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Options for multilateral initiatives to close the global 2030 climate ambition and action gap - Policy field synthetic efuels

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Options for multilateral initiatives to close the global 2030 climate ambition and action gap - Policy field synthetic e-fuels

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This policy paper is part of the research project “Accelerating global climate action before 2030” (FKZ 3719 41 109 0) that investigates intergovernmental cooperation initiatives by G20 countries and their possible contribution to accelerate climate action before 2030. The project focuses on four policy areas: energy transition, synthetic e-fuels, sustainable food systems and forest protection; this paper looks at forest protection. The project is financed by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, supervised by the German Environment Agency and carried out by the Ecologic Institute, Oeko-Institut and Climate Analytics. The policy papers are scientific in nature, and all reflections and suggestions are derived by the authors’ experiences and from careful analysis. They aim to identify options to accelerate climate action in order to meet the globally agreed goal of staying within a temperature increase of well below 2°C above preindustrial levels and pursuing efforts to limit it to 1.5°C, without intending to prescribe specific policies.

Abstract: Options for multilateral initiatives to close the global 2030 climate ambition and action gap – Policy field synthetic e-fuels

Achieving the Paris Agreement long-term temperature goal requires closing the ambition and action gap. G20 countries have a crucial role to play in realising increased climate policy ambition. Synthetic electro fuels (e-fuels) were identified as one of the key policy areas and promising options for intergovernmental cooperation between the G20 nations. This policy paper provides a comprehensive but condensed analysis of the current landscape of the promotion of synthetic e-fuels. It provides concrete policy recommendations to improve existing and develop future initiatives in the area of production and use of synthetic post-fossil fuels. In the context of an overall decarbonisation of the energy system, the paper focuses on aviation and maritime transport and the role of green hydrogen for indirect electrification of industry sectors in addition to direct electrification. Based on the analysis of already existing initiatives four new initiatives for the promotion of an accelerated uptake of synthetic e-fuels are suggested: a Sustainable e-Kerosene Alliance, a Sustainable e-fuel Alliance for Maritime Shipping, a Hard-to-Abate Sector Partnership and finally a Global supply-demand-partnership.

Kurzbeschreibung: Optionen für multilaterale Initiativen, um die globale 2030-Klima-Ambitionslücke zu schließen – Politikfeld synthetische E-Kraftstoffe

Um das langfristige Temperaturziel des Pariser Abkommens zu erreichen, müssen die Ambitions- und Handlungslücke geschlossen werden. Die G20-Länder spielen eine entscheidende Rolle bei der Umsetzung gestiegener klimapolitischer Ambitionen. Synthetische Elektrokraftstoffe (E-Kraftstoffe) wurden als einer der wichtigsten Politikbereiche und vielversprechenden Optionen für die zwischenstaatliche Zusammenarbeit zwischen den G20-Staaten identifiziert. Dieses Strategiepapier bietet eine umfassende, aber komprimierte Analyse der aktuellen Landschaft der Förderung synthetischer Elektrokraftstoffe und enthält konkrete politische Empfehlungen zur Verbesserung bestehender und zur Entwicklung künftiger Initiativen im Bereich der Herstellung und Verwendung synthetischer postfossiler Brennstoffe. Im Rahmen einer umfassenden Dekarbonisierung des Energiesystems liegt der Schwerpunkt neben der direkten Elektrifizierung speziell auf der Luftfahrt und dem Seeverkehr sowie auf der Rolle von grünem Wasserstoff für die indirekte Elektrifizierung von Industriezweigen. Basierend auf der Analyse bereits bestehender Initiativen werden vier neue Initiativen zur Förderung einer beschleunigten Einführung synthetischer E-Kraftstoffe vorgeschlagen: eine Sustainable E-Kerosene Alliance, eine Sustainable E-Fuel Alliance für die Seeschifffahrt, eine Hard-to-Abate-Sektor Partnerschaft und schließlich eine globale Angebot-Nachfrage-Partnerschaft.

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List of abbreviations

CCfD	Carbon Contracts for Difference
CDM	Clean Development Mechanism
CEM	Clean Energy Ministerial
COP	Conference of the Parties
CORSIA	Carbon Offsetting and Reduction Scheme
DAC	Direct Air Capture
ETC	Energy Transition Commission
G20	Group of Twenty, International Forum comprising 19 of the largest countries and the EU
G7/G8	Group of Seven/Eight, International Forum comprising Canada, France, Germany, Italy, Japan, the United Kingdom, the United States (and the Russian Federation)
GHG	Greenhouse Gas
GIZ	Germanys Organisation for International Cooperation
GSDP	Global Supply-Demand-Partnership
GTZ	Getting to Zero Coalition
H2ASP	Hard-to-Abate Sector Partnership
HIA	Hydrogen Implementing Agreement
ICAO	International Civil aviation Organisation
IEA	Institute of Economic Affairs
ILUC	Indirect Land Use Change
IMO	International Maritime Organisation
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
IRENA	International Organization for Renewable Energy
ITC	International Technology Centre
ITPO	Investment and Technology Promotion Office
LeadIT	Leadership Group for Industry Transition
LNG	Liquified Natural Gas
MI	Mission Innovation
NHS	National Hydrogen Strategy
OECD	Organisation for Economic Cooperation and development
PtX	Power to X
RD	Research and Development
RE	Renewable Energy
RECPnet	Resource Efficient and Cleaner production
REEEP	Renewable energy and Energy Efficiency Partnership
SDG	Sustainable Development Goal
SeAMS	Sustainable e-fuel Alliance for Maritime Shipping
SeKA	Sustainable e-Kerosene Alliance
UN	United Nations
UNIDO	United Nations Industrial Development Organisation
WEC-DE	World Energy Council Germany

Summary

The use of synthetic fuels is essential to achieve full decarbonization of economies, especially in so called "hard-to-abate" sectors which include industry processes, especially chemical industry, and freight and long-haul transport particularly aviation and maritime transport. In this context, synthetic fuels including hydrogen generated from renewable energy, so called electrofuels or e-fuels, open the possibility of indirect electrification.

The paper aims at providing an overview of existing multilateral initiatives for the promotion of hydrogen and/or synthetic e-fuels including an analysis of selected initiatives in terms of their success, expected impact and cost-effectiveness with the view to develop and discuss options for future multilateral cooperation on synthetic e-fuels in the years to come. We identified eight existing initiatives and conducted an in-depth analysis of the four initiatives most relevant for the promotion of e-fuels:

- International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE);
- Mission Innovation (MI);
- Leadership Group for Industry Transition (LeadIT);
- Getting to Zero Coalition (GTZ).

Based on the in-depth analysis of existing initiatives we identified several gaps in the current landscape of initiatives:

- Initiatives focus on H_2 and related technologies (fuel cells), only GTZ has a specific focus on synthetic e-fuels;
- IPHE & MI have a bias towards road transport and/or buildings, initiatives focusing on "hard-to-abate" sectors or international transport were established only recently;
- None of the analysed initiatives explicitly focuses on the global mitigation potential of synthetic e-fuels;
- Potential options for future cooperation could focus on aviation, maritime transport, 'hard-to-abate' sectors and/or supply-demand.

For closing theses gaps we developed and sketched four potential new initiatives aiming at accelerating the global uptake of synthetic e-fuels. Three of these initiatives focus on one of the "hard-to-abate" sectors while the fourth initiative aims at integrating supply and demand for and from all these sectors.

- **Global supply-demand-partnership (GSDP)**: Establishing global supply and demand chains for e-fuels;
- **Sustainable e-Kerosene Alliance (SeKA)**: Establish a global continuously increasing e-fuel mandate;
- **Sustainable e-fuel Alliance for Maritime Shipping (SeAMS)**: Establish a GHG reduction certificate system with continuously increasing reduction requirements;
- **Hard-to-Abate Sector Partnership (H2ASP)**: Leveraging LeadIT knowledge brokerage to achieve more specific commitments aiming at investments shifts.

The following table provides an overview of four options and their assessment in terms of the criteria developed for this project (i.e. chances for success and effectiveness; efficiency and costs; transparency and international structures and sustainability and environmental integrity).

Table 1: Overview of options for further promoting the global uptake of synthetic e-fuels

Criteria/options	1 GSDP Global supply-demand-partnership	2 SeKA Sustainable e-Kerosene Alliance	3 SeAMS Sustainable e-fuel Alliance for Maritime Shipping	4 H2ASP Hard-to-Abate Sector Partnership
Chances for success and effectiveness	High	Medium	Medium	High
Efficiency and Costs	High efficiency Medium costs	Medium efficiency High costs	Medium efficiency High costs	Medium efficiency High costs
Transparency, international structures	Low	High	High	Low
Sustainability, environmental integrity	High	High	High	High
Priority	High	Medium	Medium	High

Source: own compilation.

Each of the sketched initiatives could be considered as a separate option. However, since each of the options has its specific focus which all together are required to accelerate the uptake of synthetic e-fuels at the global level, the combination of all options could be considered as an option on its own. The GSDP could be considered as the umbrella initiative, which coordinates activities under the sectoral initiatives aiming at identifying and making use of potential synergies between the three sectors on the one hand and the fuel producers on the other hand.

We therefore recommend that the Global Supply and Demand Partnership (GSDP) is pursued with high priority as a new initiative under the G20 and that the other three other options are integrated into the GSDP. Both, the Sustainable e-Kerosene Alliance (SeKA) and the Sustainable e-fuels Alliance for Maritime Shipping (SeAMS) could spur and accelerate existing discussions on the increased uptake of synthetic e-fuel in aviation and maritime transport under ICAO and IMO, respectively. The Hard-to-Abate Sector Partnership (H2ASP) could build on and enhance the momentum of existing initiatives such as LeadIT, MI and IPHE with the view to enhance the uptake of synthetic e-fuels and/or hydrogen in industrial sectors such as steel, cements and certain chemicals, particularly in developing countries.

1 Introduction

1.1 Relevance of the policy field

The use of synthetic fuels is essential to achieve full decarbonization of economies, especially where options for direct electrification of demand sectors are limited.[1] In this context, synthetic fuels including hydrogen generated from renewable energy, so called electro-fuels or e-fuels, open the possibility of indirect electrification. At the same time the generation of such e-fuels can support integration of variable renewable energy (RE) and thus the transition to 100% renewable electricity supply providing options to enhance flexibility and reliability (Fuentes Hutfilter, et al., 2020).

In Fuentes Hutfilter et al. (2020) we have identified an emerging policy area focusing on so called "hard-to-abate" sectors such as some industry processes, especially chemical industry, and freight and long-haul transport, where synthetic fuels produced from green hydrogen (from electricity generated with RE) plays an important role.[2] This policy area has been gaining momentum based on dynamic technology advances including technologies to produce hydrogen (electrolysers), and is therefore emerging as a key policy area for the achievement of long-term mitigation targets (Fuentes Hutfilter et al., 2020).

The technological process steps for the production of synthetic fuels from RE (e-fuels) are known. But, similar to RE sources about 25 years ago, e-fuels are not yet competitive with fossil fuels and are therefore only available in sufficient quantities for pilot projects. However, strong cost reductions for key technologies such as electrolysers are already noticeable and are expected in the near future, especially if economies of scale are achieved through targeted initiatives. In individual process steps, the technology has to be developed further and made ready for the market. Because the overall efficiency of electric drive systems is 2.5-5 times higher than that of e-fuels (Agora, 2018), e-fuels should primarily be used in areas where electric drives can only be expected in niches in the long term, in particular in aviation and maritime transport. While there is practically no alternative to e-kerosene in aviation, the situation in maritime transport is currently more open, since in addition to hydrogen, ammonia, methanol, etc. can also be used as fuels and they can be used with different propulsion systems including internal combustion engines, turbines and in fuel cells with electric motors. Another area of application for e-fuels that is already very worthwhile in the short and medium term, is the replacement of hydrogen generated from fossil fuels.

1.2 Background and development regarding multilateral cooperation

In order to achieve economies of scale, production quantities have to be increased considerably. Although individual countries, as well as RE sources, can act as pioneers, global coordination of efforts to penetrate the market of e-fuels in terms of production capacity, environmental standards and necessary infrastructure (storage, refuelling, transport, etc.) is necessary in the

[1] Certain synthetic fuels are hydrocarbons. The use of synthetic fuels will – strictly speaking – therefore not lead to decarbonisation. However, if the carbon used to produce synthetic fuels is from non-fossil sources such as ambient air or biomass, their use does not contribute to global warming. In the remainder of this policy paper we therefore "defossilisation" use in the context of synthetic fuels rather than the more common term "decarbonisation".

[2] This policy paper addresses one of four policy areas identified as priority areas for enhanced international cooperation. The other policy papers address the policy fields "energy transition", "sustainable food systems" and "forest protection". Since the increased uptake of e-fuels, among others, depends on the availability of RE, the future development of e-fuels would profit from progress achieved in the global energy transition.

medium term. The topic is highly important on a global scale because most industrialized countries, like Germany, will not be able to meet their long-term needs for e-fuels from domestic production due to the limited realizable and/or competitive potential for the generation of electricity from RE cover. In addition, in other regions of the world, RE electricity and e-fuels can be generated not only in large quantities, but also significantly more cost-effectively than in most industrialized countries. This includes Australia, for example, with an outstanding role as a highly developed industrial country and G20 member, and in geographical proximity and strong trade relations with a large number of countries with high current (e.g. China, Korea, Japan) and future demand (strongly growing regions of Southeast Asia, South Asia with particularly strong growth in demand and decarbonization needs for transport and industry). It can therefore be expected that a new world market for synthetic fuels (or green hydrogen) will establish itself, which in the best case can replace the current fossil fuel-based market. The central role of some industrial processes that cannot be decarbonized by direct electrification (such as iron ore reduction for steel production) for global decarbonization efforts is also relevant for the development of the global green hydrogen market. This raises the question of new global institutions that could advance the development of such a market and replace bilateral activities that are currently taking place between industrialized countries and potential producer countries.

A number of sustainability criteria must be fulfilled when producing e-fuels. These include in particular a exhaustive GHG balance taking into account the entire electricity system characterised by high conversion losses in the production of e-fuels and the need to add additional electricity requirements in planning for expansion of zero emission RE-based electricity generation. In this regard, strong sustainability criteria for the generation of electricity from renewable sources are crucial. The same applies for water demand for the production of e-fuels.

Several countries have already developed hydrogen strategies such as Japan and South Korea, but these are not focused on green hydrogen. Other countries have recently developed hydrogen strategies that address some of these questions. The German Government adopted a national hydrogen strategy (NHS) in June 2020[3] which includes programmes for ramping up hydrogen technologies in Germany and funding for international partnerships. It also refers to the intention to push this topic during the German EU presidency (July-December 2020). Australia has adopted a hydrogen strategy which includes a focus on potential export market opportunities. While the German strategy highlights that "only hydrogen produced on the basis of REs ("green" hydrogen) is sustainable in the long term", the Australian hydrogen strategy is deliberately "technology neutral" and therefore does not favour green hydrogen over hydrogen produced from fossil fuels, while at state level, a number of states have adopted strategies that explicitly focus on green hydrogen.

Various international or multilateral initiatives have been created that focus on either developing the hydrogen economy, such as the Hydrogen Initiative.[4] Some of the more recent initiatives focus on so called "hard-to-abate" sectors.

It is important to look into initiatives for synthetic e-fuels in the context of these broader initiatives, given the strong interlinkage outlined above between market development of e-fuels and other options for using green hydrogen.

1.3 Role of the G20 and other relevant states in the policy field

Some countries, such as Japan, are striving to switch to hydrogen-based drives in road traffic. Hydrogen is also discussed as a seasonal storage and as an energy source for exporting RE from

[3] https://www.cleanenergywire.org/factsheets/germanys-national-hydrogen-strategy.
[4] https://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/hydrogen-initiative.

countries with high potential (Australia, Argentina, Saudi Arabia) to countries with lower potential and high (Japan, Korea) or growing demand (Singapore, in the future possibly Indonesia and other rapidly growing economies in Southeast Asia). This has repercussions on other G20 countries (e.g. Australia as the current main exporter of LNG) and thus on developments in potential exporting countries, the demand for e-fuels (and other applications of green hydrogen). International aviation and maritime transport are a particularly interesting focus as e-fuels are a promising option for decarbonisation, whereas direct electrification is a more efficient option in most areas of land transport.

The analysis must also consider questions of political framework conditions (stability, constitution, etc.) in countries important for post-fossil supply as well as potential future dependencies. At the same time, these play an important role as a framework for multilateral cooperation. Other conditions and obstacles to effective climate protection through multilateral cooperation in the field of electricity-based fuels should also be considered, such as the efforts of the fossil industry to extend business models for the use of fossil fuels, for example through the targeted promotion of so-called blue hydrogen in competition with green hydrogen produced from RE sources (see also current efforts in Australia, for example, to export hydrogen from lignite in a pilot project with Japan).

We also considered to what extent strategic alliances between G20 countries that play an important role in the development of post-fossil fuels (e.g. Germany, Brazil, Argentina, Australia) could emerge as new instruments of multilateral cooperation. It is also conceivable that initiatives from the G20 for cooperation with non-G20 countries that are important for e-fuels, such as Morocco, are proposed (see German NHS).

1.4 Methodology and structure of this paper

In the aviation sector, one starting point for instruments will be cooperation under the International Civil Aviation Organization (ICAO) including the Basket of Measures, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), Sustainable Aviation Fuels, etc. In the case of maritime transport, instruments proposed as part of the International Maritime Organization (IMO) initial greenhouse gas reduction strategy are the focus of the analysis. Beyond these sector specific initiatives, we look into initiatives that focus on developing the hydrogen economy or that focus specifically on "hard-to-abate" sectors including long haul freight transport.

In section 2 of this paper, we provide an overview of current international initiatives for the promotion of e-fuels in international air and sea transport or broader initiatives that are relevant in this context. Based on this screening we consider a selection of four initiatives in more detail, assessing the following criteria elaborated further in the methodology report (Böttcher & Cames, 2021):

- **Chances of success and effectiveness**: What were the general lessons learned, success stories, failures, as well as internal and external hurdles that the initiative has faced? What were the obstacles to political feasibility?
- **Efficiency and costs**: How cost-effective is the abatement potential that the initiative expects to mobilize, and how cost-effective is the initiative's approach for doing so? What are the (transaction) costs of the initiative in question? What other costs and/or benefits need to be considered?
- **Transparency and institutional structures**: Can the initiative be implemented within the existing institutional structures? To what extent does the multilateral framework offer the

possibility of ensuring transparency on the cooperation between states and the resulting emission reductions?

- **Sustainability and environmental integrity**: To what extent does the initiative produce positive or negative ecological effects through the reduction of emissions? Which aspects of the UN Sustainable Development Goals (SDGs) are positively or negatively affected?
- **Scope for improvements and need for additional multilateral cooperation**: What are gaps in the initiative's scope that need to be addressed? Which opportunities exist for the initiative to be expanded to other actors and/or additional countries? How can coherence between initiatives be increased?

We take into account which G20 and other countries play a particularly important role in the field of synthetic fuels, including through particularly advantageous conditions for the production of e-fuels (availability of RE sources, water, geographic location, integration into global transport networks, etc.), such as Argentina, Australia, Brazil or Saudi Arabia. We also analyse the extent to which the existing activities are sufficient to promote the economies of scale in e-fuels and the continuous increase in global production volumes and identify potential gaps.

In section 3, we develop suggestions for further development of international initiatives with a view to closing the mitigation ambition and action gap as discussed in (Fuentes Hutfilter et al., 2020). In addition, strategic recommendations with regard to the perspective of post-fossil fuels in international air and maritime transport and their embedding in the broader perspective of decarbonization of the entire energy system and the role of green hydrogen are developed.

In section 4, we provide an assessment of options for enhanced international activities under the G20, again against the above mentioned criteria and derive conclusions from this assessment.

2 Evaluation of existing initiatives for multilateral cooperation

2.1 Selection of initiatives

Table 2 provides an overview of international activities and initiatives which either directly aim at promoting the use of synthetic e-fuels in aviation and maritime transport or which could in a broader sense be helpful for an increased uptake of such fuels in these sectors. This overview is based on a broad screening of internet sources and expert interviews and takes into account whether the initiative or activity is government driven or includes governments from G20 countries, whether it addresses or promotes technologies which are necessary or helpful for the future use of synthetic e-fuels (e.g. hydrogen), since when the initiative or activity exists and organizations that are members of the initiative or support it.

Table 2: Overview of initiatives in the policy field of synthetic e-fuels

Name of the initiative	Active since	Focus	Membership
1) World Energy Council Germany (WEC-DE)	1924	Technology and fuel open competency network; roadmap study for the intern. development of PtX	67 German companies; member committees in 92 countries
2) International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)	2003	Hydrogen, fuel cells, land-based transport	20 countries, 15 of them G20 members
3) IEA Hydrogen Implementing Agreement (HIA)	1977	hydrogen future in all sectors of the economy through RD&D activities	24 countries, 10 of them G20 member,3 intern. organizations, 5 companies
4) Clean Energy Ministerial (CEM)	2010	Transition to a global clean energy economy	26 countries, 17 of them G20
5) Energy Transition Commission (ETC)	2015	Intern. think tank, focusing on economic growth and climate change mitigation	46 CEOs or presidents from companies or research organizations
6) Mission Innovation (MI)	2019	8 innovation challenges, including renewable and clean hydrogen	25 countries, 16 of them G20 members
7) Leadership Group for Industry Transition (LeadIT)	2019	“Hard-to-abate” sectors in industry (steel, cement, chemicals)	13 countries, 7 of them G20 member, 15 companies
8) Getting to Zero Coalition (GTZ)	2019	Defossilisation of maritime shipping	14 countries, 3 of them G20 member

Source: own compilation.

The overview illustrates that there are only few international initiatives which directly aim at promoting e-fuels in aviation or maritime transport or the "hard-to-abate" sectors. Some of the existing initiatives do not include governments or are research-oriented and do not include on-the-ground activities for the promotion of synthetic e-fuels. Others have a scope which is too broad and does not address the specific requirements of synthetic e-fuels.

Based on this screening of these international initiatives while considering the criteria mentioned above (government involvement, active since, focus, membership), we have selected the international activities 2, 6, 7 and 8 for an in-depth assessment. The summaries of theses assessments are provided below (sections 2.2 to 2.5).

2.2 International Partnership for Hydrogen and Fuel Cells in the Economy

2.2.1 Short description

The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) was initiated by the U.S. Department of Energy and the U.S. Department of Transportation in 2003. Initially it was focusing on Hydrogen only. The promotion of fuel cells was added as an additional goal in 2009. Currently it includes 20 member countries. Most of them are also G20 members. IPHE's mission is "to facilitate and accelerate the transition to clean and efficient energy and mobility systems using hydrogen and fuel cell technologies across applications and sectors" mainly through (1) information sharing, (2) informing future government RD&D and through (3) fostering collaboration.

2.2.2 Chances of success and effectiveness

Due to its focus on 'soft' measures, IPHE does not provide financial support for investment projects and has not adopted GHG mitigation targets. However, in 2005 G8 countries mandated IPHE in the Gleneagles Plan of Action: Climate Change, Clean Energy and Sustainable Development[5] to promote "research and development of technologies and practices that use hydrogen as an energy carrier".

Hydrogen is a key intermediate product for the generation of e-fuels. However, until now IPHE is focusing on Hydrogen as fuel and on fuel cells only and does not address e-fuels at all. Aviation and shipping are so far not in their focus. This can be an obstacle for the promotion of e-fuels but also an opportunity for cooperation, if, for example, the knowledge gathered by IPHE is made available for other initiatives, which focus on e-fuels.

2.2.3 Efficiency and costs

Since IPHE is mainly an information sharing activity, it does not directly contribute to measurable GHG emissions reduction. Accordingly, quantifiably targets such as a date for global defossilisation or a contribution to global GHG reduction efforts have not been adopted.

IPHE's contribution to global GHG mitigation is rather indirect so that neither cost-benefit assessments nor transaction costs can be attributed.

2.2.4 Transparency and institutional structures

IPHE is one of the earliest international activities addressing the topic of alternative fuels. It has gathered valuable experience and build up a network of actors which might be relevant for the

[5] http://www.g8.utoronto.ca/summit/2005gleneagles/climatechangeplan.html.

promotion of e-fuels, since – even if the direct technological focus is different – pursues a similar perspective of defossilisation of the global economy.

IPHE established two working groups (Education & Outreach; Regulations Codes, Standards & Safety) and a task force (Hydrogen Production Analysis) in which representatives of governments and of various NGOs can participate. In addition, it regularly conducts global conferences and web-based seminars.

IPHE member countries report about their activities in the context of IPHE's mission, though the extent of information, data and reports varies considerably between different states.

Since IPHE from its inauguration mainly focused on 'soft' measures, it does not provide estimates of GHG emission reductions induced or achieved. Since education and fostering collaboration is the main goal rather than direct emission reduction, such estimates are likely to include large uncertainties due to the 'soft' nature of the measures conducted by IPHE. However, by the end of 2019, IPHE had held 32 steering group meetings, 14 education & outreach events and several workshops and international forums.

2.2.5 Sustainability and environmental integrity

IPHE's focuses on information sharing with regard to the production and use of hydrogen. It aims at "clean and efficient energy and mobility systems". Some member countries share information about their activities in terms of generating hydrogen from nuclear which may not be considered sustainable by all countries since it involves high societal und environmental risks including through nuclear waste disposal. For e-fuels from renewable sources, however, IPHE's activities may directly or indirectly contribute to SDGs (7) Affordable and Clean Energy, (8) Decent Work and Economic Growth, (9) Industry, Innovation, and Infrastructure, (11) Sustainable Cities and Communities and (13) Climate Action. Due to its education and collaboration focus the impact is likely to be positive but small, though, and depends on the origin of the energy for production processes.

2.2.6 Scope for improvements and need for additional multilateral cooperation

The promotion of hydrogen is currently gaining importance in many countries, as the adoption and publication of several national hydrogen strategies suggests (EU, FRA, CHN, DEU, JPN, NDL, NOR, KOR, GBR, USA).[6] In its 17 year of existence, IPHE may have contributed to paving the way for these strategies. However, currently it is hardly involved in most recent developments. The focus on fuel cells may be too narrow for the broader perspective in which hydrogen is a building block for many other fuels, products, uses and applications. However, due to its track record in developing knowledge and standards for the production of hydrogen, it could support other initiatives rather than being an option for the promotion of e-fuels as such.

IPHE already includes several countries with a likely large potential for generating e-fuels, such as Argentina, Brazil and Norway. For enhancing its effectiveness and outreach it could be considered whether other countries with similar potential, such as Saud Arabia (G20), Qatar or Morocco could be encouraged to join the initiative.

[6] https://www.energynetworks.com.au/news/energy-insider/19-strategies-15-countries-one-element/.

2.3 Mission Innovation

2.3.1 Short description

Mission innovation (MI) was founded 2015 at COP21 in Paris with the aim to "reinvigorate and accelerate global clean energy innovation with the objective to make clean energy widely affordable".[7] It includes 24 countries plus the European Union, which represent 80% of the global clean energy research and development expenditure. Most of its members are G20 countries, though some G20 countries are missing (Argentina, Russia, South Afrika, Turkey). MI's objectives are 1) boosting public-sector investment at national level, 2) increase private sector engagement and investment, 3) enhance cross-border networks and partnerships and 4) raise greater awareness. It focuses on 8 innovation challenges,[8] one of them is renewable and clean hydrogen. Synthetic or e-fuels are not a core focus although some MI member countries mention synthetic fuels in their plans or report of R&D projects or funding opportunities in that technological area. MI is currently considering three new 'missions' for the period beyond 2020, one on Hydrogen and potentially one in defossilising shipping.

2.3.2 Chances of success and effectiveness

Duet to its focus on 'soft' measures, MI does not provide financial support for investment projects. Most mitigation efforts to close the gap occurs at national level of MI member countries. However, coordination of efforts should enhance chances to deliver the global GHG reduction goal. Towards this purpose, an information hub for sharing funding opportunities by MI member countries was established.

MI is primarily an intergovernmental activity. However, the sub-group business and investor engagement enables participation of private stakeholders and aims at encouraging public-private collaboration. It aims at doubling within 5 years the public investment[9] in R&D for clean energy.

2.3.3 Efficiency and costs

Despite its quantitative goal of doubling public investment in R&D for clean energy within 5 years, it is mainly an information sharing activity, which does not directly contribute to measurable GHG emissions reduction. Accordingly, quantifiably targets such as a date for global defossilisation or a contribution to global GHG reduction efforts have not been adopted.

MI's contribution to global GHG mitigation is rather indirect so that neither cost-benefit assessments nor transaction costs can be attributed.

2.3.4 Transparency and institutional structures

MI regularly organizes high-level ministerial meetings. So far, four ministerials plus additional high-level meetings have been held, often in the context of other meeting (COP, UN summits as One Planet or World Economic Forum in Davos). The steering committee includes representatives from each member country and provides strategic guidance to MI's secretariat for implementing its action plan.

MI has established three sub-groups, which enable the participation of private entities and stakeholders: the analysis and joint research sub-group facilitates sharing of knowledge in terms of the innovation challenges, the business and investor engagement sub-group identifies

7 http://mission-innovation.net/about-mi/overview.
8 http://mission-innovation.net/our-work/innovation-challenges.
9 http://mission-innovation.net/wp-content/uploads/2017/06/MI-Action-Plan.pdf.

opportunities for private sector engagement and finally, the ministerial planning team prepares the annual ministerials.

MI member countries report about their activities in the context of MI's mission, though the extent of information, data and reports varies considerably between different states. Since MI focuses on 'soft' measures, it does not provide estimates of GHG emission reductions induced or achieved. However, MI reviews its impact and reports about its activities and to which extent it is on track towards its goal of doubling public investment in clean energy R&D. 2018, in its third year of existence, 55% of that goal had been achieved. In addition, funding for 59 new international collaborations had been mobilized, 100 innovations were identified that could avoid up to 2 Gt CO_2 emissions in 2030 and 46 events on 4 continents involving 4,300 innovators, investors and policy makers had been conducted.

2.3.5 Sustainability and environmental integrity

MI may directly or indirectly contribute to SDGs (7) Affordable and Clean Energy, (8) Decent Work and Economic Growth, (9) Industry, Innovation, and Infrastructure, (11) Sustainable Cities and Communities and (13) Climate Action. Due to its education and collaboration focus the impact is likely to be positive but small, though.

2.3.6 Scope for improvements and need for additional multilateral cooperation

The promotion of hydrogen is currently gaining importance in many countries, as the adoption and publication of several national hydrogen strategies in many countries suggests (EU, FRA, CHN, DEU, JPN, NDL, NOR, KOR, GBR, USA, AUS).[10][11] As IPHE, which it aims to collaborate with, MI's innovation challenge 8 has a strong focus on fuel cell applications. Accordingly, there is little research on synthetic e-fuels. Only few MI members (Germany, India, European Union) have reported of e-fuel projects or shared funding opportunities. One leverage point for enhancing the global awareness of e-fuels could be to underscore the importance of this technology for "hard-to-abate" sectors such as aviation and shipping and to strive for putting this technology higher on the MI's agenda.

MI already includes several countries with a likely large potential for generating e-fuels, such as Brazil, Morocco, Norway and Saudi Arabia. For enhancing its effectiveness and outreach it could be considered whether other countries with similar potential, such as Argentina, Russia, South Africa (all G20) or Qatar could be encouraged to join the initiative.

2.4 Leadership Group for Industry Transition

2.4.1 Short description

The Leadership Group for Industry Transition (LeadIT) is an international public/private collaboration jointly initiated by the Swedish and Indian governments. The expectation of LeadIT as expressed in the original UN press release is the following:

- "ambitious, public-private effort, to ensure heavy industries and mobility companies can find a workable pathway to deliver on the Paris Agreement";
- "bringing together governments and global companies to accelerate the transformation of heavy industry";

[10] https://www.energynetworks.com.au/news/energy-insider/19-strategies-15-countries-one-element/
[11] https://www.industry.gov.au/sites/default/files/2019-11/australias-national-hydrogen-strategy.pdf

- "facilitate early diffusion of technology and support to developing countries in this journey".[12]

Over the early stages of this group's existence (only created in September 2019) the group's key learnings, as reported by the secretariat hosted by the Stockholm Environment Institute, have been those related to how best the group can contribute within the existing framework of initiatives currently working on similar goals. LeadIT's focus on public private partnerships, while emphasizing the importance of political leadership, is believed to be complimentary to the work of other platforms.

2.4.2 Chances of success and effectiveness

The initially planned focus on in-person dialogues as a way to build further partnerships and disseminate knowledge products has had to be rethought in the context of the cancellation and postponement of many forums due to the coronavirus. This has led to the use of alternative media for information dissemination such as the Global Dispatches podcast recorded on carbon lock-in and a web-based seminar held with the deputy Prime Minister of Sweden and the CEO of Scania. The originally planned timeframes for achieving LeadIT's initial objectives have also had to be lengthened, which will allow for deeper collaboration with other initiatives like Mission Innovation and Energy Transitions Commission, as well as greater collaboration with the finance sector, with an aim to now work with the Net Zero Asset Owner Alliance moving forward.

2.4.3 Efficiency and costs

A core aim of LeadIT is to assist governments and industries to co-produce Industry Transition Roadmaps by providing technical assistance and facilitating study trips to expose stakeholders to existing examples of industry transition. These roadmaps and study trips for the purpose of disseminating relevant technical knowledge increase the replicability of any given proposed or underway industry transition, saving valuable time and resources that may have otherwise be spent in partner countries developing this knowledge locally, while spurring innovation where it may otherwise not have occurred.

This reduction in time and resources required for catalysing an industry transition translates into considerable near- to mid-term emissions reductions, crucial for achieving the Long-Term Temperature Goal of the Paris Agreement.

Widespread adoption of new technologies such as e-fuels, electrolysers, direct air capture units etc., brings with it the potential for new manufacturing and export opportunities for countries. These opportunities will potentially come at the expense of existing industries (e.g. fossil fuel extraction, processing), implying that countries more reliant on such industries face potential economic costs and may benefit from fostering such new manufacturing and export sectors.

2.4.4 Transparency and institutional structures

LeadIT, an initiative created jointly by the Swedish and Indian governments, is currently composed of 28 member entities, thirteen countries (out of which six G20 members: Australia, Argentina, Germany, India, South Korea, the UK) and fifteen companies. A majority of the current member countries and companies (nine countries, twelve companies) are European, while three member companies are Indian. Of the twelve European member companies, five of these are Swedish, with the remainder Dutch, Danish, Icelandic, German and British.

LeadIT has acknowledged that in order for the initiative to achieve its desired objectives, there is a need to engage with a broad range of economic and political actors. This includes those from

[12] https://www.un.org/en/climatechange/assets/pdf/release_industry_transition.pdf

both the public and private finance sectors to spur an enabling environment. In this vein, a number of forums and processes have been targeted for engagement and for the timely publication of opinion in high-impact media outlets.

A key priority for LeadIT in addition to the creation of future roadmaps, is the publication and synthesis of data from existing industry transition roadmaps. The output from these syntheses is to be a report and interactive online map that standardizes the content of existing industry transition roadmaps as much as possible according to factors such as: the process used to develop the roadmap, range of actors involved, and key targets and policy levers. The intent behind this is to allow comparison of roadmaps around the world, which will provide an insight into where LeadIT can best offer targeted support. This will also provide a useful framework for the creation of planned future roadmaps.

2.4.5 Sustainability and environmental integrity

Beyond direct CO_2 emissions reductions achieved through fuel switching or adoption of carbon neutral technologies, there are considerable additional environmental benefits on offer through achieving industry transitions.

The removal of coal use in iron and steel production and in industrial boilers would not only reduce environmental damages due to mining and fugitive methane emissions, but also the toxic substances in coal ash that contaminate the local environment where coal is burnt. Replacing marine and aviation fuels with clean e-fuels would ameliorate negative localized impacts in areas of concentrated traffic, like Sulphur-dioxide and NO_x emissions from bunker fuel, and particulates from jet fuel and lead from aviation gasoline that accumulates in the vicinity of airports.

Environmental considerations relating to the nascent green hydrogen industry are also important, as producing hydrogen from electrolysis powered by renewables requires both considerable water resources and land to situate the required RE sources. An examination of how such competition for land and water resources affects each local and regional area is necessary, in particular, the extent to which projects may displace land for food production, forests or conservation purposes.

2.4.6 Scope for improvements and need for additional multilateral cooperation

In the group's nascent state, neither China, nor the US, who combined accounted for roughly half of global CO_2 emissions from industry (IEA, 2019) are members of LeadIT. Given their dominant share of output and emissions, they should be top priorities for recruitment into the group.

With LeadIT membership currently limited primarily to European countries and to European and Indian companies, there is a need to diversify the geographical scope of the initiative. Argentina, India, South Korea, and Australia can provide a regional voice to encourage others in their regions to join.

The 2020 G20 summit is a key opportunity to lobby as a unit to expand membership, with six current member countries part of the G20. The planned EU/China summit (originally planned for September 2020, now indefinitely postponed due to COVID-19 pandemic) that LeadIT are targeting is also an opportunity for representatives of the numerous EU LeadIT members to engage with Chinese officials on the issue of industry transition and present LeadIT membership as a viable option to address it.

The lack of exposure so far of LeadIT activities is an area of potential improvement, as at the time of writing, very little in terms of the groups plans or specific targeted initiatives was available in

the public domain. Despite a meeting of LeadIT members occurring at COP25, reporting of the outcomes or content of the meeting was minimal.

In order for the planned syntheses of existing industry transition roadmaps to be as effective as possible it is important for LeadIT to reach out to organizations, companies, or industry groups in both member and relevant non-member countries in order to first ascertain the current state of relevant knowledge products in existence, and secondly to obtain access to those that would suitably augment the database once it is created. For example, so far not much focus has been put on dedicated multilateral initiatives, rather just dialogue, knowledge brokerage.

2.5 Getting to Zero Coalition

2.5.1 Short description

The Getting to Zero Coalition (GTZ) was launched at the UN Climate Action Summit in September 2019 in New York. It aims at facilitating that maritime shipping achieves the target set out in IMO's initial GHG mitigation strategy of reducing emission until 2050 by at least 50% compared to 2008. Towards this purpose new fuels for zero emission ships need to enter the market by 2030 whilst ensuring a rapid uptake of these technologies, hereafter. GTZ focuses on raising awareness, building and expanding the coalition, developing a shared knowledge base and facilitating the sharing of key findings. 111 companies plus more than 20 other organizations have joined the coalition so far. 14 countries endorsed the coalition, though only few G20 members (France, South Korea, United Kingdom).

2.5.2 Chances of success and effectiveness

Since GTZ is predominantly a non-governmental initiative of companies from the maritime sector, it does not provide financial support for research, development and deployment investments. However, it promotes the introduction of sustainable zero carbon energy sources, which include in addition to biofuels and other REs such as solar and wind, explicitly hydrogen and synthetic e-fuels and works towards the vision of commercially viable and scalable solutions that enable zero emission vehicles by 2030 and rapid growth of this fleet thereafter.

2.5.3 Efficiency and costs

Since GTZ is mainly a joint initiative of companies in the maritime sector, it does not directly contribute to measurable GHG emissions reduction. However, the coalition aims at achieving the GHG reduction goals set out by IMO (-50% GHG emissions by 2050 compared to 2008).

Since GTZ's contribution to global GHG mitigation is rather indirect, neither cost-benefit assessments nor transaction costs can be attributed.

2.5.4 Transparency and institutional structures

GTZ is a non-governmental initiative which is endorsed by several governments; however, it is not a government driven initiative but launched by stakeholders. Stakeholders are therefore involved per definition. It is hosted by the Global Maritime Forum (GMF) but does so far not have administrative structures such as a secretariat.

Due to the fact that it was initiated only in late 2019, there are no reports about its activities or assessment of its impact so far.

2.5.5 Sustainability and environmental integrity

GTZ may directly or indirectly contribute to SDGs (7) Affordable and Clean Energy, (13) Climate Action, (14) Life Below Water and (17) Partnerships for the Goals. Due to its focus on facilitating collaboration and since it was launched in 2019 only, the impact is likely to be positive but small.

2.5.6 Scope for improvements and need for additional multilateral cooperation

In April 2018, IMO adopted its initial GHG mitigation strategy and established the goal to reduce by 2050 the GHG emissions of international maritime transport at least by 50% compared to 2008. Later in 2018, during COP25 in Katowice, Maersk, one of the largest container shipping companies, announced its company specific goal to become carbon neutral by 2050 without using offsets from other sectors. GTZ embarks on this spirit and includes a large number of companies which are active in international maritime transport. Even though the coalition was endorsed by several governments, including several European Member States (France, United Kingdom, Netherlands, Denmark, Finland, Sweden, Belgium Ireland, Poland), it is not an intergovernmental initiative.

However, this may indicate that there is actually a gap of such an initiative at government level and thus a potential leverage point for future activities under the G20.

3 Options for increased multilateral cooperation

The analysis of the selected existing initiatives in section 2 reveals some similarities and differences. Both the IPHE and MI are intergovernmental initiatives which aim at promoting the global development of hydrogen and fuels cells (IPHE) or more generally accelerating innovation of clean energy technologies including hydrogen. They both include 20 or 25 member countries, respectively, most of them G20 members (15/16). LeadIT is a joint initiative of 13 countries and 15 large companies while GTZ is a clearly industry-driven initiative, though endorsed by 14 countries. Involvement of G20 countries in the latter two initiatives is generally lower than in the first two initiatives (LeadIT 7, GTZ 3). France, Great Britain and South Korea are involved in all four initiatives while Australia, Germany and India are involved in three of the initiatives (all but GTZ). Brazil, Canada, China, Italy and the USA are only involved in the government-driven hydrogen initiatives (IPHE, MI).

In terms of technological focus, the first three initiatives clearly focus on hydrogen and related technologies such as fuels cells and hydrolysers, while only the last initiative (GTZ) considers synthetic e-fuels as a key technological option for defossilisation. The existing initiatives mainly promote an exchange in terms of technological knowledge but hardly address regulatory or market structure issues. However, an international coordination of such issues would be particularly important for sectors like aviation and shipping, which predominantly operate beyond national territories.

Regarding sectoral coverage and potential applications for hydrogen or e-fuels, the first two initiatives have at least a bias towards land-based transport and/or buildings while the latter two initiatives focus on “hard-to-abate” industrial sectors (steel, cements, chemicals) and maritime transport, respectively. In terms of history it should be noted that IPHE has a history of more than 17 years while the other three assessed initiatives were all inaugurated only very recently in 2019.

This overview illustrates that the global promotion of synthetic e-fuels for industry and international transport is in its infancy. The existing initiatives are a welcome first step towards enhancing and accelerating the research, development and deployment of these technologies with the view to spur the uptake of e-fuels in those sectors. However, none of the analysed initiatives explicitly focusses on the global mitigation potential of synthetic e-fuels. We, therefore, see the need for considerable additional actions to build on the first wave of initiatives that currently exist.

In this regard, we look at further options to stimulate the attention towards these technologies in the context of the G20. We outline below four potential initiatives, which make use, to the extent possible, of existing structures and interconnect to existing initiatives where appropriate. The outlines of those potential initiatives are first sketches, which should be elaborated in more detail if they should be pursued under the G20. Each of the sketched initiatives can be considered as a separate option. However, certain combinations of these options could be considered as an option on its own for fostering the uptake of synthetic e-fuels at the global level. We have formulated potential names for these four proposed initiatives to distinguish between them more easily.

3.1 Option 1: Global supply-demand-partnership (GSDP)

As with today’s fossil fuels, the future demand for e-fuels can hardly be supplied by generation from Germany or Europe only (WEC, 2018; Ram, et al., 2018). Even though the technical supply potential may suffice, it may, including transport cost, be cheaper to generate e-fuels in regions where the supply potential is even substantially larger than in Germany or Europe and import e-fuels from abroad. Such a strategy could, in addition, facilitate the transition to a post-fossil

economy in countries which are currently heavily depending on fossil fuel exports and/or provide development opportunities for countries in the Global South.

While there is already some international coordination for facilitating global supply of hydrogen as a 'precursor' of e-fuels, an international coordination for initiating the generation of e-fuels globally is lacking so far. And even if hydrogen is required to generate e-fuels it is not sufficient since other inputs such as non-fossil CO_2 are required as well. Therefore, not every site, which would be feasible for electrolyzers, may be appropriate for e-fuel generation as well.

On this background it could be an option to initiate a Global Supply-Demand Partnership (GSDP) under the G20 with the view to facilitate the development of global supply chains for e-fuels. The main aim of GSDP would be to internationally coordinate the development of regulation and market structures, which enable making use of comparative advantages of the involved countries. To ensure that the regulations work it is essential that business sector entities are involved from the outset and that practical experience is gained through the implementation of international pilot projects which involve companies from and sites in several countries.

The initial activities of GDSP could include the issues listed below:

- **E-fuel generation potential atlas**: This overview of regional conditions relevant for the generation of e-fuels (solar and/or wind potential, availability of appropriate areas and water, etc.) aims at identifying the most attractive regions for e-fuel generation. The analysis would not start from scratch but commissioning and adopting an update of existing analysis (WEC, 2018; Ram, et al., 2018) under GSDP would ensure 'ownership' of the information and could contribute to outreach and expansion of this initiative.
- **Sustainability criteria**: e-fuel generated from fossil fuels would increase global GHG emissions rather than reducing them (Kasten, Heinemann, Seebach, & Sutter, 2019). To ensure e-fuels reduce GHG emissions and contribute to the sustainable development goals (SDG) a GSDP initiative should elaborate and adopt a clear and comprehensive set of criteria (additional RE capacities, non-fossil input factors such as CO_2, water supply, etc.) and a detailed set of guidelines for monitoring these criteria.
- **Guarantees of origin**: e-fuels can be generated through different production routes involving different input factors. To ensure that e-fuels comply with the above-mentioned sustainability criteria, a system of guarantee of origin should be established. This would include issuance of certificates and a registry where the supply chain of an e-fuel unit can be tracked from its generation to its use. Insights from the discussions around the CDM could provide impetus for the conversion of requirements for the production of synthetic e-fuels into certifiable criteria, which are laid down in the context of a multilateral process.

While the GSDP initiative would likely be most effective if it was endorsed by all G20 countries, it could still develop some significant momentum if it initially involved some of the important supply and demand countries. On the demand side, the European G20 members (France, Germany, Great Britain, Italy) would be potential candidates. On the supply side, Australia, China and Saudi Arabia (WEC, 2018, p. 46) might be interested candidates which could be convinced to join the initiative from the outset. Beyond G20, Chile, Morocco and Norway might be interested in joining the GSDP initiative.

For the initiation it would be important that energy, environment and/or climate ministers kick-start the initiative in the context of a high-level inauguration event. However, for ensuring continuity and effectiveness it would be important to establish a structure such as a secretariat

which takes care of the tasks in between international gatherings. Such a secretariat could be established at one of the funding members or at existing international organizations, such as the IEA or IRENA. Despite the fact that non-OECD countries such as China have less reservations against OECD than 10 years ago, IRENA as an UN body may me more appropriate to host the GSDP's secretariat.

The activities outlined above would mostly require in-kind contributions of the GSDP member and only a limited amount of financial resources would be required to establish and maintain a specific secretariat. However, to gain momentum it would be important that the global demand for e-fuels increases continuously. If such an increasing demand would not be ensured from the other options suggested above, it would be important to establish a mechanism under the GSDP initiative. This mechanism could, for example, initially be based on public procurement of the participating countries or fuel mandates or Carbon Contracts for Difference (CCfD) based subsidies for the generation of e-fuels as described in more detail in the options below. To make use of synergies, such funding initiatives could build on platforms, which are currently developed under the German Hydrogen Strategy[13] for building an international hydrogen market.

3.2 Option 2: Sustainable e-Kerosene Alliance (SeKA)

Even though e-kerosene is one of the most promising technological options for defossilising aviation (LBST & BHL, 2016), this technology received little attention under ICAO so far. ICAO is focusing on conventional biofuels despite the fact that their availability and their GHG reduction potential are limited due to their competition with food production for arable land and due to GHG emissions induced through indirect land use change (ILUC), respectively. While there are several activities such as working groups, conferences and publications on biofuels, there are hardly any activities on e-kerosene. ICAO's Sustainable Aviation Fuel Guide (ICAO, 2017), for example, provides comprehensive background for all types of biofuels but does not mention synthetic e-kerosene at all. At the 40th Assembly there was just one information paper submitted by Germany, which addressed the reduction potential of e-kerosene (ICAO, 2019b).

Seemingly, the discussion processes under ICAO are too slow to keep pace with the speed of these technological developments. An initiative outside ICAO, for example in the context of G20 could fill that gap. The Sustainable e-Kerosene Alliance (SeKA) would aim at promoting the accelerated uptake of e-kerosene for aviation.

While research and development are important for making new climate neutral technologies basically available for the market, the larger share of technological learning is usually made when new technologies are more and more deployed in the field. Even though certain steps in the generation process of e-kerosene, such as direct air capture (DAC), are still in their infancy, the generation technology is advanced enough for an extended deployment in the field. This can be achieved through a combination and staged introduction of policies which create increasing demand for e-fuels. Such policies could include pilot projects, public procurement, a blending mandate or drop-in quota or subsidies which would make e-kerosene compatible with fossil kerosene. To ensure efficient use of these subsidies, they could be auctioned through so called Carbon Contracts for Difference (CCfD), which avoid free riding by potential suppliers.

Particularly a continuously increasing fuel mandate or drop-in quota could be an effective tool for triggering and achieving the full phase-out of fossil kerosene. However, if applied unilaterally by one country or a small group of countries, plane operators could at least partly evade the requirements through tankering strategies. One aim of the SeKA would be to ensure a coordinated

[13] https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6, particularly measures 34-38.

approach for such a policy in preferably all but at least a larger number of the G20 countries. Since G20 countries cover the large majority of global aviation traffic (ICAO, 2019a), such an initiative could certainly limit the potential for evasion and thus make such a policy more effective. Such G20 first mover approach should pave the (run) way for finally adopting such a continuously increasing drop-in quota under ICAO. However, even if G20 may be quicker than ICAO, coordinating such an initiative would take some time. To not postpone any demand for e-kerosene until the coordination among G20 was successful, a group of interested G20 countries could focus on and coordinate their pilot projects and/or public procurement programs, with which they could for example cover the total fuel demand of all government and/or military fights.

In addition, SeKA could spur activities under ICAO towards making synthetic e-kerosene eligible under CORSIA and towards certification of e-kerosene drop-in quotas beyond 50%. Since e-kerosene is a hydrocarbon, which is quite similar to fossil kerosene, the existing supply infrastructure (tanks, pipelines, etc.) can basically be used further. However, there are small differences in terms of aromatic compounds which may cause some difficulties during the transition phase. SeKA could trigger discussion under ICAO and provide input to these discussions with the view to solve any upcoming issues in this context as soon as possible.

Since ICAO is the appropriate body to internationally coordinate policies and activities for the promotion of e-kerosene, no separate structure for SeKA may be necessary. SeKA may rather be working in parallel to ICAO with the view to facilitate and accelerated discussions related to increasing up-take of e-kerosene. The financial resources to establish and maintain SeKA are certainly limited and may even be negligible. However, investing in pilot projects or procuring e-kerosene for public purposes will require additional government expenditure. But it can be expected that the shares of these amounts in the overall government budgets are small, so that there may be no need to harmonize such activities among SeKA member countries.

3.3 Option 3: Sustainable e-fuel Alliance for Maritime Shipping (SeAMS)

There are similarities but also differences in terms of synthetic e-fuels between aviation and maritime shipping. Both will require extensive use of e-fuels for defossilisation and both sectors are difficult to regulate because they operate on international territories so that all states have to agree on their regulation. However, technology-wise there are significant differences: energy density in terms of weight and volume is an issue for maritime transport but they are less important than for aviation. Alternative fuels with lower energy density will reduce transport capacities and/or require more frequent tankering. Moreover, ships are – different to planes – not produced in series but individually designed and build for purpose. On the one hand, this basically enables retrofitting of many existing ships and/or installation of dual fuel propulsion systems which provides flexibility during the transition phase towards defossilisation of maritime transport. On the other hand, this provides for a multitude of potential alternative fuel and propulsion systems combinations[14] so that it is currently less clear than in aviation which will be the dominating technology or technologies to reduce GHG emissions in maritime shipping. And since the future is likely to be fundamentally different to current fuels, redesign of existing and building of parallel tank infrastructures may be necessary.

In terms of political regulation maritime shipping seems to be somewhat ahead of aviation. While aviation was, with adopting CORSIA at ICAO's 39th Assembly (ICAO, 2016), the first sector which established an international market-based policy to regulate GHG emissions, IMO adopted in 2018 with its initial GHG mitigation strategy (IMO, 2018) the target to reduce GHG emission by at least

[14] Fuels: hydrogen, ammonia, methanol, e-diesel, etc.
Propulsion systems: internal combustion engine, turbine, fuel cell, electro motor, etc.

50% compared to 2008 by 2050 and to aim for phasing them out as soon as possible in this century in consistency with the Paris Agreement. While the short, medium and long-term policies to achieve this goal are still under discussion, the sector has a clear perspective and that seems to trigger more activities towards achieving that goal than in the aviation sector. In 2018, Maersk, one of the largest container shipping companies, announced to fully defossilise its fleet already by 2050.[15] In 2019, IMO established a "dedicated workstream for the development of lifecycle GHG/carbon intensity guidelines for all relevant types of fuels. This could include, for example, biofuels, electro-/synthetic fuels such as hydrogen or ammonia, etc.".[16] Prior to the establishment of this workstream, IMO had conducted a symposium with a specific focus on the "role of alternative fuels in the decarbonization of international shipping".[17] In parallel to these developments, the Getting to Zero Coalition (section 2.5), a non-governmental initiative of more than 100 companies from the maritime sector was also founded in 2019.

As an option to support these existing activities and to further promote the uptake of synthetic e-fuels in international shipping a Sustainable e-fuel Alliance for Maritime Shipping (SeAMS) could be initiated under the G20. Its focus would be to spur and accelerate the identification of the dominant fuel-propulsion-system combination(s) with the view to coordinate the timely development of the required global fuel supply infrastructure. The main activities which could be supported or initiated are listed below:

- Develop stringent sustainability criteria including land and water requirements and a GHG emission methodology to determine lifecycle GHG reduction and cost per t GHG;
- Conduct a lifecycle assessment of e-fuel propulsion-system combinations in terms of GHG reduction and costs;
- Coordinate a limited period of competition between technologies with the view to identify the potentially dominating technologies;
- Asses the global distribution of e-fuel generation potential;
- Coordinate the development of global supply infrastructures.

While some parallelism of different fuel-propulsion-systems may support resilience of the sector, the current multitude of options is certainly not sustainable. Until it becomes more obvious, which technology will become dominant and which will not survive it would be inappropriate to subsidize the development of long-lasting infrastructure from government budgets.

However, to accelerate the emergence of a dominant technology it might be necessary to trigger some deployment of the different competing fuel-propulsion-systems. Since most of them cannot be dropped into fossil fuel as in aviation, the establishment of a pure fuel mandate will hardly work towards this goal. For some vessels retrofitting or amending their propulsion systems may work while others are unable to switch to another fuel. However, a technology open GHG reduction requirement based on tradable certified reduction units might work. The number of certificates to be issued could be determined on the basis of the lifecycle emission methodology mentioned above. Ships that cannot fulfill the reduction quota would be required to purchase certificates from other ships which outperform their requirements. Such a system of tradable certificates is certainly more complex than a simple drop-in quota. However, it could promote competing fuel-propulsion systems and accelerate the emergence of dominant systems. Since the

[15] Financial Times, 05/12/2018, Maersk pledges to cut carbon emissions to zero by 2050, https://www.ft.com/content/44b8ba50-f7cf-11e8-af46-2022a0b02a6c.

[16] http://www.imo.org/en/MediaCentre/PressBriefings/Pages/26-ISWG-GHG.aspx.

[17] http://www.imo.org/en/About/Events/Pages/Symposium-on-IMO-2020-and-Alternative-Fuels--.aspx.

development of such a tradable certificate scheme is more complex and may even provide more options for evasion through tankering strategies, a coordinated effort of several countries would considerably enhance the effectiveness of such an approach. A coordinated approach with several or all G20 countries supporting the establishment of such a certificate system would increase the likelihood of finally adopting such a global scheme under the IMO.

Since IMO is the appropriate body to internationally coordinate global policies and activities for the promotion of e-fuels, no separate structure for SeAMS may be necessary. SeAMS may rather be working in parallel to IMO with the view to facilitate and accelerated discussions related to increasing up-take of e-fuels. The financial resources to establish and maintain SeAMS are certainly limited and may even be negligible.

3.4 Option 4: Hard-to-Abate Sector Partnership (H2ASP)

This initiative could leverage the efforts of existing initiatives that focus on technology development through learning networks, as well as exchange between governments and industry. The added value of a new partnership would be to aim for more specific commitments consistent with the Paris Agreement and action plans focusing on actors such as governments, industry, investors, for example in relation to emission reductions to be achieved, or investment shifts. Existing initiatives, and in particular the recently initiated LeadIT could be used as a starting point, but also the broader and more visible MI and the much more established traditional IPHE.

The idea would be to move a step beyond the knowledge brokerage and exchange that is undertaken by existing initiatives and develop a more targeted and committed initiative. It could build on the existing link to research and development, but bring on board some other actors such as civil society and trade unions, for example linking it to the issue of growth, economic development and employment opportunities (e.g. New Economy), as well as sustainable development particularly in emerging economies. India as one of the founders of LeadIT would be an important actor. An important theme is technology deployment and appropriate international cooperation, avoiding the pitfalls and learning from the experience of the decade long discussions on "technology transfer".[18] Here there are potential synergies with the actions of LeadIT, as its planned Industry Transition Roadmap knowledge products have the potential to act as sources of guidance for local requirements and to highlight ideal candidates for early interventions, especially given the organization's initial focus on the Indian context.

Another potential stakeholder in the development and ongoing operation of such a proposed new initiative is the United Nations Industrial Development Organisation (UNIDO). A core focus of UNIDO is the deployment and implementation of sustainable technologies in developing countries and emerging economies. To do so, UNIDO often engages with and funds external organizations tasked with executing projects on the ground. An example is its cooperation with the Renewable Energy and Energy Efficiency Partnership (REEEP), an international multilateral partnership based in Vienna, Austria, with 359 members including governments, international organizations, foundations, academic institutions and companies. REEEP leverages UNIDO funding originating from various national governments to facilitate the global deployment of sustainable energy solutions in developing countries.

If a UNIDO mandate was established focusing on the development of markets and technologies necessary to advance synthetic e-fuels, it would create an opening for an organisation to work in partnership with UNIDO channeling public funds into high impact projects in developing countries. Such an approach would also assist with capacity building in targeted countries, a

[18] https://unfccc.int/topics/climate-technology/the-big-picture/what-is-technology-development-and-transfer.

crucial factor to ensure the necessary ongoing investment in and scaling up of these technologies. The design of any new organisation should consider the existing UN-affiliated mechanisms engaged in assisting technology transfer such as: UNIDO International Technology Centres (ITCs) and Investment and Technology Promotion Offices (ITPOs), the Global Network for Resource Efficient and Cleaner Production (RECPnet), and the UNIDO-UNEP Green Industry Platform, to prevent any duplication of efforts.

Regarding the potential structure and administration of any new initiative, consideration should be given to the likely benefits of establishing a dedicated, full-time organisation that is able to ensure continuity of effort and the ability to scale up as necessary. The impetus for a focus on tangible goals of emissions reductions and/or scaling up of investment may not lend itself to a looser affiliation of actors with an external organisation contracted for the role of secretariat, as has been adopted by some other multilateral initiatives.

In this regard, Germany's recently established international PtX Hub could be instructive.[19] It will be managed by Germany's well-funded Organisation for International Cooperation (GIZ) and will act as its central hinge to implement an internationally coordinated approach to the development of synthetic e-fuels.

[19] https://ptx-hub.org.

4 Conclusions and recommendations

The use of synthetic e-fuels or hydrogen produced from renewable energies is essential to achieve full decarbonization of economies, especially where options for direct electrification are limited, particularly aviation and maritime transport but also several "hard-to-abate" industrial sectors such as steel, cement and certain chemicals.

Since the required transition towards decarbonized economies cannot be triggered by individual countries alone, international coordination of activities towards this goal is essential. G20 is one of the most appropriate forums for such coordination. In this paper we analysed the current landscape of international activities aiming at promoting the increased use of synthetic e-fuels and suggest options for enhancing international cooperation.

This analysis of the landscape illustrated that the global promotion of synthetic e-fuels for industry and international transport is in its infancy. The existing initiatives are a useful attempt to establish some initial momentum for enhancing and accelerating the research, development and deployment of these technologies. However, there is an identified need for significant enhancements to existing initiatives, and for additional multilateral initiatives with goals that have a greater potential for achieving the necessary emissions reductions or scaling up of investment that are in line with the goals of the Paris Agreement. We therefore outline four potential G20 initiatives for promoting the increased uptake of synthetic e-fuels. Table 3 provides an initial assessment of the expected performance and impact of these options.

The contribution of each of the initiatives to global GHG mitigation and sustainable development cannot be quantified but is likely to be significant. However, to ensure this it is important that all initiatives for the promotion of synthetic e-fuels and hydrogen pursue stringent criteria in terms of global GHG impacts as well as in terms of land and water use for the assessment of induced activities. It is essential that only energy from renewable sources is used for the production of synthetic e-fuels and hydrogen.

Each of the sketched initiatives could be considered as a separate option. However, since each of the options has its specific focus which all together are required to accelerate the accelerated uptake of synthetic e-fuels at the global level, the combination of all options could be considered as an option on its own. GSDP could be considered as the umbrella initiative, which coordinates activities under the sectoral initiatives aiming at identifying and making use of potential synergies between the three sectors on the one hand and the fuel producers on the other hand.

We therefore recommend that the Global Supply and Demand Partnership (GSDP) is pursued with high priority as a new initiative under the G20 and that the other three other options are integrated into GSDP. Both, the Sustainable e-Kerosene Alliance (SeKA) and the Sustainable e-fuels Alliance for Maritime Shipping (SeAMS) could spur and accelerate existing discussions on the increased uptake of synthetic e-fuel in aviation and maritime transport under ICAO and IMO, respectively. The Hard-to-Abate Sector Partnership (H2ASP) could build on and enhance the momentum of existing initiatives such as LeadIT, MI and IPHE with the view to enhance the uptake of synthetic e-fuels and/or hydrogen in industrial sectors such as steel, cements and certain chemicals, particularly in developing countries.

Table 3: Overview of options for further promoting the global uptake of synthetic e-fuels

Criteria/options	1 GSDP Global supply-demand-partnership	2 SeKA Sustainable e-Kerosene Alliance	3 SeAMS Sustainable e-fuel Alliance for Maritime Shipping	4 H2ASP Hard-to-Abate Sector Partnership
Activity	Establishing global supply and demand chains for e-fuels	Establish a global continuously increasing e-fuel mandate	Establish a GHG reduction certificate system with continuously increasing reduction requirements	Leveraging LeadIT knowledge brokerage to achieve more specific commitments aiming at investments shifts
Chances for success and effectiveness	High	Medium	Medium	High
	Post-fossil alternative for potential supply countries	May take time, rather in the longer term	May take time, rather in the longer term	Example of similar successful initiative in renewable energy domain e.g. REEEP
Efficiency and Costs	High efficiency Medium costs	Medium efficiency High costs	Medium efficiency High costs	Medium efficiency High costs
	Coordinated approach could accelerate economies of scale	Specific reduction costs are high but could be reduced through economies of scale	Specific reduction costs are high but could be reduced through economies of scale	Substantial investment needed to establish and operate dedicated, organization
Transparency, international structures	Low	High	High	Low
	Establishment of new structures	Support of existing ICAO structures	Support of exiting IMO structures	Establishment of new structures
Sustainability, environmental integrity	High	High	High	High
	With stringent sustainability criteria	With stringent sustainability criteria	With stringent sustainability criteria	With stringent sustainability criteria
Priority	High	Medium	Medium	High
	Could develop new momentum due to win-win situation	Should be pursued to spur developments under ICAO	Should be pursued to spur developments under IMO	Could help address long-standing and critical issue of technology transfer

Source: own compilation.

Due to the focus on comparative advantages, both supply countries (Australia, China and Saudi Arabia from G20 plus Chile, Morocco and Norway as non-G20) and demand countries (France, Germany, Great Britain, Italy, Indonesia, Japan and Korea form G20 plus Singapore and Thailand from non-G20) could profit from this initiative and would be potential allies for kick-starting this initiative under G20.

However, given the core role India had in initiating MI and the fact that if will be G20 presidency in 2022, India would be a key partner country for initiating this activity. Germany will be G7 presidency at the same time and the global promotion of hydrogen and synthetic e-fuels is already identified as one of the core topics. Such joint effort with India might also ensure that this initiative integrates the developed and developing world and is not dominated by countries from the OECD.

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