The Dawn of a Geopolitics of a Hydrogen-based Economy. The Place of European Union

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Abstract: *As the world economy is confronted with the urgency of climate change, the emergence of new technologies and a redefinition of the balance of power, one of the areas that attracts more and more interest is that of the hydrogen-based economy. The paper proposes a classification of participants into 4 categories and analyses their current and announced strategies and actions related to the utilization of hydrogen in economy. At the same time, the paper offers some arguments in relation to the complementary nature of electrical battery and hydrogen-based utilizations in economy. The global distribution of the key players reflects an important asymmetry and supports the idea of the emergence of a new type of balance of power and of international relations which will translate into a new geopolitical map of the world. In this context, the European Union emerges as one of the main participants in the energy transition towards the goal of net zero carbon emissions in 2050 and even if there are great differences in the degree of preparedness among the member states, the conclusion is that all of them should participate at the earliest stage possible.*

Keywords: *hydrogen economy, hydrogen society, energy transition, geopolitics, net zero carbon emissions.*

JEL classification: *F23, F64, O33, Q42.*

1. Overview: some clarifications regarding concepts and terminology

The concept of geopolitics has a broad range of meanings and carries with it a considerable clout: usually it is correlated with great powers, international politics, spheres of influence and the like. The multitude of interpretations raises the need to clarify the focus of this approach in order to avoid unfulfilled expectations or, even worse, misunderstandings. Encyclopaedia Britannica defines geopolitics as "the analysis of the geographic influences on power relationships in international relations" (Deudney, D.H., 2013), while Geopolitical Futures, a private intelligence organization, uses a more comprehensive approach, starting from the observation that "human life is defined by place" and proposing a sui generis definition of geopolitics as: "the earthly affairs of the city" or in a more didactical sense: "the study of human communities living in a defined space". (Geopolitical Futures, 2018).

It is interesting to mention that in a historical period of intense technological changes during and after the First Industrial Revolution, approximatively between the second half of the 19th century and the end of the First World War, **geopolitics was often regarded from the perspective of new technologies' impact on international politics of great powers**.

This fact is of interest today, 100 years since the end of the First World War, because humankind **faces another period of major technological changes**, and both international organizations (like World Economic Forum), think-tanks (like Chatham House, European Council of Foreign Relations or Atlantic Council) or individual

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experts support the idea that this fact will influence geopolitics (Kastner, A., 2021). Great technological changes, the access to them and, equally important, the capacity to use them on a large scale have always been related to the decline, consolidation, or redefinition of regional or global powers, function of their position vis-à-vis those changes. A classic example is that of the rise of the British Empire (Alonso-Trabanco, J.M., 2020) in relation to the emergence and adoption of new technologies. Anyway, while the emergence of new powers (regional or global, according to each historical period) is mostly related to economic and military powers and the capacity to project these powers at a distance, before the expansion and consolidation of economic and military powers, there is the emergence, expansion and consolidation of technological changes of a disruptive nature (sometimes called "frontier technologies").

The impact of technological changes seems so great during this decade, that the Atlantic Council named this period the "Geotech Decade" and argued that, while opportunities seem to be great, the threats could be even greater, from increased inequality to expansion of competition and conflict into new spaces, such as cosmic and cyber space (Atlantic Council, 2021). **Two remarks** from the conclusions of the Atlantic Council's Report of the Commission on the Geopolitical Impacts of New Technologies and Data seem relevant for this research: **the first** is that "In the coming GeoTech Decade, data and technology will have a disproportionate impact on geopolitics, global competition, and global opportunities …"; **the second**, which represents one of the final recommendations, states that the United States administration should: "guide technology cooperation and sharing with nondemocratic nations based on respecting democratic values" (Atlantic Council, 2021). While the first conclusion is somehow self-evident, the second one invites to reflection and pragmatism, as any country of the world will operate in a global environment where other actors, with other values and cultures, manifest themselves and where prudent cooperation is better than confrontation.

Based on the above considerations, **the concept of "geopolitics"** in the context of a hydrogen-based economy will be used in the sense of a **map of the world** where aspects related to production, distribution and utilization of hydrogen **will influence the relative position of the major and minor players and their decisions**, will redesign the regional and global balance of power, and will influence the international relations of individual political entities.

In the above interpretation we use the metaphor of **"map of the world"** to underline the importance of place, of location in the sense of available resources, but also in the sense of the extent to which these resources are capitalized. From the point of view of this approach to geopolitics, the relative power of each political entity will be, once again, determined by **"what you have, and what you do with what you have"**. New technologies but also the impact of climate change determine a shift towards new sources of energy, new industrial processes, and new means of transport, even a new way of life. From a certain perspective, the nature of some of the green sources of energy (such as solar, wind, or biomass) creates much more favourable circumstances for almost all nations of the world, because these green sources of energy **can be found in many more locations** (in fact, in almost all locations) than coal, oil and gas. On the other hand, the mere existence of such green energy sources does not automatically translate into energy: political decisions must be made, and financial, technological, and human resources must be available.

From this difference between the existence of green sources of energy and their capitalization (that is **from potential to conversion into reality**), comes the geopolitical interpretation of the hydrogen-based economy. As in many other cases, the existence of potential green sources of energy is not always accompanied by the existence of the means to utilize them. Under these circumstances the entities that have the financial, technological, and human resources will seek to exploit the opportunities from their countries or from abroad. The states with less resources may negotiate with the interested parties either the exploitation of green resources and/or the placement of the distribution networks on their territories. Almost everybody has something to negotiate but not everybody will be able to do so.

Another concept that needs a clarification in the context of this research is that of the **"hydrogen-based economy"**. We must state from the very beginning that this concept is rather misleading. To the reader unfamiliar to the subject, it may give the impression of a situation in which hydrogen will replace entirely or almost entirely classic sources of energy like oil or natural gas, which is not the case.

At the same, there is ample evidence in support of the use of the "hydrogen economy" or "hydrogen-based economy". The official documents of the European Union (strategies, directives, reports), as well as of many important players of the world economy (United States, Japan, Germany, United Kingdom, South Korea, Russia, etc.) use the term "hydrogen economy"; it is interesting to mention that Japan goes beyond the concept of hydrogen economy and has set in 2017 the goal of becoming a "hydrogen society" (Kashiwagi, T, 2017). Therefore, discussing about "hydrogen economy" is not proposing a new concept or envisaging a potential scenario, but analysing the implications of official decisions that have billion dollars budgets and are in the course of implementation.

The official documents of the European Parliament and European Commission present the hydrogen economy like one in which the role of hydrogen is (at least for the moment) that of an **energy carrier** that can be used in **a variety of situations that otherwise are difficult to become carbon neutral**, such as metallurgy, production of construction materials like cement, heavy transport (including river and sea transport, as well as railways, heavy trucks and even aviation), energy storage, public and home heating. The list of possible utilizations of hydrogen is extremely large and the number of real-life applications is continuously growing. **In essence, as it results from above, hydrogen is already used and will be used in economic activities where electrical batteries are not feasible or not applicable**.

One important aspect is that, while at present hydrogen is **just an energy carrier**, in the future **it may become a source of energy** (like wood, coal or oil), by means of direct production from solar energy. Promising results have already been obtained in the field of **artificial photosynthesis** (which is also called "direct solar water splitting" or "photo-catalytic water splitting"), which allow sunlight to directly dissociate water (including sea water) into hydrogen and oxygen with the help of a catalyst made of commonly available materials like silicon and gallium nitride (Chowdhury, F.A., Trudeau, M.L., Guo, H., Mi, Z., 2018). In essence, artificial photosynthesis uses solar energy, carbon dioxide from the air and water from the environment and generates electricity and hydrogen (Slav, I., 2020).

One of the major consequences of artificial photosynthesis would be that **the energy from the sun would be converted directly into hydrogen**, without the need of transforming solar energy into electricity and then storing electricity in batteries (as it happens today). The mentioned method will also allow for the conversion of carbon dioxide into methane, methanol, formic acid, or synthetic gas. An even more interesting aspect is that this method increases its efficiency of conversion in time, instead of decreasing it, as it happens with a lot of other catalysts (Moore-Michigan, N.C., 2021).

Artificial photosynthesis, even still in its early days, has an efficiency rate equal or higher than that of natural photosynthesis (3% for the artificial photosynthesis compared to a minimum of 0.1% for natural photosynthesis and an average of 2.9 – 6%). In order to understand the size and importance of natural photosynthesis by which plants and organisms convert solar energy into chemical energy that can be further used as required, enough is to mention that natural photosynthesis convert into chemical energy about 100 TW of energy from the sun every year, this amount being 6 times larger than the whole energy demand of the world population (Abas, N., Kalair, E., Kalair, A., ul Hasan, Q., Khan, N., 2020).

In our opinion, an important aspect is that fundamentally **hydrogen-based utilizations are not in competition with electricity/battery-based utilizations**. In fact, the two approaches are complementary. Hydrogen is more versatile as it can be used:

- for obtaining electricity (in fuel cells);
- for storing electricity for long periods of time;
- as a fuel (for heating homes, in metallurgy, production of construction materials, etc.);
- as an input in chemical industry (for instance for producing ammonia which can be used for transporting hydrogen or as a fuel).

Since the moment electricity is obtained (either from batteries loaded from various sources or from hydrogen used in fuel cells), the rest of the equipment is the same (be it electric cars, electrical appliances at home or electrical industrial equipment). A TV set, an electric oven or an air conditioning unit will be just the same and will function just the same, irrespective of the fact that electricity comes from a hydropower station, a nuclear station, from photovoltaic cells, from a wind turbine or from fuel cells using hydrogen.

Therefore, whatever options would be available as regards the generation and transport of electricity, the tools and equipment using electricity would be the same. It is true that because the transition towards green sources of energy involves huge amounts of money, there is a fierce competition for funding, and it is not rare the case that advocates of one side or the other (electrical batteries versus hydrogen based technologies) may try to demonstrate that one solution is better than the other. Based on the analysis of literature and of the technological applications already in use, our opinion is that the two approaches (electrical batteries and hydrogen technologies) will coexist and be complementary.

2. Methodology

The purpose of this research is to identify and classify the significant players in the forthcoming hydrogen economy from the point of view of their technological capabilities, market power, main competitive advantages and their determinant place in the hydrogen value chain. With this goal in view, we decided to analyse several aspects based on data available until mid-year 2021. These aspects refer to:

- The existence of hydrogen strategies or similar plans at the level of major economies or integration organizations (such as European Union);
- The global distribution of hydrogen related projects;
- The global distribution of hydrogen refilling stations;
- The European distribution of networks for hydrogen transport;
- The existence of business associations including large and very large multinational companies from energy, technology, oil and gas, public utilities/ distribution sectors.

Based on the existence and distribution of the above aspects, and considering the trends manifested in the last 5 to 10 years, we aim to draw some conclusions regarding the key players and at the same time competitors in the hydrogen related economic activities, as well as their global distribution. In the context of this analysis, one point of interest will be the determination of the place and competitive advantages of the European Union.

We have chosen this approach because all the aspects considered are based on reality, either in an **absolute sense** (existence of electrolyser capacities, of business associations, of hydrogen refilling stations, of networks for hydrogen transport, etc.) or **in a relative sense** (the case of hydrogen strategies that are to be implemented until 2030 or of the electrolyser, distribution networks or refilling stations that are in operation or at different stages of maturity).

3. Hydrogen-based economy: the main players and their global distribution

The utilizations of hydrogen in view of creating a more environmentally friendly economy are already numerous and they will be more and more diverse and used on an ever-larger scale. As mentioned above, hydrogen can be an energy carrier, a means of energy storage, an input for chemical industry, and so on. These utilizations are already found in numerous industries: energy, transport of all types, metallurgy, construction materials, chemical, etc. Given this broad scope of utilization and the high number of economic sectors involved, it is normal that the number of players (both on the supply and the demand side) is and will be very high. In fact, almost **all players** involved in economic activities are to be found in one way or another in the hydrogen-based economy.

Under these circumstances we propose a classification of these big players into 4 categories:

1. **Players on the energy supply side** (those that will produce hydrogen by whatever means possible and acceptable). In this category one can find public or private companies, in many cases with previous experience in energy production, but also oil and gas companies or large investment funds that perceive a long-term opportunity.
2. **Players on the energy demand side** (those that will use hydrogen for industrial, public, and domestic purposes). This category is very broad and includes all industries (as all of them will replace faster or slower and to a larger or a smaller extent the fossil fuels), public administrations, domestic consumption (households).
3. **Suppliers of technologies and equipment** (usually large, transnational companies already involved in production of energy generating equipment, transport vehicles (including ships and planes), infrastructure components for storage, distribution and selling of hydrogen, etc.
4. **Suppliers of scientific and technological results related to production, transport, and utilization of hydrogen** (institutes and other public or private research centres, universities, technological companies). This group is essential for accelerating the transition to a hydrogen-based economy and its results refer to new materials that allow higher efficiency in the production of hydrogen, materials for artificial photosynthesis, for fuel cells, for distribution of hydrogen via pipeline networks, as well as various materials and technologies related to electrical engines, combustion engines using hydrogen or ammonia, metallurgy, and so on.

The players from categories 3 and 4 **overlap to a certain extent** (as some suppliers of technology and equipment carry out themselves research activities), but they do not coincide entirely as research institutes and academia have an important contribution in many areas related to hydrogen production, distribution, and utilization.

Looking at the above classification, one can note that while players on **the energy demand side** are to be found **all over the world**, players on **the energy supply side** as well as those on **the supply of technology/scientific and technological knowledge side are localized**, function of geographical characteristics (availability of solar, wind, geothermal, tidal energy), financial capabilities or technological experience. From a governmental perspective, the adoption of adequate policies also represents a factor of differentiation, as not all governments will adopt at the same time and on an equally broad basis policies supporting the transition to hydrogen.

3.1. Existing hydrogen strategies, similar plans, and hydrogen related projects

Based on the existing hydrogen policies and strategies, one can expect that until 2030 **major consumption/demand side centres** will be: European Union, Japan, South Korea, while **major production/supply centres** will be: Middle East, North Africa, South America, Australia. From a quantitative point of view, by the end of December 2020, 33 countries and European Union (as an integrated organization) have announced strategies, national or regional policies supporting the production and use of hydrogen (Faris, J., 2020).

Among the most advanced economies, both in planning and implementation one can mention (in alphabetical order):

- Australia has an official strategy called "Hydrogen under 2" which aims at reducing the cost per kg under 2 Australian dollars. By the adopted strategies and policies Australia aims to become a major exporter for the Asian region, particularly for Japan.
- Canada has a hydrogen strategy that provides this source will cover around 30% of the energy needs of the country by 2050 (Patel, S., 2021).
- China has large scale plans for production and utilization of hydrogen and it is currently the largest producer of hydrogen in the world, even if not from green sources of energy.
- Chile has as goal to be in 10 years among the top 3 global exporters, with electrolyser capacity of 25 GW and the cheapest green hydrogen in the world at about 1.50 US$/kg (FCHEA, 2021).
- European Union is one of the most advanced, if not the pioneer of the transition towards a hydrogen economy, having already both a regulatory framework for the transition and adequate financial means. The targets of the European Union are: electrolyser capacities of 6GW in 2024 and 40GW in 2030; production of 1 million tons of green hydrogen in 2024 and 10 million tons in 2030. Among the most advanced member countries of the European Union that adopted and implemented hydrogen strategies are Germany, France, the Netherlands, Norway, Spain (Patel, S., 2021).
- France also has a hydrogen strategy since 2020 and set its goal an electrolyser capacity to produce hydrogen of 6.5 GW until 2030.
- Germany has a hydrogen strategy since 2020 aiming at increasing the electrolyser capacity 200 times until 2030, up to 5 GW, with another 5 GW to be added between 2035 – 2040.
- Japan has a hydrogen strategy since 2017 and aims to become a "hydrogen society" and supports the development of international trade with hydrogen,

with special ships already operational and undergoing real-life tests. Through its strategy Japan aims to prove that a hydrogen economy is cost effective (Dvorak, P., 2021).

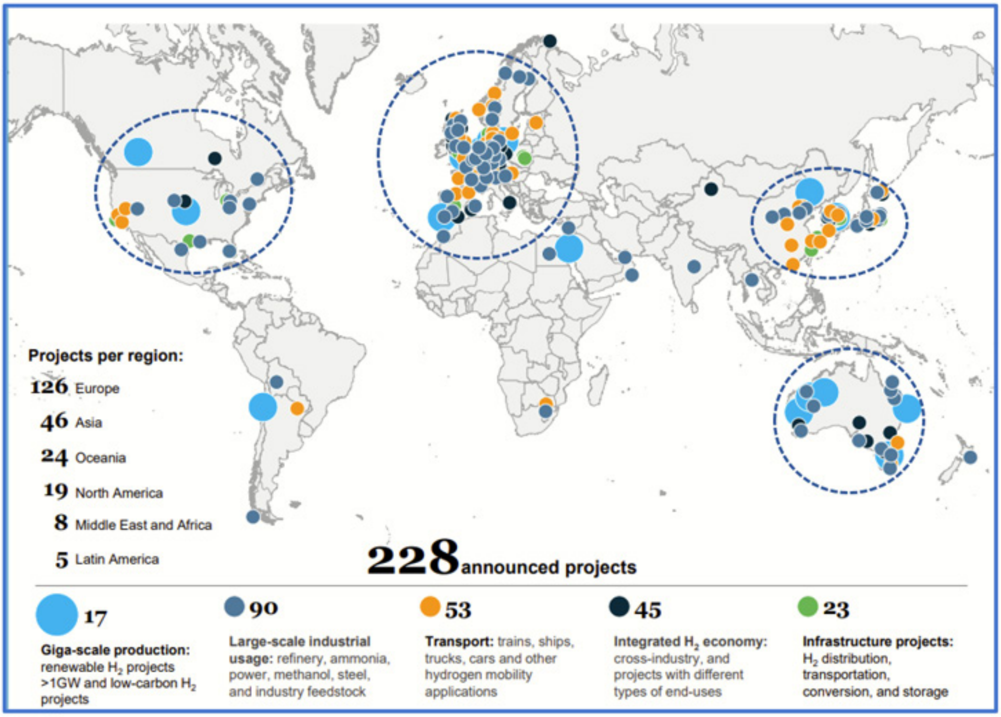
- Russian Federation has designed its hydrogen strategy in cooperation with Germany and Japan, and made it public in August 2021 (Patonia, A., 2021). Russia has as goal to become until 2050 a major exporter of hydrogen to the European Union and other regions.
- South Korea has a Hydrogen Economy Roadmap since 2019, with clear targets until 2030 for a very large numbers of fuel cell vehicles and refilling stations.
- Saudi Arabia aims to be the largest world exporter of hydrogen in the world by 2030.
- Spain plans to have, according to its hydrogen strategy, an electrolyser capacity of 4 GW by 2030
- Great Britain published in August 2021 its hydrogen strategy and has as goals the building of electrolyser capacity of 5 GW and an electricity production of 40 GW only from off-shore wind by 2030 (Equinor, 2021; National Law Review, 2021).United States has an approach based primarily on supporting research and letting the private companies to implement the results. The first official document setting the guidelines for a hydrogen economy in United States has been presented in 2002 (US Department of Energy, 2002). As of mid-2021 particularly ambitious plans related to the hydrogen economy are to be found in California.

While the situation is dynamic and the above list is far from being complete, at the beginning of 2021, European Union has been leading the global race towards hydrogen production and utilization. This statement can be demonstrated by the fact that, out of 228 large projects related to hydrogen that are in various stages at a global level, 126 are located in Europe (which represent 55%), 46 in Asia, 24 in Oceania (particularly in Australia), 19 in North America, 8 in Middle East and Africa, and 5 in Latin America.

The financial effort allocated for the implementation of these projects is estimated between 300 – 500 billion US dollars (out of which 80 billion in mature projects as of 2020), and it is correlated as distribution by countries, based on the existence of hydrogen and zero carbon emissions strategies (Hydrogen Council, McKinsey & Company, 2021).

A graphical representation of this distribution of projects and their areas of applicability gives a picture of the present key players in the forthcoming hydrogen economy and their global distribution (*Figure 1*).

Figure 1. Global distribution of hydrogen projects as of beginning of 2021



Source: Map annotated by author from Hydrogen Council, McKinsey & Company, (2021): Hydrogen Insights - A perspective on hydrogen investment, market development and cost competitiveness, February, page 15.

From a geopolitical point of view several conclusions can be drawn based on the above graphical representation and related information. **The key aspect** is that, at a global level, hydrogen projects are concentrated in **4 broad clusters** with Europe as the densest one, followed by Asia, Oceania (mostly Australia) and North America (mostly United States).

Some characteristics of each hydrogen cluster are presented below.

- **Europe and particularly Western Europe**. Although the hydrogen projects in the European Union are decided on a member state basis and represent in most cases private or public-private initiatives, the framework established by the European Union Green Deal and Hydrogen Strategy supports hydrogen initiatives and secure the long-term perspective for the business sector. At the same time, the existence of a significant number of large engineering companies in Western Europe, of large energy distribution companies and of oil and gas companies has provided favourable circumstances for an early start in the race towards a hydrogen economy.
- **Asia**. In this region the concentration of hydrogen projects is determined by Japan and China. The Japanese economy is dependent on energy imports and, following the Fukushima disaster in 2011, aims to scale down the use of nuclear energy. At the same time, Japan is a country very aware of environmental impact of economic activities and very advanced from a scientific and technological

point of view. As for China, the country has become for many years the manufacturing centre of the world economy and has a large experience in the production of clean energy technology (China produces 60% of solar power equipment used in the world and 5 of the top 10 wind turbine manufactures are in China). Also, China announced a plan to reach carbon neutrality by 2060, and it is currently the largest producer of hydrogen in the world, although for the moment mostly from coal (Meidan, M., 2021). According to international analysts, China will be the prime competitor for the European Union in the race for hydrogen economy.

- **Australia** has the potential and the ambition to become a key player in the global hydrogen economy. The Australian government adopted detailed strategies and plans for developing production of green hydrogen as well as of hydrogen export hubs. Australia is very active in scientific and economic cooperation in the field of hydrogen having ongoing agreements with Japan, South Korea, United Kingdom, Germany, Singapore. Australia intends to export 3 million tons of hydrogen per year by 2040, which may generate incomes of about 10 billion dollars (ARENA, 2021).
- **United States** is a major but specific player in the emerging hydrogen economy. United States has very high or even the highest scientific and technological capabilities (depending on the domain) in the world, but it is not the most active in the field of hydrogen, from the point of view of the whole economy because of 2 reasons: 1) the federal government is much less involved in the economy compared to European countries and European Union institutions, or to China, Japan or Australia; 2) on a pure market basis, the large scale adoption of hydrogen technologies is not yet cost effective. This is why, the US Department of Energy released in November 2020 a Hydrogen Program Plan (named H2@scale) that focuses on research, development and demonstration activities related to hydrogen. Therefore, in the United States the federal government focuses on research, development and demonstration and the results are to be implemented by state and local administrations, as well as by the business sector considering their cost-effectiveness or depending on their long-term strategies. Another specific characteristic of the US approach is that it is technology neutral, without expressing a preference for the so-called green hydrogen (Deckman, K., 2020). Anyway, the United States economy has both the capacity and the tradition of moving forward very fast once a decision is made (as it happened in the 1960s in the race to the Moon after the Sputnik moment). As an example, in California, which is the most environmentally friendly state, a document issued at the beginning of August 2021 by the California Fuel Cell Partnership envisages (only for this state) on the roads, by 2030, the presence of 70,000 heavy trucks based on fuel cells that will be supplied by 200 hydrogen filling stations as well as the target of 100% zero emissions heavy trucks by 2045 (Green Car Congress, 2021).

3.2. Hydrogen filling stations: a global picture

One of the factors which are essential in the large-scale deployment of hydrogen-based vehicles (cars, trucks, buses, etc.) is the existence of a reasonable number of filling stations. Hydrogen based vehicles using fuel cells are already mature as technology, they have a competitive production cost, a low cost of operation and their tanks can be filled in under 5 minutes, providing a range of 500 – 800 km. But the big hurdle is represented by the lack of hydrogen filling stations. From this point of view, the global picture is characterized by an **uneven distribution**.

The total number of operational hydrogen filling stations by the end of 2020 was of 553, a number almost **6.5 times higher** than the number existing in 2015. More than 50% of these stations are in the Asia – Pacific region (that is 275) and around 33% in Europe (that is 200). The country with the highest number of hydrogen filling stations is Japan (with 142), followed by Germany (with 100), North America (with 75 out of which 49 in California), China (with 69), South Korea (with 60), France (with 34 and 38 more planned).

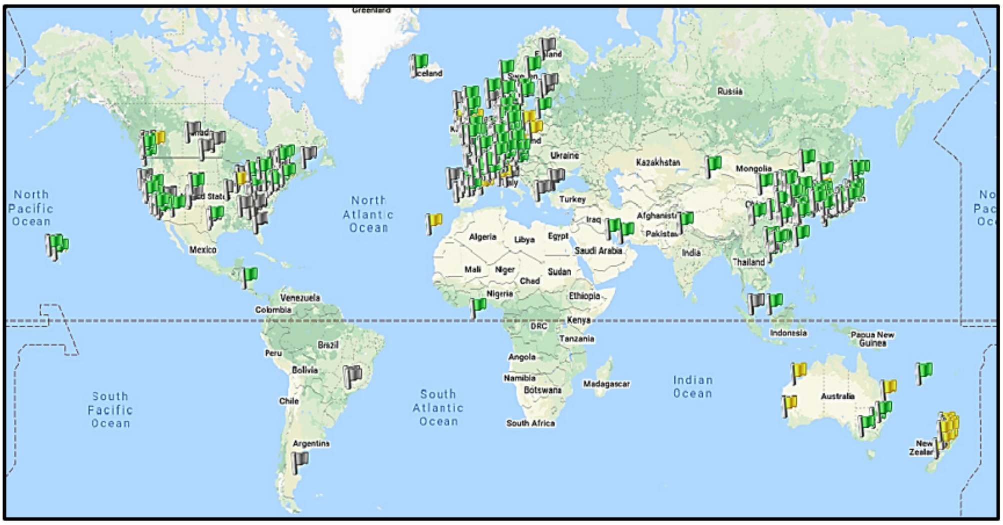
To underline the dynamics of opening new hydrogen filling stations, suffice it to say that only in 2020 a number of 107 new filling stations went into operation, out of which 72 in Asia, 29 in Europe, 6 in North America. The most active countries in this respect were Japan with 28 new stations, South Korea with 26, China with 18, Germany with 14 (Ludwig-Bölkow-Systemtechnik GmbH, 2021).

Other sources offer higher figure (584 stations), depending on what kind of stations are considered (only for on-the-road vehicles or on-the-road plus stations located inside industrial companies, which are used for fork-lifts or other internal transport) or the sources of data, but these minor differences do not change the magnitude, the dynamics, or the regional distribution (Business Wire, 2021).

A distribution of hydrogen refuelling stations is presented in *Figure 2*, where the green flags represent stations in operation as of June 2021. If one focuses on the distribution of hydrogen filling stations in Europe, a clear divide and disbalanced distribution emerges, not only between Western and Eastern Europe, but also within Western Europe (*Figure 3*).

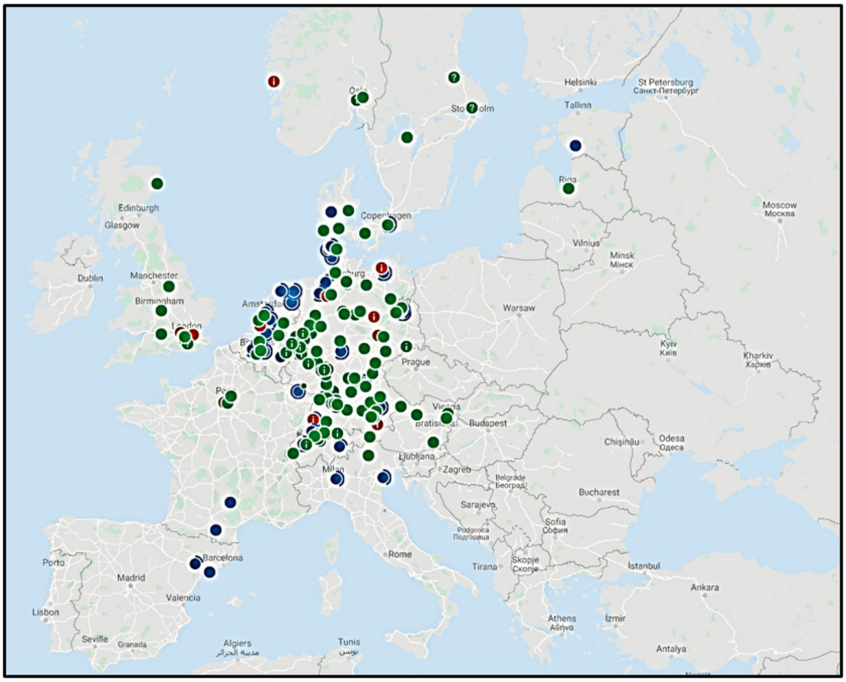
This disbalanced distribution is correlated with the technological and financial capabilities of the countries, but also with their vision. This distribution may represent a useful warning signal for the decision makers from the countries that are not for the moment part of the hydrogen transition as such non-participation today may translate into long term development gaps for those and costly and less efficient efforts to catch up.

Figure 2. The distribution of hydrogen refuelling stations as of June 2021



Source: H2 Stations Map, www.h2stations.org

Figure 3. Distribution of hydrogen refuelling stations in Europe as of June 2021



Source: Filling up with H2- Hydrogen mobility starts now, H2 MOBILITY Deutschland GmbH & Co KG, https://h2.live/en/

3.3. European distribution of networks for hydrogen transport

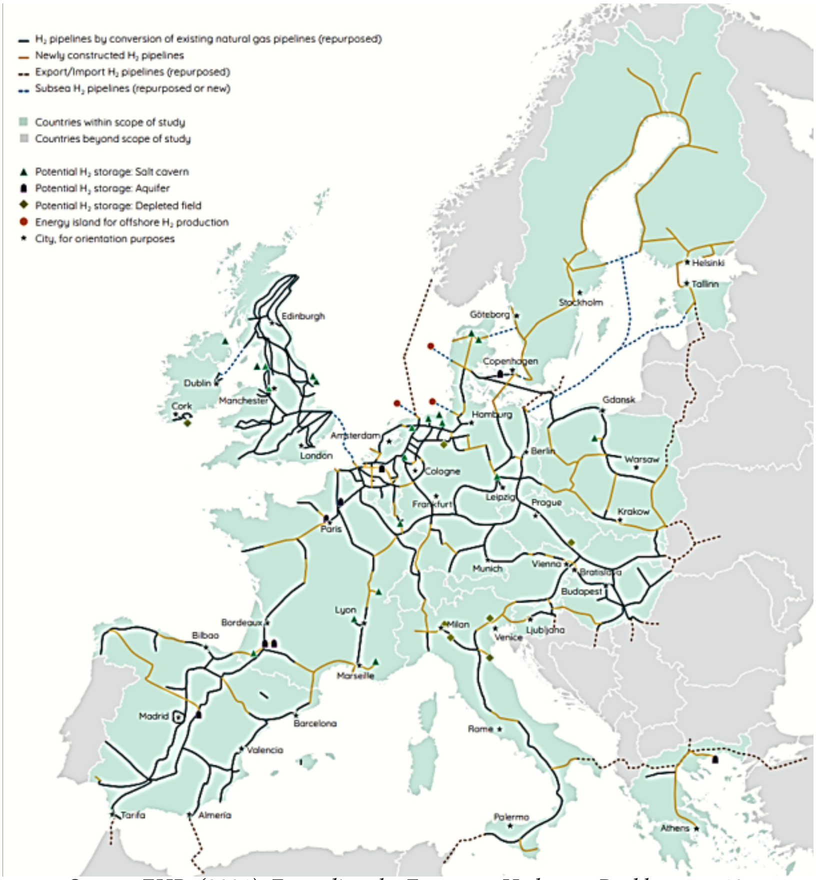
While the existence or planned development of inter-connected networks of pipelines for the transport of hydrogen is of importance everywhere in the world, the focus of this analysis is on European Union. The importance of a pipeline distribution for the transport of hydrogen in Europe arises from the fact that not all hydrogen can be used on the site of production, and from the fact that it is not feasible to transport all hydrogen in pressurized or liquefied form. According to some estimates, by 2050, the demand for green hydrogen in the European Union and United Kingdom will reach 2,300 TWh and will represent 20 – 25% of all energy consumption (Eckert, V, 2021).

In 2020, several gas infrastructure companies joined forces to design a so-called **European Hydrogen Backbone** which refers to a pipeline network for transporting hydrogen across 10 countries. In April 2021, this initial vision was updated, involving 21 gas distribution companies from 21 European countries. What is important from the point of view of implementation costs, but also with regards to the speed of implementation is that a large part of this network (69% of it) will result from adapting and upgrading existing gas pipelines. The targets for the length of this network are **11,600 km by 2030** and almost **40,000 km** (39,700 km to be precise) **by 2040** (EHB, 2021). The importance given by the participating countries and business companies to this initiative is reflected in the major increase of almost 3.5 times of the length between 2030 and 2040.

The coverage of this European hydrogen distribution network as intended for 2040 is presented in *Figure 4*, and from this map **an important asymmetry is evident**, with the network concentrated in Western Europe, with a certain participation of Central Europe (Poland, Slovenia, Slovakia, Czech Republic, Hungary) and practically no participation from countries in South-Eastern Europe and Balkans.

Countries located in the neighbourhood of Romania, like Poland, Czech Republic and Slovakia consider their participation in the European Hydrogen Backbone as a key to giving up the use of coal in their economies, while Czech Republic and Slovakia could even become regional hydrogen hubs (Simon, F., 2021).

Figure 4. Envisaged European Hydrogen Backbone in 2040



Source: EHB, (2021): Extending the European Hydrogen Backbone, p. 12

3.4. The existence and geographical distribution of hydrogen associations

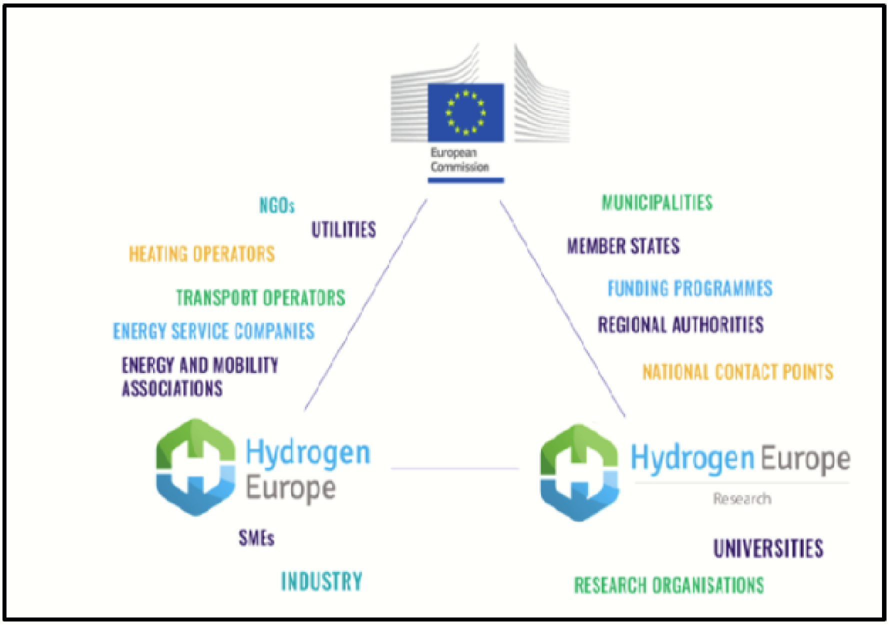
In response to the need to decarbonize the economy, an objective that is perceived more and more as an immediate necessity at a global level, the business sector has responded by creating associations of large companies, with a regional, continental, or global coverage. At the same time, particularly in the European Union, public-private partnerships have been established in order to focus efforts and better coordinate the use of resources and the inter-connection of hydrogen production centres, distribution networks, financing and research activities.

The generic goal of these associations is to support an accelerated transition to hydrogen economy, to secure synergies along the hydrogen value chains and to obtain more coherent and consistent approaches. The largest ones include, besides CEOs of technological companies, oil and gas companies, international banks and other investors, research institutes and innovative companies. The existence of such associations can represent a catalyst for accelerating hydrogen projects, joint projects with the participation of the members, transfer of best practices, facilitation of public-private partnerships, advocacy activities in relation to various authorities and administrations.

In the following, we present some of the largest hydrogen associations, starting with those with global coverage, then listing the most important associations from the European Union and ending with some associations from the most ambitious countries in the field of hydrogen. The list is far from complete and its purpose is just to illustrate the significant interest raised by hydrogen-based technologies among all important economic and technological actors:

- **World Energy Council**. Although not entirely dedicated to hydrogen, this global forum, with origins dating back to 1923, has over 3,000 members from 90 countries and reunites representatives of governments, business sectors and experts covering all issues (including hydrogen related ones) pertaining to supply and demand of energy (World Energy Council, 2021).
- **Hydrogen Global**, a platform established in 2019 by the World Energy Council, aims at creating a forum of debate for strategies, technologies, deployment plans and any other form of interaction among decision makers from government, business, civil society. The importance of the platform stems from the fact that its initiator, World Energy Council, is a reputed organization in the field of energy, functioning since 1923 (World Energy Council, 2021).
- **World Hydrogen Leaders**, established in 2020, reunites over 800 expert members from all over the world, specialized in industrial intelligence (H-World Hydrogen Leaders, 2021).
- **Hydrogen Council**, which reunites global companies from over 20 countries from all continents. The number of members increased from 17 in 2017, when the association was established, to 123 in 2021. Among the well-known companies that are members, one can find: 3M, Airbus, Air Liquide, Alstom, BMW, Bosch, British Petroleum, China Energy, Daimler, EDF, Engie, Honda, Hyundai, Kawasaki, Michelin, Microsoft, Shell, Total, Toyota, ThyssenKrupp, Itochu, Mitsubishi, Sumitomo, Saudi Aramco, Siemens, BPN Paribas, Credit Agricole, Société Générale (Hydrogen Council, 2021).
- **Hydrogen Europe** is a very large and active association promoting the utilization of hydrogen and fuel cells. In 2021, it consisted of 260 business companies from 27 countries, 26 national associations, and 91 universities and research organizations from 26 countries, which are grouped in a related association named Hydrogen Europe Research (Hydrogen Europe, 2021).
- **Fuel Cells and Hydrogen Joint Undertaking (FCH JU)** is a tripartite public-private partnership reuniting European Commission, Hydrogen Europe and Hydrogen Europe Research (FCH JU, 2021). The activity of this group emerged in 2002 in connection with the initiative of the High Level Group on Hydrogen, proposed by Romano Prodi, at that time president of the European Commission, and two European Commissioners, Loyola de Palacio, at that time Commissioner for Energy and Transport, and Philippe Busquin, at that time Commissioner for Research. The structure of this public–private partnership is presented in *Figure 5*.

Figure 5. The public–private partnership Fuel Cells and Hydrogen Joint Undertaking



Source: FCH – JU, 2021): Who We Are, at page https://www.fch.europa.eu/page/who-we-are

- **European Clean Hydrogen Alliance – ECHA**, which was announced in March 2020 as part of the new industrial strategy of the European Union. It reunites, as of July 2021, more than 600 members from the part of business, local and national authorities, research and academia, civil society, and other stakeholders. The investment agenda of the members, which is based on the European Union Hydrogen Strategy, amount to about 430 billion Euros until 2030 (ECHA, 2021).
- Among the key hydrogen association in Australia there are: **Australian Association for Hydrogen Energy** (AAHE, 2021), established in 2009, reuniting business, academia, federal and local governments; **Australia Hydrogen Council**, established in 2017 by Toyota and Hyundai, with 76 members in 2021 (AHC, 2021); **Hydrogen Australia**, established in 2019 as an advocacy and support group by Smart Energy Council and the Australian Association of Hydrogen Energy (Hydrogen Australia, 2021).
- **Japan Hydrogen Association (JH2A)** was established in 2020, following the adoption of the Basic Hydrogen Strategy (in 2017), of the Strategic Roadmap for Hydrogen and Fuel Cells and of the Strategy for Developing Hydrogen and Fuel Cells Technologies. A number of 87 Japanese large companies are participating (among which the 9 original companies: ENEOS, Iwatani, Kawasaki Heavy Industries, Kobe Steel, Mitsui, Sumitomo Mitsui Financial Group, Kansai Electric Power Company, Toshiba, Toyota). An important observation is that Japan is the country with the longest track record regarding the uses of hydrogen in economy (as it started in early 1970s after the first oil shocks), and the most dedicated to the building of a "hydrogen society" with a long term and permanent large support from the part of the Japanese government (Okutsu, A., Shibata, N., 2020). As a result, Japan has the largest

number of hydrogen filling stations in the world (142 by the end 2020).

- **China** is a big player not only as the manufacturing hub of the world economy, but also because China is in a league of itself due to its size from whatever point of view we analyse it: economic, environmental, industrial, financial, etc. Since 2010, the Chinese production of hydrogen increased by 6.8% every year, reaching in 2020 about 20 million tons, which represents about 33% of the world production and 10% of its energy consumption (Casey, J.P., 2021). Being a centrally planned economy, the state plays an important role in the transition to a larger production and utilization of hydrogen. In August 2020, the Chinese president announced that China was to peak carbon emissions until 2030 and reach carbon neutrality by 2060. The key players involved in the Chinese hydrogen transition, with clearly defined responsibilities, are the following institutions: Ministry of Science and Technology, National Development and Reform Commission, National Energy Administration, Ministry of Industry and Information Technology, Ministry of Finance, Ministry of Transport, State-owned Assets Supervision and Administration Commission of the State Council, State Administration for Market Regulation, National Bureau of Statistics, local governments (Jianjun Tu, K., 2020).
- In the **United States** the approach to building a hydrogen-based economy differs from that of other countries in that at this stage the federal government is focusing on hydrogen related technologies and market development. The US Department of Energy has launched in 2016 the H2@scale project which gives hydrogen a key role in reducing the emissions of carbon from energy intensive sectors of economy (Mammoser, A., 2020). The H2@scale program is funded and coordinated through Energy Efficiency and Renewable Energy Office (EERE) and Hydrogen and Fuel Cell Technologies Office (HFTO). Among the hydrogen markets identified in United States until now, there are: data centres, ports, metallurgy, heavy duty trucks. The US approach can be defined as holistic, based on a close cooperation between federal government, local governments, business, research, and academia. Despite a perceived late start, once the knowledge and business models are defined, they will be implemented throughout United States. At the same time, the US approach involves a strong commitment and support from the part of the government, correlated with a strong cooperation with the business sector.

Conclusions

2020 brought with it not only the beginning of the 3rd decade of the 21st century and the Covid-19 pandemic, but also the beginning of a transition to:

- a new technological era and related new energy orientations;
- the manifestation of very clear negative consequences of the climate change.

In our opinion it is very likely that these two elements will be fused into an energy transition. As previous energy transitions showed (such as the transition from wood to coal, from coal to oil and gas, the emergence of nuclear energy, etc.), such transitions have a major impact on the global balance of power, on the relative position of the economies and political entities, on the alliances and global value chains.

In this context, coming back to the title of this paper, one can ask: can we speak about the early stages of a geopolitics of the hydrogen-based economy?

In our view, the answer is at the same time: **Yes**, and **No**.

The answer is **Yes** because, as one can see from the previous maps and facts, the states and the economies of the world are not participating in an equal manner to this energy transition. On the contrary, one can see clear divisions between those very active and those (almost) absent. This asymmetry represents the foundation of the future inequalities in international economic relations, but also the basis for new alliances and new competition races. This geopolitical picture (in the sense described at the beginning of the paper) is new, because the criterion is new (the existence of strategies, policies, funds and projects related to a hydrogen-based economy).

At the same time, the answer is **No**, because if one looks at the active participants, at the pioneers of the energy transition which casts hydrogen in one of the leading roles, the feeling of déjà vu is very strong: the key players are almost the same, even if in different or more nuanced positions. All participants support the idea of fighting climate change and decarbonizing their economies. The approaches are different based on the different geographical place from which they contemplate the world and their various histories and heritages of all sorts (technological, financial, human).

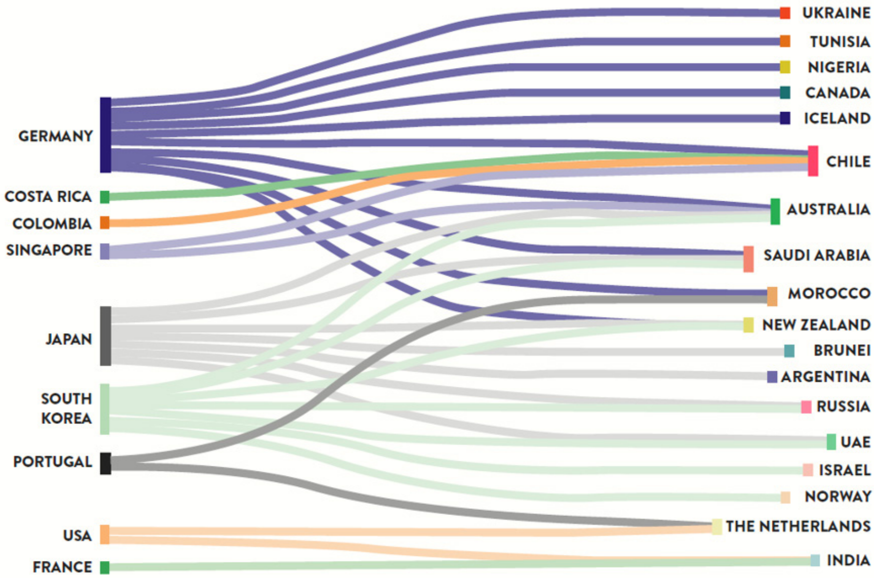
Getting back to the 4 categories of participants in the hydrogen-based economy mentioned at sub-chapter 3, one can say that the European Union (as well as the rest of Western countries and some other European countries) and Asia (represented primarily by Japan and China) **are more focused on the demand side**. On the other hand, Africa, Middle East (including oil exporting countries), Russian Federation, some countries in Latin America (like Chile) and Australia **are more focused on supply side**.

Because of the characteristics of their location, resources, and economies some countries (such as Japan, Australia, Saudi Arabia, or Chile) pay a greater interest to international sea transport of hydrogen. European Union countries focus on securing supply of hydrogen from internal and international sources (particularly Northern Africa, Ukraine, and others, potentially Russian Federation), as well as on decarbonizing, as fast as possible, industries that otherwise are hard to re-orient towards electricity (like metallurgy, construction materials, heavy duty trucks, buses, certain railways, etc.).

In North America, particularly in the United States, but also in the United Kingdom the approach to hydrogen is both systematic and pragmatic with the aim to develop the necessary technologies and create the markets after which efficient and realistic technologies and business models will be implemented in the whole economy.

This variety of positions and interests already determined the establishment of international partnerships for the production and supply of hydrogen. A synthetic view is reflected in *Figure 6*. Attention should be given to the fact that this graph reflects the situation in the first half of 2021, and it is neither complete, nor fixed for a long period of time. Anyway, this graph illustrates the international relations that are established in relation to hydrogen production and trade, and indicate a new and active area of interest for diplomacy. Some countries, particularly those on the left side of the graph, are more interested in the consumption of hydrogen / demand side (Germany, Japan, South Korea). Other countries, particularly those on the right side of the graph (Ukraine, Tunisia, Chile, Australia, Saudi Arabia, Brunei) are looking more at their hydrogen export potential.

Figure 6. Bilateral partnerships related to hydrogen projects



Source: World Energy Council, Hydrogen on the Horizon: Ready, Almost Set, Go? 2021, p. 4

In the end, a question is rised: **what happens with the countries that are not among those which already have projects underway, a strategy or a participation to some form of international cooperation related to hydrogen?**

In our view, the recommendation for these countries is to be aware of the international trends, to learn from the experience of the global and regional hydrogen related associations and to identify the projects they can participate in. Countries that already have experience with generating electricity from land based and offshore wind sources, solar panels, geothermal sources or biomass can find ways to capitalize on that experience and find their position in the international value chains related to hydrogen.

Countries that are members of the European Union have the potential advantage of a well-defined regulatory framework in support of a hydrogen-based economy at the community level, as well as of the existence of many European technological companies, energy distribution companies, oil and gas companies and institutional investors that can be attracted as be partners in the local, regional, or country level hydrogen related projects.

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