Sustainable potentials for renewable gas trade

Synthesis Report of WP3

of the IEA Bioenergy Intertask project
Renewable gas - deployment, markets and sustainable trade

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Synthesis Report of WP3 of the IEA Bioenergy Intertask project "Renewable Gas: Deployment, markets and sustainable trade"

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ABBREVIATIONS AND ACRONYMS

BCM	billion cubic meters
Bio-SNG	Synthetic Natural Gas from biomass
BY	Belarus
CH_4	methane
CO_2	carbon dioxide
DNV-GL	Det Norske Veritas group - German Lloyd
EBA	European Biogas Association
EC	European Commission
ERGaR	European Renewable Gas Registry
ERIG	European Research Institute for Gas and Energy Innovation
EU	European Union
GfC	Gas for Climate
GHG	greenhouse gas(es)
GO	Guarantee of Origin
H_2	(molecular) hydrogen
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IEA Bio	International Energy Agency Bioenergy Technology Collaboration Programme
IEA H2	International Energy Agency Hydrogen Technology Collaboration Programme
IPCC	Intergovernmental Panel on Climate Change
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
IRENA	International Renewable Energy Agency
ISO	International Standardization Organization
JRC	European Commission Joint Research Centre
LH2	liquefied hydrogen
LHV	lower heating value
LNG	liquefied natural gas
Mt	million tons
NZE	net zero emission
PtG	power-to-gas
REGATRACE	Renewable Gas Trade Centre in Europe
RG	renewable gas(es)
RU	Russian Federation
SM	synthetic renewable methane
SNG	Synthetic Natural Gas
TRL	Technology Readiness Level
vol%	per cent by volume
UA	Ukraine
UK	United Kingdom
US	United States of America

Objectives of the IEA Bioenergy Strategic Intertask Project "Renewable gas - deployment, markets and sustainable trade"

The IEA Intertask project concerns the prospects of implementing renewable gases (RG) in the energy markets of IEA countries, and beyond. The aims of the RG project are to

- provide state-of-the-art overviews on prospects, opportunities and challenges for various mechanisms that could help deploying biogas, biomethane and other renewable gases in energy markets in IEA countries (e.g., green gas certificates), and beyond
- discuss technological and sustainability issues of RG from a deployment perspective and derive respective recommendations for policymakers.

The project aims to provide decision makers and the research community with a comprehensive overview of what is currently known regarding renewable gases, considering both technology development/infrastructure and which mechanisms exist and are considered to fulfil the important role of renewables gases in global climate scenarios for a well-below 2°C world.

Summary of key findings

This synthesis report summarizes the key findings from the IEA Bioenergy Intertask project "Renewable Gas - deployment, markets and sustainable trade[1] - Work Package 3 on sustainable potentials for international renewable gas (RG) trade with a focus on biomethane.

Renewable gases will be key components of a global energy system aiming at net zero greenhouse gas emissions by 2050. RG will have to strongly increase, and **international trade** may become an important component of decarbonizing the global energy system. International trade of RG can be either **physical** through gas pipelines (or as liquefied gases in ships), or **virtual** through the exchange of certificates such as Guarantees of Origin.

In the short- and medium term, **biomethane is the major RG being traded** internationally, and prospects for further growth are significant in Europe but also in Latin and North America and South-East Asia, where current trading is rather low.

In the longer-term, "green" **hydrogen** (H_2)[2] has a high potential for international RG trade. The 2050 potential green H_2 exporting countries are seen as those offering low-cost renewable electricity for H_2 production, i.e., wind- and sun-rich regions with access to international pipelines and/or ports in Africa (e.g., Morocco), Europe (Portugal, Spain), Latin America (e.g., Chile), Middle East (e.g., Saudi-Arabia), and Oceania (Australia and New Zealand). H_2 trade will rely on existing gas pipelines and new dedicated H_2 pipelines, or transport with ships (ammonia, LH_2). Up to **1/3 of green H_2 will be traded internationally by 2050**, a share slightly higher than the current share of natural gas traded globally.

For trade of green H_2 and its derivatives, regulatory hurdles remain, especially the definition of "greenness" and respective GHG emission thresholds, but ongoing work in the EU and internationally aims to address these issues.

1 https://www.ieabioenergy.com/blog/task/renewable-gas-%e2%80%90-deployment-markets-and-sustainable-trade/

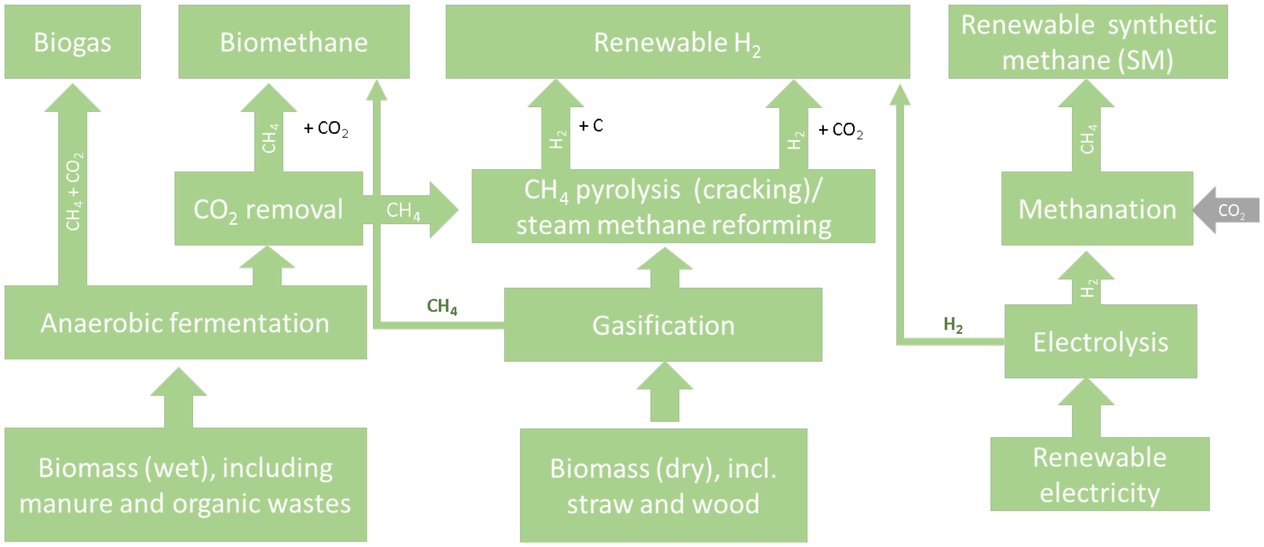
2 In this paper, renewable synthetic methane (SM) derived from green H_2 is included in the H_2 trade potentials.

1. Introduction

A global energy system aiming at net zero greenhouse gas emissions by 2050 will include renewable gases (RG) as key components (IEA 2021a). With fossil gas supply peaking in the mid-2020ies and shrinking fast up to 2050, RG will have to strongly increase, and international trade may become an important component of decarbonizing the global energy system (Daioglou et al. 2020).

Several pathways exist to provide renewable gases, as depicted in Figure 1.

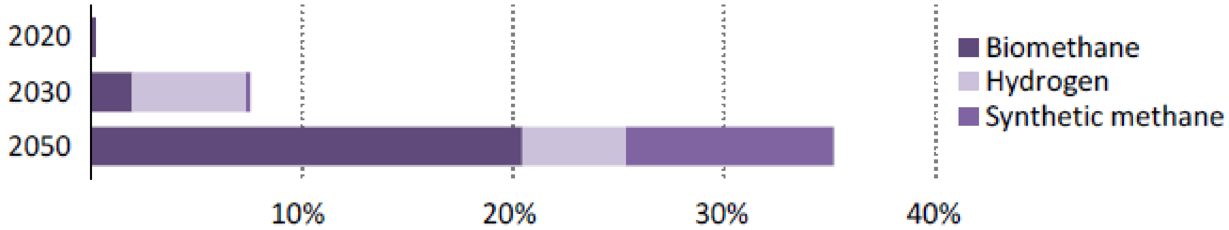
Figure 1 Simplified overview of renewable gases production pathways



Source: Fritsche (2022)

The IEA NZE scenario assumes a major role for renewable gases, especially for biomethane, but also for H_2, and H_2-based synthetic methane (Figure 2).

Figure 2 Gas grid shares of renewable gases in the IEA NZE Scenario



Source: IEA (2021a)

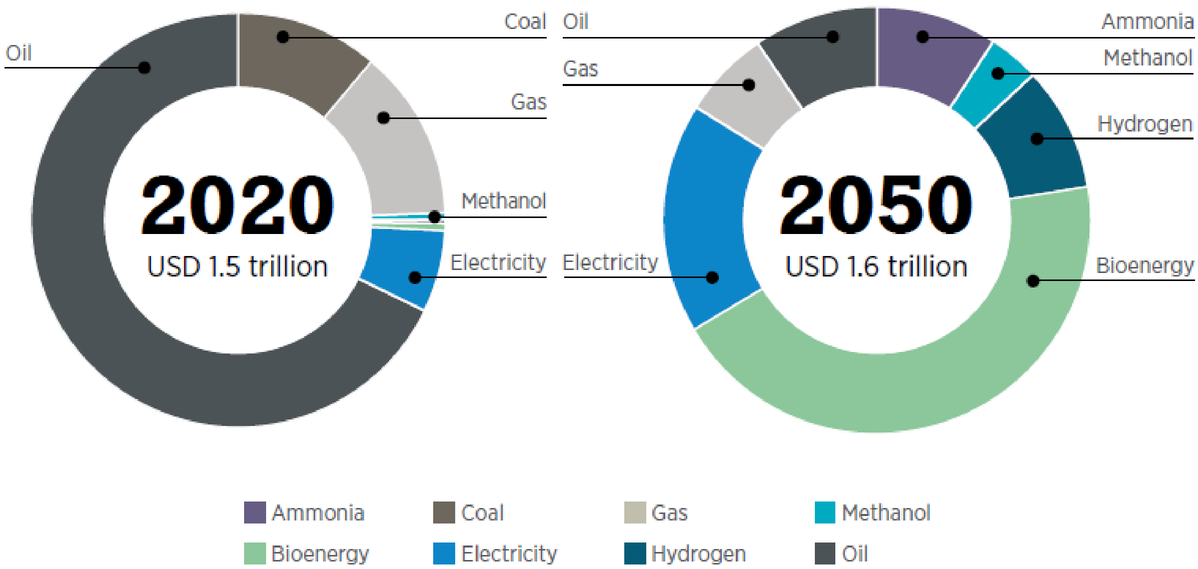
The two main RG options for trade are biomethane and "green" hydrogen[3]. The following synthesis on sustainable RG trade potentials addresses the medium-term (year 2030) and longer-term (year 2050) and presents estimates for respective potentials, with a quantitative focus on biomethane.

3 Either as gaseous or liquefied H_2 resp. synthetic renewable methane (SM).

2. Renewable gas trade options

Trade is a vital component of the current global energy system, and the transformation towards a renewable, zero-carbon system will affect future trade patterns drastically, yet with only a small change in overall amount, as shown in Figure 3.

Figure 3 Shifts in the value of trade in energy commodities, 2020 to 2050



Source: IRENA (2022)

Trading of RG between countries or regions requires the physical movement of the respective gases, or the virtual transfer of RG quantities from one country to its trade partner country through certificates, either per “book & claim”, or mass balancing approaches.

The **physical** trade of RG can have two modes:

Domestic RG is injected into gas pipeline within the exporting country, and transport between countries is carried out through high-pressure pipelines, or in liquefied form through shipping (Bio-LNG or LH_2). In the latter case, the liquefied RG is regasified in the receiving port and injected into the national gas grid of the importing country[4]. Biomethane and SM can be used without limitation in natural gas infrastructure, including liquefaction plants (IEA 2020).

In contrast, there is currently not much infrastructure for H_2 transport, but when blending H_2 with natural gas, existing systems could be used, within a limit of max. 20 vol% (Fritsche 2022).

The **virtual** trade of RG through certificates, especially Guarantees of Origin (GO), is not hindered by physical infrastructure constrains but by lacking agreements on requirements and governance of the systems used to certify RG “bookings” (Sánchez & Jacobsen 2021). As of now, several RG certification systems have been developed especially in Europe but are not fully compatible nor being agreed internationally, but standardization bodies such as CEN and ISO are working on it (Fritsche 2022).

For the discussion of sustainable RG trade potentials, the mode of trade is not relevant, though.

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[4] Note that for small quantities and distances, liquefied RG can also be transported in specialized trucks.

3. Potentials for renewable gas trade

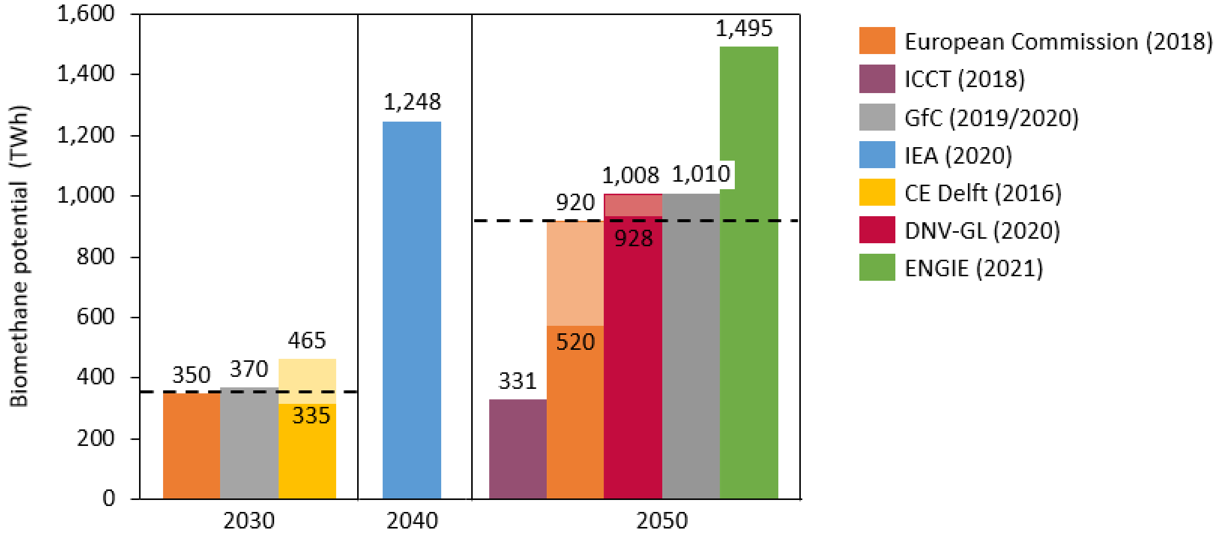
Trading of RG is still in an early stage – yet, as Thrän et al. (2014) indicated and Junginger et al. (2019) confirmed, there is growing trade in **biomethane** especially in Europe[5], and much interest in that in other parts of the world (see Section 3.1).

For **hydrogen** and derived products, IRENA (2022) discusses global and Wang et al. (2021) European perspectives for respective trade in the 2050 timeframe (see Section 3.2). The analysis of H_2 strategies and roadmaps given by Fritsche (2022) provides perspectives of countries' ambitions. The 2050 potential green H_2 exporting countries are seen as those offering low-cost renewable electricity for green H_2 production via electrolysis, i.e., wind- and sun-rich regions with access to international pipelines and/or ports in Africa (e.g., Morocco), Europe (Portugal, Spain), Latin America (e.g., Chile), Middle East (e.g., Saudi-Arabia), and Oceania (Australia and New Zealand). Yet, the quantification of future H_2 trade potentials is still at the beginning.

3.1 Biomethane

Today, Europe is the main producer of biomethane (IGU 2021; Liebetrau, Fritsche & Gress 2021). Europe also holds significant biomethane domestic potential (Birman et al. 2021). Several studies calculated the biomethane potential in the European Union (EU27) for 2030 and 2050 and estimated the potential to be around 350 TWh by 2030, and up to nearly 1,000 TWh in 2050 (Birman 2021; GfC 2021). Figure 4 shows the results of the studies including gasification from wood.

Figure 4 Biomethane potential reported in different studies



Source: GfC (2021); note that the potentials include biomethane from gasification of woody biomass

It must be mentioned, however, that Figure 4 shows the total methane potential from anaerobic digestion and gasification without considering whether the gas is used domestically as biogas for on-site electricity production, or whether it is upgraded to biomethane and injected into the gas grid. In 2020, biomethane production (32 TWh) accounted for only 17% of total biogas production (191 TWh) in the EU (EBA 2021).

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5 The EU is supporting the Renewable Gas Trade Centre in Europe (REGATRACE) to foster such developments, see https://www.regatrace.eu/

Whether biogas will be used less for on-site cogeneration in the future, or whether it will be upgraded more and fed into the natural gas grid, depends essentially on the national subsidy conditions. If we assume that growth will only take place for biomethane production and that biogas production will remain constant, then biomethane production in 2030 will be around 190 TWh, thus substituting a share of less than 5% of natural gas consumption.

So far, the volumes of biomethane traded among EU countries are rather small - about 3 TWh in 2020 (dena 2021), corresponding to 0.06 % of natural gas consumption in the EU.

Given the extensive natural gas infrastructure existing in Europe, the ambition of the EU to increase its renewable energy share and decrease GHG emissions on the one hand, and the significant agricultural and forest resources of Eastern European countries and Russia on the other hand, several studies tried to identify the export potential for biomethane from this region (Angelova 2012; Angelova et al. 2012; Fritsche & Iriarte 2016; GfC 2021).

GfC (2021) found for Belarus (BY) a potential of more than 100 PJ of biomethane, and for the Ukraine (UA), more than 700 PJ, both for the year 2030. For Russia (RU), the 2030 potential was estimated as nearly 2500 PJ. For RU and UA, these potentials consist for about 90% of biomass from abandoned agricultural land, while for BY, the agricultural share is about 50%. The reminder of the export potentials represents biomethane from the gasification of forest biomass.

In recent work for the German National Energy and Climate Plan, IINAS estimated global export potentials for biomethane (Kemmler et al. 2020), building on earlier work (Fritsche & Iriarte 2016), and identified biomethane export potentials for 2030 from (Western) Russia of about 1250 PJ, and for UA of 500 PJ. In a projection towards 2050, these export potentials were reduced due to rising domestic demands to about 950 PJ (RU), and 400 PJ (UA). These potentials considered only biomethane from abandoned/marginal land, and future domestic uses were subtracted from the export potential.

For the Ukraine, BAU (2021) expects biomethane exports as an option, but the current political situation in this country and in Russia does not allow to assume much by 2030. In a **post-war long-term perspective**, economic cooperation of the EU with Russia and the Ukraine may include biomethane trade, given its potential for avoided “stranded assets” in the gas transmission infrastructure.

Table 1 Biomethane export potentials from Eastern Europe and Russia

Country	2030	2050	Source
Belarus	137		Angelova et al (2012)
Russia	2450		Angelova et al (2012)
Russia	1250	938	Kemmler et al. (2020)
Ukraine	711		Angelova et al (2012)
Ukraine	500	375	Kemmler et al. (2020)

Source: own compilation; data given in PJ of biomethane (LHV)

Outside Europe, grid-based international biomethane trade has not started yet[6], but interest in e.g., Africa (for city grids), and Latin America as well as parts of Asia is rising (Junginger et al. 2019). Respective studies on the export potentials are not available, though.

The current state of biomethane development in selected IEA member countries is reported

[6] There is some inter-state trade within Canada and the US, though.

regularly[7], and an overview of biomethane potentials from manure are available in Liebetrau et al. (2021) for Austria, Australia, Canada, Germany, Ireland, Norway, and the UK.

For the **United States**, Argonne National Laboratory gives a biomethane production in 2020 of 17.4 TWh (approx. 63 PJ)[8]. Market researchers report that US biomethane production is growing at an annual rate of 35%, boosted by policy support at state level (CEDIGAZ 2021).

For **Canada,** the Canadian Biogas Association estimates that biogas generated at least 195 MW of electricity and 400 TJ (≈140 GWh) of renewable natural gas in 2017.

Biogas production in **Brazil** was approx. 11 TWh in 2020, of which 19 % (2.1 TWh) were processed into biomethane (in 8 plants)[9]. The total biomethane potential from sugar cane industry, animal manure, agriculture and sanitation is estimated as 440 TWh[10]. The Energy Research Office (Empresa de Pesquisa Energética, EPE), indicates a higher biogas potential of 516 TWh in 2030 and 785 TWh in 2050. Derived from this, EPE forecasts that the installed capacity of the biogas-fuelled combined heat and power plants will amount to 458 MW_{el} in 2030 and 2,850 MW_{el} in 2050, corresponding to the use of 8.5 TWh and to 56 TWh of biomethane, respectively. The estimated production of biomethane as biofuel would reach 21 TWh in 2030 and 131 TWh in 2050[11].

According to Dale et al. (2020) **Argentina** has a huge potential for biomethane production of 144 TWh per year. However, biogas does not yet play a significant role in the national energy supply and the production and use of biomethane is still in its infancy.

In **Australia**, the first biogas upgrading facility is expected to come online in 2022, supplying Sydney's local gas grid[12].

In **China**, biogas production reached 85 TWh in 2018 (IEA 2020), but despite investment by the central government, the market has not developed as expected. Thus, China has revised its production targets for biomethane downwards, from 300 TWh by 2030 as planned previously to 200 TWh (CEDIGAZ 2020).

In **India**, although biogas is widely spread in the country with 5 million plants (mainly small-scale household units), biomethane plants are just starting to spread. Biomethane production reached 0.5 TWh in 2020 (MNRE 2021).

In view of the fact that in the vast majority of countries the quantities of biomethane available will be significantly less than the demand for natural gas, it can be assumed that first it is going to be used in the country where it was produced. This could indicate that, for the foreseeable future, cross-border traded volumes will remain low relative to production[13].

Thus, it remains difficult to estimate the extent to which given country potentials for bio-methane will contribute to international trade. Incentives for cross-border trading depend also on differences between national requirements in the energy and transport sectors and can vary when sector-specific regulations and different greenhouse gas reduction measures are applied.

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7 https://task37.ieabioenergy.com/country-reports.html

8 https://www.anl.gov/es/reference/renewable-natural-gas-database

9 https://abiogas.org.br/wp-content/uploads/2021/06/PANORAMA-DO-BIOGAS-NO-BRASIL-2020-v.8.0-1_1.pdf

10 https://abiogas.org.br/wp-content/uploads/2021/01/Infograficos-Abiogas_D_2021-1.pdf

11 https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-227/topico-458/DEA%2013-15%20Demanda%20de%20Energia%202050.pdf#search=biogas%20458%20MW

12 See https://jemena.com.au/about/innovation/malabar-biomethane-project

13 This is theoretical. In the real world, domestic use or trade of biomethane depend on market opportunities.

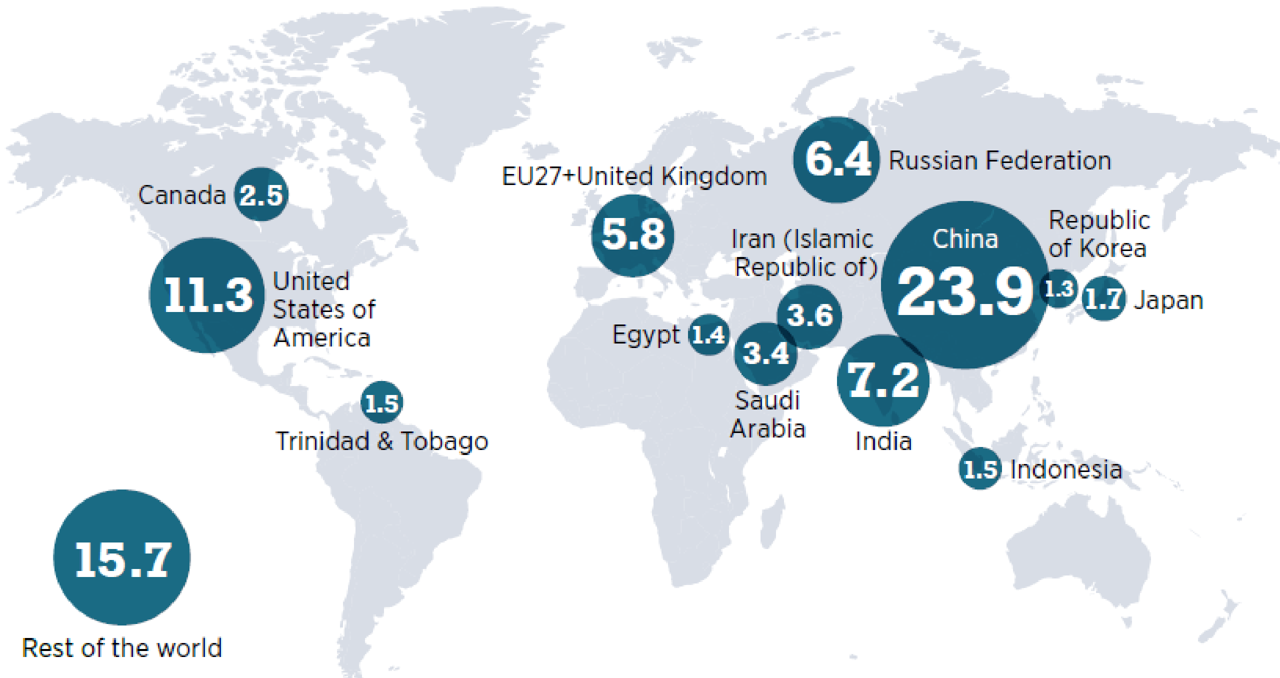
3.2 H_2 and SM

Currently, H_2 production and use are quite localized – some 85% of H_2 is produced and consumed on-site than bought and sold on the wider market (IEA 2019).

„Even where hydrogen is sold, it is usually not transported across large distances because of the logistical difficulties and costs. Over time, hydrogen could become an internationally traded commodity“ (IRENA 2022).

H_2 is already in use (Figure 5) but is predominantly produced from fossil fuels.

Figure 5 Hydrogen consumption in 2020



Source: IRENA (2022); data given in Mt of H_2; values are derived from current production of ammonia, methanol, refining and direct reduced iron for steel

As of now, the sustainable trade potential of hydrogen and synthetic renewable methane cannot be quantified due to the very early development of the respective technologies and logistics.

Yet, several countries have the ambition to ex- or import significant amounts of H_2 in the future, as indicated in Table 2.

Table 2 Overview of national H_2 targets and trade perspectives

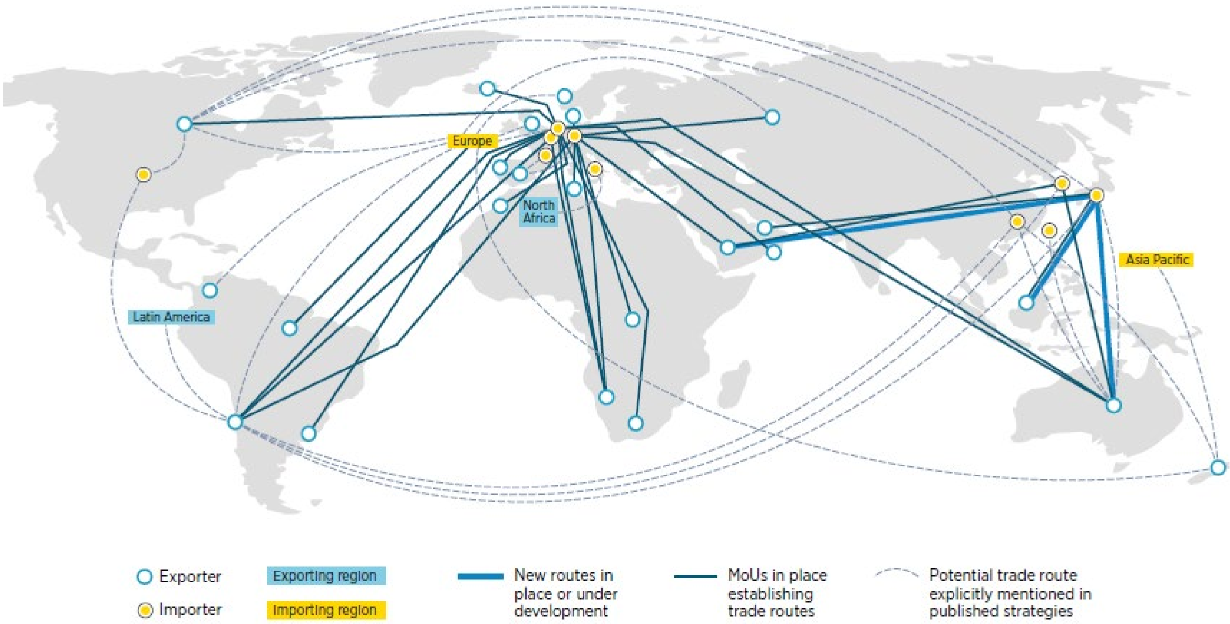
	H_2 targets [TWh_{LHV}]		H_2 trade	
Country/Region	**2030**	**2050**	**export**	**import**
Austria	4 - 8			x
Australia			x	
Canada	133	667	x	
Chile	125		x	
Colombia	5		x	
China	297		n/a	
Czech Republic	3		n/a	
European Union	200			x
Finland	3	5		x
France	33			x
Germany	14			x
Hungary	2			x
Italy	25			x
Japan	10 - 100	667		x
Korea	88			x
Netherlands	15 - 20			x
Norway			x	
New Zealand			x	
Poland	10		n/a	
Portugal	10 - 13	25	x	
Russia	67		x	
Spain	20		x	
United Kingdom	25			x
total	**1088 - 1192**	**1363**		

Source: own compilation based on Fritsche (2022) and IEA (2021b); n/a = information not available

IRENA (2022) estimates that roughly 1/3 of green H_2 will be traded internationally by 2050, a share slightly higher than the current share of natural gas traded globally.

Several countries are very active in creating bi- and multilateral agreements on H_2 trade, as reported in IEA (2021b). IRENA (2022) visualized the current state and perspectives of such arrangements, as shown in Figure 6.

Figure 6 An expanding network of hydrogen trade routes, plans and agreements



Source: IRENA (2022)

The potential export "clusters" identified by IRENA are in Africa[14], Latin America, the Middle East, and Australia, Canada, New Zealand, Russia, and Southern European countries. This fits rather well with the country trade ambitions given in Table 2.

For the EU27 + UK, Wang et al. (2021) estimated a **domestic** green H_2 supply potential of 4,000 TWh by 2050, and green H_2 **import** potentials from Northern Africa and the Ukraine of 1,700 TWh by 2050. Imports would be transported mainly through pipelines.

Given the very early stage of H_2 trade on the one hand and the rather large potentials on the other hand, the future dynamics of H_2 ex- and imports will depend on realizing cost reductions for electrolysers, investments in renewable electricity and H_2 transport infrastructure as well as success in market introduction schemes which factor in (rising) CO_2 prices.

The lead time of respective policies and market developments imply that substantial "green" H_2 trade cannot be expected before 2030 – yet there will be some forerunner countries such as e.g., Australia, Chile, the EU, Japan, Saudi Arabia, the UK, and the US.

In that context, several countries such as Norway and Russia see a role of low-carbon H_2 from natural gas ("blue" or "turquoise") as a means to start investments and bring down cost of transport infrastructure, as indicated in IEA (2019), Fritsche (2022), and IRENA (2022).

[14] The ongoing project H2ATLAS-AFRICA - a joint initiative of Germany and African partners – explores H_2 production potentials from renewable energy sources in the Sub-Saharan region (SADC and ECOWAS countries), see https://www.h2atlas.de/en/.

3.3 Regulatory issues of RG trade

Trade in biomethane has passed various regulatory hurdles in the last years so that further growth and market development using existing natural gas infrastructure can be expected (IEA 2020).

In the EU, biomethane is regulated under the Renewable Energies Directive (RED II, see EU 2018), requiring demonstrating GHG emission reductions, and providing “Guarantees of Origin” (GO) to prevent double counting. To foster biomethane trade in the EU and neighboring countries, the European Renewable Gas Registry (ERGaR)[15] was established in 2016 as a trans-national biomethane registration system, enabling cross-border transfer of certificates for renewable gases, including sustainability certification (with mass balancing) and certificates of origin via the European natural gas network while preventing double sale and double counting. ERGaR is operational with first trades started in 2021.

For “green” H_2 and its derivatives, though, trade hurdles remain. Besides the challenge of reducing production cost, international trade faces unresolved regulatory issues, especially in the definition of “greenness” and respective GHG emission thresholds, and the so-called **additionality** requirements for green H_2 (Fritsche 2022; Heinemann et al. 2021).

The recent **EC proposal** for a Directive on common rules for the internal markets in renewable and natural gases and in hydrogen (EC 2021a+b) includes the **mandatory certification** of H_2 to demonstrate a GHG emission reduction of at least 70%. This obligation would apply also for H_2 imports to the EU.

Given the importance of the issue for international trade, several countries agreed on a *Hydrogen Production Analysis Task Force* to reach consensus on a methodology and analytical framework for determining H_2-related GHG emissions (IEA 2021b). This group operates under the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) and is expected to deliver a proposal in 2022.

The work of the IPHE Task Force and the ongoing negotiations on the EU proposal for renewable gases will determine if the regulatory trade barriers for “green” H_2 can be overcome in the next years.

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[15] https://www.ergar.org/

4. Conclusion and perspective

Trading of renewable gases is still in an early stage, but there is growing international trade in **biomethane** especially within Europe, and much interest in other parts of the world.

For **H_2** and derived products, quantifying future trade potentials is at the beginning, with some "clusters" of countries emerging as foreseeable ex- and importers in the 2050 time horizon.

Trade in biomethane has passed various regulatory hurdles in the last years so that further growth and market development using existing natural gas infrastructure can be expected.

For "green" H_2 and its derivatives, hurdles remain, though. Ongoing work of the IPHE Task Force and negotiations on the EU proposal for renewable gases will determine if the regulatory trade barriers can be overcome in the next years.

The innovation potential for lower-cost and low-GHG emission H_2 is rather high, as past and ongoing work of the IEA Hydrogen Technology Collaboration Programme indicates[16]. With respective deployment, the international H_2 trade will increase.

The continuous monitoring of renewable gas policies carried out by the IEA and support to countries in formulating respective policies given by IRENA are valid activities to foster the further uptake of renewable gases in the global energy system.

The scenarios for decarbonization show that biomethane plays a major role by 2030, and (green) hydrogen and its derivatives will have to be taken on after that, with an increasing share of international trade.

[16] See https://www.ieahydrogen.org/

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