from for EEG levy (see Section 3; Art. 3b EEV). The criteria for the renewable electricity drawn from the grid refer to the location of the plant (at least 80% of it must originate from plants located in the German price zone; no more than 20% may come from plants located in a price zone that is electrically connected to Germany), as well as additionality. While no subsidy payments may be claimed for the electricity used, unlike the criteria discussed at the EU level, this does not preclude procurement from plants that have previously received subsidies. The requirements of the EEV will be further developed once the EU Commission's delegated act is available.

Besides the final form of the requirements, **the type of proof that must be submitted to prove compliance with the criteria has yet to be clarified at the EU level**. The EEV stipulates that the GOs that are cancelled for the renewable electricity must also contain information on the optional coupling between electricity and GO supply in accordance with

Art. 16(3) HkRNDV. In such balance-sheet coupling, a balance-sheet energy flow from the balancing group of the RE plant for which GO are issued to the balancing group of the energy supplier to whom the GO are transferred must be proven (see Section 2.1.2 in Styles et al. 2021). Further EEV criteria could raise market demand for GO that meet certain quality criteria in the future (e.g., unsubsidised electricity generation from plants in the German price zone). The role of GO in providing proof of the criteria set out in Art. 27(3) RED II is still unclear. In particular, additional proof or a further development of the existing GO systems (e.g., with the integration of time stamps, see EnergyTag 2021) would be necessary to prove a temporal (e.g., quarter-hourly) connection between generation and consumption.

Table 5: Requirements for the production of green hydrogen

Possible requirements of the delegated act based on Art. 27(3) RED II (as of July 2021)	**Requirements for the purpose of the EEG-surcharge exemption (Art. 3b EEV)**
• **Energy sources:** Renewable sources only, no biomass or storage plants. • **Plant location:** Electricity and hydrogen production plants must be located in the same price zone or in neighbouring price zones without systemic grid bottlenecks. • **Additionality:** Power must be bought from unsubsidised plants (never received any subsidies); commissioning of the power plant no sooner than 12 months before the electrolyser. • **Documentation requirements** for electricity use and hydrogen production	• **Energy sources:** RE plants as defined in Art. 3(21) EEG 2021). • **Plant location:** At least 80% of the power must come from RE plants in the German price zone, no more than 20% from RE plants in a price zone that is electrically connected to Germany. • **System-serving mode of operation:** Exemption can only be claimed for the first 5,000 full-load hours within a calendar year. • **Additionality:** No subsidy payments under the EEG, the EEV, the Combined Heat and Power Act or other payments to promote RE may be claimed for the electricity. • **Reporting obligations** on electricity consumption and compliance with the conditions
Verification in case of on-grid power procurement	**Verification in case of on-grid power procurement**
• **PPA** between RE plant and electrolyser • **Quarter-hourly balancing** of renewable power generation and consumption (unless the RE share in the price zone of the electrolyser is higher during the quarter-hour of electricity consumption than in the country as a whole)	• **Cancellation of GO** in accordance with Art. 30 HkRNDV • For RE plants in Germany, GO must include the **optional link between electricity and GO supply** in accordance with Art. 16(3) HkRNDV.
Verification in case of off-grid power procurement	**Verification in case of off-grid power procurement**
• **No requirements for simultaneity** between generation and consumption	• RE power generation and electricity consumption in the hydrogen plant must be **simultaneous in terms of 15-minute intervals.**

Source: Based on Art. 3b EEV; Hoffmann and Antoni 2021.

6. Conclusion

The verification of RE involves interfaces at various levels, and their number is set to increase further due to the future possibility of issuing GOs (in accordance with Art. 19 RED II) for renewable gas, heating and cooling within the EU and due to the increasing transnational trade in RE. On the one hand, there are interfaces at the national level between the different **verification systems for a given energy carrier** (e.g., between GO and mass balancing systems for gas) **and between the verification systems of different energy carriers** (e.g., between GOs for gas and GOs for electricity and heat/cold). On the other hand, **interfaces between the RE verification systems of different EU and, potentially, non-EU countries** must be considered on an international level. Finally, interfaces **between RE verification systems** (of one and/or several energy carriers) **and regulatory instruments or compliance options** exist both at the national and the international level.

There are **various options for the contentual and administrative design of these interfaces**. The most important contentual criteria are arguably the avoidance of double marketing and double claiming of the RE attribute, user confidence, and the climate protection effect of the system (cf. Verwimp et al. 2020; Van Stein Callenfels et al. 2020). These general criteria must be observed not only regarding the individual systems but also in dealing with the interfaces between them. In addition, more specific criteria have been and are still being developed regarding the verification interfaces (e.g., criteria for power used in electricity-based fuels for transport, etc.). In administrative terms, the question arises as to how different verification systems can be linked technically and organisationally at the national and the international level. Here, the spectrum ranges from completely centralised solutions (a single transnational register for all types of verification) to completely decentralised designs (peer-to-peer approaches without any registers). At least regarding the eligibility of gases and liquid fuels for RE targets, a movement towards a more centralised organisation is emerging in light of current regulatory efforts to create an EU-wide Union Database. Electricity GO registries are predominantly organised nationally (and in some cases even regionally).

In conclusion, it should be noted that very different challenges arise in the verification of the RE attribute for each energy carrier. The details of these specific challenges and solution options are elaborated in further project reports.

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