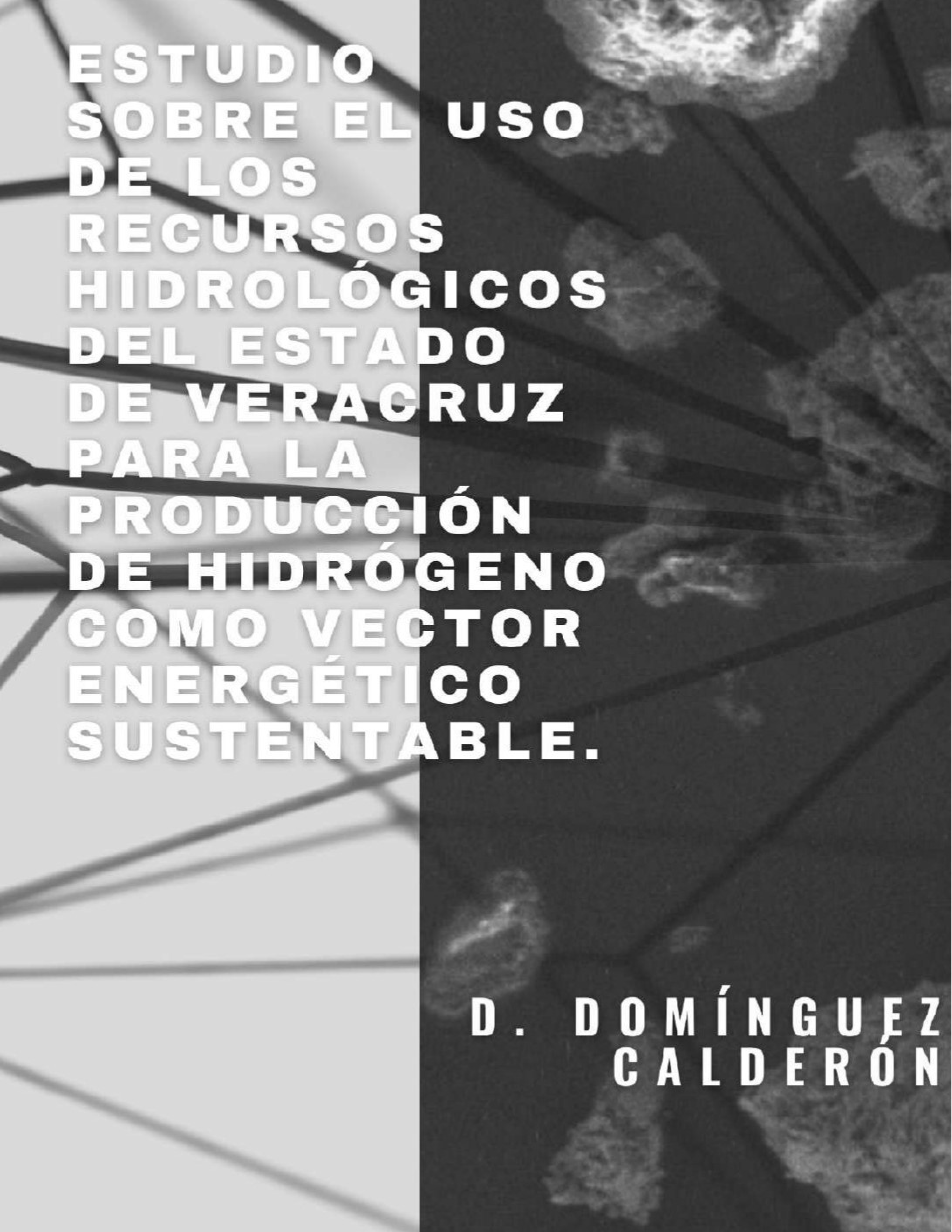

ESTUDIO SOBRE EL USO DE LOS RECURSOS HIDROLÓGICOS DEL ESTADO DE VERACRUZ PARA LA PRODUCCIÓN DE HIDRÓGENO COMO VECTOR ENERGÉTICO SUSTENTABLE.

D. DOMÍNGUEZ CALDERÓN

STUDY ON THE USE OF THE VERACRUZ HYDROLOGICAL RESOURCES FOR HYDROGEN PRODUCTION AS A SUSTAINABLE ENERGY VECTOR

ESTUDIO SOBRE EL USO DE LOS RECURSOS HIDROLÓGICOS DEL ESTADO DE VERACRUZ PARA LA PRODUCCIÓN DE HIDRÓGENO COMO VECTOR ENERGÉTICO SUSTENTABLE

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ABSTRACT

With the promulgation of Energy Reform and its entry into force as of December 20, 2013, a new stage in the history of the Mexico in energy matters begins. Within the different topics or points covered by this reform, we will focus only on the aspect of renewable energies, since previously in Mexican legislation there were limitation to the energy model, for the inclusion of renewable energies in production and marketing to large scale by private capital. Based on our new national energy paradigm; the present work aims to carry out a study in the field for renewable energies, on the great potential that would take advantage of the use of hydrological resources available in the Veracruz state, on the production and use of Hydrogen as a clean energy vector and as a promising source in the coming years. Hydrogen, the most abundant element of the universe since it is not free in nature, is necessary to produce it from hydrogenated substances, mainly water and hydrocarbons. The easy availability and abundance of the material from which hydrogen can be obtained, as well as the diversity of means to obtain it; provide a great potential as an energy alternative. This, coupled with the fact that the use of hydrogen only leaves water as the only residue; makes it very favorable to the environment, looking for ways to produce it only with renewable energy sources, such as solar, wind, hydraulic, among others. These characteristics will boost an energy economy based abundant hydrogen. To have a clear idea of the study to be carried out, an overview of the hydrological resources of Veracruz will be investigated and then will be analyzed data collected from studies about main rivers, and if there are correlation between their's variables and will graph; and some preliminary results will be reported in the present work.

Keywords: *fossil CO_2 emissions, Greenhouse gas, hydrogen, hydrological resources, renewable energy, vector.*

Fecha de aceptación: Noviembre 07, 2020.

RESUMEN

Con la promulgación de la Reforma Energética y su entrada en vigor a partir del 20 de Diciembre del 2013, comienza una nueva etapa en la historia de México en materia energética. Dentro de los diferentes temas que abarca esta reforma, nos centraremos únicamente en el aspecto de las energías renovables, ya que anteriormente en la legislación Mexicana había limitaciones al modelo energético, para la inclusión de las energías renovables en la producción y comercialización a gran escala por parte del sector energético privado. Basado en nuestro nuevo paradigma energético nacional; el presente trabajo tiene como objetivo realizar un estudio en el campo de las energías renovables, respecto al gran potencial que llevaría el aprovechamiento de los recursos hidrológicos en el estado de Veracruz, sobre la producción y el uso del hidrógeno como vector de energía limpia y una fuente prometedora e inagotable en los próximos años. El hidrógeno, es el elemento más abundante del universo y que no se encuentra de manera libre en la tierra, es necesario producirlo a partir de sustancias hidrogenadas, principalmente agua e hidrocarburos. La fácil disponibilidad y abundancia de los elementos del que se puede obtener hidrógeno, así como la diversidad de medios para obtenerlo; brindan un gran potencial como alternativa energética. Todo esto, unido al hecho de que el uso del hidrógeno solo deja agua como único residuo; lo hace muy favorable al medio ambiente, buscando formas de producirlo, solo con fuentes de energía renovables, como solar, eólica, hidráulica, entre otras. Estas características impulsarán una economía energética basada en el hidrógeno.

Para tener una idea clara del estudio a realizar, se investigará un panorama general de los recursos hidrológicos del estado de Veracruz y luego se analizarán datos de estudio obtenidos sobre los principales ríos de la región, la correlación existente entre sus variables; los resultados obtenidos serán graficados, y finalmente se informara las conclusiones que de ello deriven, en el presente trabajo.

Palabras clave: *energía renovable, emisiones fósiles CO_2, gas Greenhouse, hidrógeno, recursos hidrológicos, renovable, vector.*

INTRODUCTION

Hydrogen is the most abundant in the universe and yet, on Earth, it is rarely in a free state. Hydrogen is a carrier of energy (such as electricity), it is necessary to produce it from other raw materials (water, biomass, fossil resources), and to convert these matters in hydrogen must follow some transformations in which it is consumed some primary energy source (nuclear, renewable or fossil). Hydrogen is currently used in many industrial processes, therefore, what is emerging in the present moment is the use of hydrogen as a new energy vector that allows compatible development with respect for the environment. On the other hand, hydrogen offers in the long term intrinsically clean closed energy cycle scenario that's constitutes the great attraction of this carrier of energy. It´s about drinking water from nature, separating it into its components (oxygen and hydrogen) by means of electricity of renewable origin, storing hydrogen, transporting it, distributing it and, finally when using it following conventional thermal processes (internal combustion engines or turbines), or electrochemicals novelty (fuel cells), we would return the same amount to nature of water that we had previously taken from it. In the thermal conversion of hydrogen nitrogen oxides would be emitted (although in a much lower proportion than those emitted with fossil fuels), while in use with batteries of fuel emissions would be zero.

With renewable energy and water, and using hydrogen and electricity as energy vectors, it would be possible to meet all energy needs with an emission of pollutants practically null. If an energetic scenario of this style comes into being, then it could be said that the "hydrogen revolution" would have occurred and we would have entered the era of hydrogen. In the evolution towards a future energy scenario in which hydrogen (as an energy carrier); for first time in history the establishment will break through of an energy system based on natural resources (renewable and water), the depletion of fossil fuels is a incontestable fact; that is way it is necessary to lead Humanity towards a safer, durable and non-polluting energy system. Hydrogen, together with renewable electricity as energy carriers offers this possibility.

Figure 1. *Photography onf the Veracruz south river, Mexico (Dominguez-Calderon et al., 2020).*

In the path towards this goal there are no insurmountable technical and economic effort is required constant for a few decades [1].

Dr. Alejandro Rojo Valerio, director of the Center for Research in Automotive Mechatronics (CIMA), of the Tecnológico de Monterrey, Toluca campus, affirms that we are living a transition stage: "The studies mark that, by 2040, more than 50% of the vehicles of the world will be electric; it is expected that by 2060 half of the electric vehicles will be powered by hydrogen". Four kilos of compressed hydrogen are enough to cover 400 kilometers at price similar to gasoline, but being lighter, it makes cars that use gasoline less heavy. "Three times more kilocalories are obtained per gram of hydrogen than gasoline itself (Figure 2).

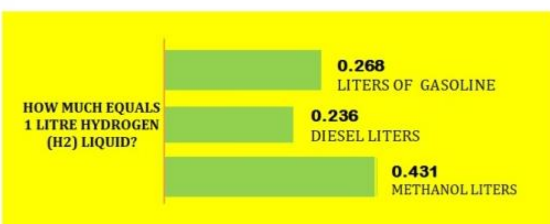

Figure 2. *Hydrogen comparative with others fuels (image courtesy of Asociación Española de Hidrógeno).*

That is a very interesting attraction", says Arturo Fernandez Madrigal, a researcher at the Institute of Renewable Energies of the UNAM and a member of the Mexican Academy of Sciences.

Is hydrogen a solution to the energy requirements of today's societies? "yes it can be", shares Dafne Daniela Jacobo Davila, president of the Aeronautics Academy. The water vapor that is produced from the generation of energy with hydrogen would help to clean the atmosphere of harmful gases, says this researcher from the National Polytechnic Institute (IPN), developed a hydrogen-based engine for an aircraft. In that project led by Brian Oribio Alarcón, "the polluting gases were zero" and "the engine power did not show changes in relation to the use of fossil fuels, "says Jacobo Davila, who says that the energy of this fuel gives off four times less heat than fossil fuels, that is, it is more efficient. If it sounds so good, why aren`t we using hydrogen in cars, ships, planes and in the industry? A drawback is that 95% of the world`s hydrogen is obtained through a process of burning hydrocarbons where greenhouse gases such as carbon dioxide are released. To achieve a "green hydrogen", from oxygen. However, only 5% of hydrogen production is thus obtained.

Is it possible to achieve electrolysis on and industrial scale to obtain hydrogen? "It is possible and perhaps a little expensive; Due to the way of production, it does not require much maintenance, but the fuel generating device is expensive. However, that raw material, which is salt water, is abundant", explains Dafne Jacobo

Dávila. Renewable methods for hydrogen production are currently being promoted; "for example, with the use of biomass, where methane is obtained and the hydrogen, or photoelectrolysis, use sunlight by illuminating solar cells that give us electricity that is used for water electrolysis", shares Arturo Fernández Madrigal, who also collaborates with the National Renewable Energy Laboratory DOE-USA in the preparation of semiconductor materials for the production of renewable hydrogen. In the case of photoelectrolysis, the photon of solar radiation helps to separate the molecule of water into hydrogen and oxygen.

Fernández Madrigal thinks that we are living a transition from hybrid models, which use gasoline and electricity, to electric ones; finally, hydrogen will arrive. But there is still a proper legal framework. In the case of México, according to his researcher, who was president of the Mexican Hydrogen Society, AC –a nonprofit organization that foster and disseminates knowledge regarding hydrogen –although research and various studies have been carried out at the academy universities have developed some projects, the industry is not yet integrated into this initiative due to the lack of tax incentives. It is only necessary to see the development that other countries have on the subject to realize that México does not yet have place among the most advanced, such as Switzerland and Germany [2].

The price of fuels, the pressure to reduce toxic emissions in the environment coupled with the need to innovate in transport option increase competition between technologies and auotmakers in the race for electric mobility [3]. The automotive sector is not the only attractive niche for technological investment. Agribusiness, the pharmaceutical sector, the development of bio-foods, hydrocarbons and medical devices have great growth potential, according to Rogelio Garza, ex sub secretary of Industry and Commerce of the Ministry of Economy [4].

The industry has changed in the las 10 years and will continue to change, there will be more sustainable products. In the year 2040, renewable energies will continue to gain ground and, when combined with natural gas, and emerging technologies, such as micro-networks, they will be able to create energy efficient, robust systems of high efficiency of high efficiency and low carbon emission. Advanced biofuels are envisioned through algae, carbon sequestration and new hydrogen-associated technologies. In 50 years it will reach between 60% and 70% of the total electricity generation worldwide. For the new renewable generation, there are two promising technologies. First we will see a quantum leap with hydrogen, which still has limitation, but it will be a discruptive and competitive technology against batteries to store energy. Then the tidal-wave force, where there are some generation prototypes with currents [5].

In the next 10 years we will experience the results of advances in artificial intelligence (IA), and increase in quality standards, control and immediate responses. There will be a closer collaboration between nations, private and governmental entities, and there will be more stringent approaches to ecological, social and economic [6]. "But the challenge is to reach a method so that, through the separation of hydrogen from the molecule of water, the extra energy that comes from the electrical generation in solar and wind plants can be stored" says the International Energy Agency in its report "The future of hydrogen: measuring today`s opportunities", published this year at the G20 meeting in Japan [7].

What is Mexico`s participation in the global renewable energy landscape, and what regulations are being implemented to contribute to sustainable energy development?, as well as what is the potential of Veracruz state in this energy sector and what development does the hydrogen compared to other renewable energy sources?, and what projects currently exist in our region of this important energy vector.

Finally, what solutions could be proposed to boost hydrogen as a future energy and economic vector, and thus contribute of Mexico towards a competitive economy alongside the most developed economies worldwide?

CLIMATE CHANGE: WORLD EMERGENCY

Ten years we have to avoid a global catastrophe of droughts, food shortages, and forest fires. The 2015 UN 2030 Agenda, signed by 193 countries, includes 17 Sustainable Development Goals (SDG) and 167 goals. "The planet will reach the crucial threshold of 1.5 degrees Celsius above pre-industrial levels by 2030," notes the United Nations Intergovernmental Panel on Climate Change (IPCC). Most analysis models predict that there will be less than a million square kilometers of sea ice in the middle of this century. For Kosonen "we are already in the danger zone". Bothe poles are melting at an accelerated rate: which will precipitate the risk of extreme drought, forest fires, floods and shortages of food for animals and millions of people. "The next decade is key," says Joeri Rogelj, a scientist at Imperial College London. A coalition of important figures including former UN chief Ban Ki-moon, billionaire Bill Gates and World Bank CEO Kristalina Georgieva, launched in 2018 an

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important message: "It is not enough to limit global warming even more, we must to do a lot to make sure to will we survive…too." Ban Ki-moon was blunt: "Around 100 million people could fall back into extreme poverty by 2030 due to climate change [8]."

TRENDS IN GLOBAL CO_2 AND TOTAL GREENHOUSE GAS EMISSIONS-2019 REPORT

In the 2018, the growth in total global greenhouse gas (GHG) emissions (excluding those from land-use change) resumed at a rate of 2.0%, reaching 51.8 gigatonnes of CO_2 equivalent ($GtCO_{2eq}$) after six years, with a somewhat lower annual growth of around 1.3% (Figure 3).

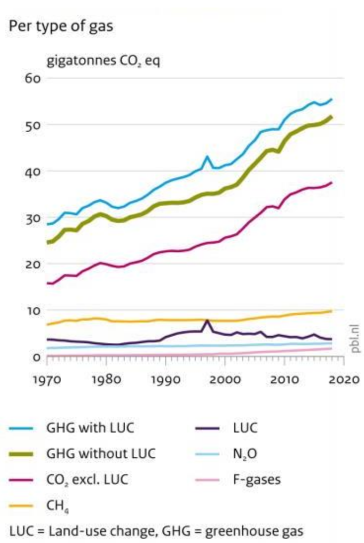

Figure 3. *Growth in global greenhouse gas emission in 2018 highest since 2011(image courtesy of PBL Netherlands Environmental Assessment Agency).*

In 2018, the growth in total global GHG (GHG) emissions (excluding those from land-use change resumed at a rate of 2.0% (+/-1%), reaching 51.8 gigatonnes of CO_2 equivalent11 12 ($GtCO_{2eq}$) after six years (since 2012), with a somewhat lower annual growth of 1.3% on average and compared with the much higher average annual growth rate of 2.5% in the first decade of this century (Figure 4). This new time series marks the end of global emissions peaking in 2015 and 2016.

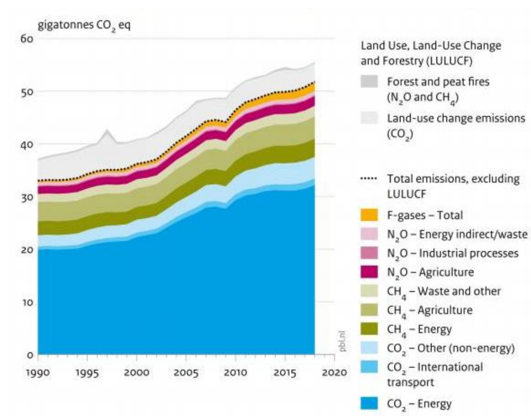

Figure 4. *Global greenhouse gas emissions, per type of gas and source including LULUCF (image courtesy of PBL Netherlands Environmental Assessment Agency).*

The five largest emitters of GHG, together accounting for 62%, globally, are China (26%), the United States (13%), the European Union (more than 8%), India (7%), and the Russian Federation (5%) and Japan (almost 3%). These countries also have the highest emission levels (Figure 5).

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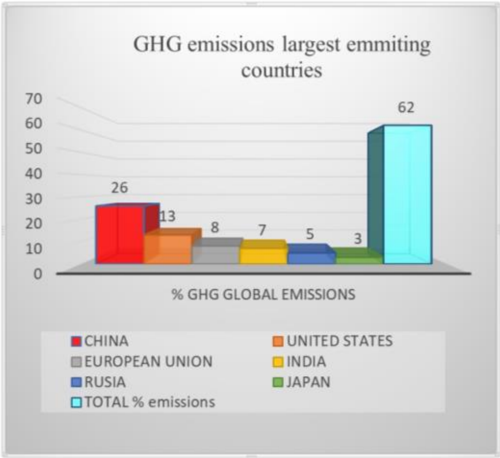

***Figure 5.** Global greenhouse gas (GHG) emissions, five largest countries emitters (image courtesy of PBL Netherlands Environmental Assessment Agency).*

Global CO2 emission shows largest increase since 2011, and China showed very high annual growth in CO2 emissions due to its rapid industrialization [9].

MEXICO IN THE FACE OF CLIMATE CHANGE

How serious is Mexico taking the issue of climate change?

"Mexico from the point of view of the United Nations, has always been a leader. It was the second country to have a law, after the United Kingdom. It was the law of 2012. If you go to a state or a municipality of the largest, at least, they already have a climate change´s agenda. In the legislative part we have environmental and climate change commissions. Ideally, we would have much more prepared cities and municipalities, that we would have a cleaner energy matrix. Right now of energy matrix that Mexico has, which is basically the generation of electricity, 75% still depends on hydrocarbons and more or less 25% is renewable where the large hydroelectric plants are, but also and important solar and wind power propulsion. Today as representative of United Nations Environment Program (UNEP), it has promoted the Green Economy Initiative1, the General Climate Change Law2 and the most important results we have had in Mexico, the Energy Transition Law3" (Barrientos Maria, 2019, p. 12,14), [10].

At the United Nations Conference on Sustainable Development (Rio + 20), the Green Economy- in the context of sustainable development and the eradication of poverty- was recognized as tool to achieve sustainable social, economic and environmental development. UN Environment has defined Green Economy as "that economy that results in better human well-being and social equity, significantly reducing environmental risk and ecological shortages." In its simplest expression, a Green Economy can be considered as one that is low in carbon, resource efficient and socially inclusive.

Mexico

A quantitative study of Green Economy is being finalized to assess the potential of propose polices in the natural capital and transport sectors, as well as the impact of the elimination of subsidies harmful to the environment [11].

The P4G supports the "Zero Emission Bus Rapid-deployment Accelerator (ZEBRA)" projects in Mexico to increase the deployment of electric buses, and the "Cities Climate Action", an energy efficiency program [12].

The Sustainable Development Goals (SDGs) constitute a universal call to action to end poverty, protect the planet and improve the lives and perspectives of people around the world. In 2015, al United Nations Members States approved 17 Objectives as part of 2030 Agenda for Sustainable Development, which establishes a plan to achieve the Objectives in 15 years.

The use of renewable energy in sectors such as heating and transportation should transportation be increased. Likewise, public and private investment in energy are necessary; as well as higher levels of financing and polices with bolder commitments, in addition to the willingness of countries to adopt new technologies on a much broader scale.

The Secretary General of the Unite Nations called for all sector of society to mobilize in favor of a decade of action at three levels: world action to ensure greater leadership, more resources and smarter solutions regarding the Sustainable Development Goals; action that includes the necessary transitions in the policies, budgets, institutions and regulatory frameworks of governments, cities and local authorities; and action by people, including youth, civil society, the media, the private sector, trade unions, academic circles and other stakeholders, to generate an unstoppable movement that drives the necessary transformations [13].

Sustainable Energy for All (SEforALL) is an international organization working with leader in government, the private sector and civil society to drive further, faster action toward achievement of Sustainable Development Goal 7 (SDG7), which call for universal access to sustainable energy by 2030, and the Paris Agreement, which calls for reducing greenhouse gas emission to limit climate warming to below 2^{o} Celsius.

Theirs work also supports progress against the decarbonization targets laid out in the Paris Agreement [14].

The PNUD (United Nations Development Program) supports and promotes a transformation of the energy sector market through a series of interventions in policies, finance, capacity building and awareness raising.

Promoting investments that help obtain sustainable energy products and services, and reducing the risk of the political and financial environment [15].

The private sector is an important vehicle for technology development and innovation, representing a hub for technical progress [16].

IRENA (International Renewable Energy Agency) encourages governments to adopt enabling policies for renewable energy investments, provides practical tools and policy advice to accelerate renewable energy deployment, and facilitates knowledge sharing and technology transfer to provide clean, sustainable energy for the world`s growing population [17].

UN-Energy, the United Nations´ mechanism for inter-agency collaboration in the field of energy, was established in 2004 as subsidiary of the Chief Executive Board, reporting to the High-Level Committee on Programmes, to help ensure coherence in the United Nations system´s multidisciplinary response to the World Summit on Sustainable energy [18].

In 2012 Mexico became the first large oil producing emerging economy to adopt climate legislation, the General Law on Climate Change [19].

Mexico is one of the five most vulnerable countries to climate change due to its biodiversity, geographic position, and poverty levels. The country has already experienced climate change effects, from severe droughts to rainstorms of increasing intensity and frequency. Meanwhile, it is the world´s 13th biggest emitter of greenhouse gases, and the world´s 11th biggest economy, projected to be the 5th largest economy by 2050.

The general Law on Climate Change strengthens Mexico`s commitment to sustainable development and its transition to a low carbon economy, promoting the creation of green jobs and innovation in clean technologies and renewable energy. The new Law is a clear demonstration of the political will of the Mexican State to meet sustainable development, renewable energies, and the transition to the new green economy models. This commitment in the next text of the Law through Article 35-III which emphasizes the central role of sustainable development, human health, biodiversity, food security, economic development, environment and "the gradual substitution of the use and fossil fuel consumption by sources of renewable energy", and Article 2-VII, which states as principal objective to "promote the transition to a competitive, sustainable and low carbon emission economy".

"The Law sets Mexico´s goals of reducing emissions by 20% by 2020 and 50% by 2050, conditioned on international support, as well as the goal of generating 35% of electricity, by renewable energy by 2024" [20].

In recent years, the international community has reached a consensus about the need to take action against global warming by reducing or cutting carbon emissions from fossil fuels.

In this context, on December 24, 2015, the Federal Official Gazette in Mexico published the decree issuing the new Energy Transition Law (Ley de Transición Energética). The Energy Transition Law aims to regulate the sustainable use of energy and articulate the electric industry`s obligation regarding the country`s need to transition to using clean energies and cutting pollution emissions, while at the same time maintaining Mexico`s productivity and competitiveness on the world stage.

The Energy Transition Law establishes that the Ministry of Energy, through the Clean Energy Goals and Energy Efficiency Goals, will promote power generation via clean energy sources to allow industry to comply with standards established in Mexico`s General Climate Change Law and Electric Industry Law.

Given the structural modifications set out in the Energy Transition Law, both electricity producers and consumers may want to structure plans for compliance with the New Mexican regulatory framework [21].

By 2030, Mexico could generate up to 46% of its electricity each year, or 280 terawatt-hours (TWh), from renewable sources. This compare with 18% using business-as-usual developments (11 TWh/year). To achieve a 46% share of renewables in electricity generation, the country is likely to see greatest deployment in wind (30 gigawatts GW) and solar photovoltaic (V) (30GW). Together these could account for 26% of total power generation in 2030. Small and large hydropower (26 GW) could contribute 12% of total power generation, with geothermal energy supplying 5% (4-5 GW) and biomass 2.5% (4 GW).

REmap 2030: Mexico´s renewable energy potential

The international Renewable Energy Agency (IRENA) has developed a global renewable energy roadmap called REmap 2030. This shows how the share of renewables in the global energy mix can be doubled by 2030, both realistically and cost-effectively. Based on Remap 2030, more than half of Mexico´s total renewable energy use would be in the electricity sector. Mexico has the potential to generate 280 TWh of renewable power by 2030, representing sixfold increase over today´s level of 48 TWh. Achieving this would require a diversified mix of wind, solar, hydro, geothermal and biomass power technologies.

Wind and solar PV combined would account for nearly 60% of Mexico´s renewable power generation, and 26% of total generation in 2030. Reaching this level of deployment requires policies that take into account Mexico´s major land area, in which demand and supply are often far apart.

Wind power represents a major opportunity across both the north and south of Mexico, with the potential to produce 92 TWh of electricity per year by 203. Nearly all of this would be derived from onshore wind. In the context of the country`s total installed wind power capacity of 1.7 GW in 2013, a total of 30 GW in 2030 would require an average annual installation rate of 1.7 GW.

Solar PV could contribute 30 GW of power capacity, generating 66 TWh of electricity per year in 2030. This would require an average annual installation rate of 1.5 GW. A quarter of the total installed capacity in 2030 would be in the form of distributed PV and mini-grid applications for street lighting, agricultural water pumping and mobile phone towers (7 GW). An additional 1.5 GW would come from concentrated solar power (CSP).

Under currents plans, Mexico would reach 17 GW of large hydropower capacity by 2030. According to Remap, a further 6.5 GW could be installed. Small hydropower capacity is already forecast to reach 1.8 GW, equivalent to an annual addition of 90 megawatts (MW) in 2015-30, or about ten small hydropower plants per year. Total installed hydropower capacity would reach 26 GW under Remap 2030. Targets to generate a share of total electricity from clean energy technologies have been set at 35% by 2024, 40% by 2035 and 50% by 2050 [22].

The national energy transition strategy shown in (Figure 6) is created, this strategy allows the current Mexican electricity system highly based on fossil fuels to turn into an electricity system that supplies 75% of the electricity demand by Renewable Energy Sources (RES), this transition strategy is built by takin the optimal combinations obtained from the scenarios created by years 2024, 2035 and 2050. In every transitions stage, each technology/energy-source capacity is clearly identified and corresponds to the combination of minimum installed capacity for every target year [23].

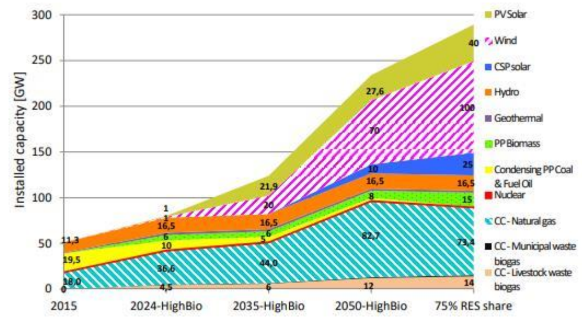

Figure 6. *Evolution of the installed capacity by technology for the Mexican electricity system (Vidal et al., 2018).*

The National Electric System Development Program (PRODESEN 2018-2032) projects in its base scenario that the demand for electricity in Mexico will grow at an average annual rate of 3.1% over the next 15 years (Figure 7).

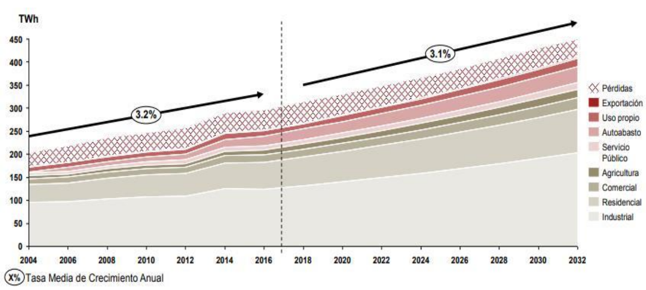

Figure 7. *Evolution of the electricity demand by sector in Mexico (Vidal et al., 2018).*

The PRODESEN proposes additions of power generation indicatively, based on the system optimization it also includes additions of 28 in the baseline scenario GW of combined cycles of natural gas and 37 GW of clean technologies in the next 15 year to achieve a 58 GW matrix in 2024. The generation wind and solar would account for 70% of total clean energy additions. Addition in clean technologies would mitigate ~54 million tons of CO_{2eq} (Mt CO_{2eq}) in 2030, with respect to a scenario in the which will cover the new demand only with generation additions based on combined cycle technology with natural gas. This would be 9 Mt CO_{2eq} below the emission GHG/GEI (Greenhouse gas) mitigation target no conditioned, which corresponds to 63 Mt CO_{2eq} in 2030 (Figure 8).

-22% GEI					EMISIONES de GEI ($MtCO_2e$) Meta al 2030
	Línea base				No condicionada
	2013	2020	2025	2030	2030
TRANSPORTE	174	214	237	266	218
GENERACIÓN DE ELECTRICIDAD	127	143	181	202	139
PETRÓLEO Y GAS	26	27	27	28	23
INDUSTRIA	80	123	132	137	118
AGRICULTURA Y GANADERÍA	115	125	144	165	157
RESIDUOS	80	88	90	93	86
SUBTOTAL	31	40	45	49	35
USCUSS[1]	633	760	856	941	776
EMISIONES TOTALES	32	32	32	32	-14
	665	792	888	973	762

Figure 8. *Greenhouse gas/GHG/GEI reduction commitments 2020-2030 (image courtesy of Mexico´s commitments adaptation for climate change 2020-2030).*

For Mexico to move to a low carbon economy in the next decades, the objectives and goals of the policies need to be aligned energy, climate, urban development, industrial and transportation of congruent, efficient, transversal and transparent way; and be promoted a better interaction between the public agencies involved [24].

For this, the generation of electricity with clean energy (renewable sources, efficient cogeneration with natural gas and thermoelectric with CO_2 capture) it must reach a 35% stake in the year 2024 and 43% by the year 2030 [25].

HYDROLOGICAL REGIONS OF MEXICO

The basins are natural units of the land, defined by the existence of a division of surface waters due to the conformation of relief. For national waters administration purposes especially the publication of availability1, Conagua has defined 757 hydrological basin as of July 7, 2016 along with its availability, in accordance with NOM-011-Conagua-2000, of which 649 were in a situation of availability.

The basins of the country are organized in 37 hydrological regions shown on map of Figure 9, which of management purposes are grouped in the 13 hydrological-administrative regions (RHA) [26].

__Figure 9.__ Hydrological regions of Mexico (image courtesy of Conagua 2018).

The hydrological-administrative regions (RHA), are formed by basin groupings, considered as the basic units for water resources management. The boundaries of the regions respect the municipal political division, to facilitate the administration and integration for socioeconomic data Figure 10 [27]. As can be seen in Figure 10, the regions with the greatest hydrological potential are the Mexico´s southern.

__Figure 10.__ Hydrological regions of Mexico that are most water source available (image courtesy of Conagua 2018).

Hydrological potential of Veracruz´s region

Veracruz, being located in the southern region according to figure 10, has great hydrological potential. As we can see in the Figure 11, Veracruz covers three hydrological regions.

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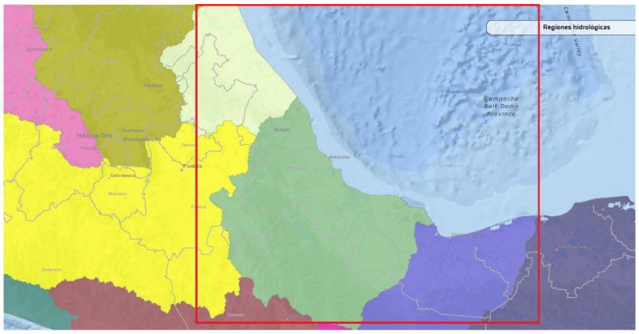

Figure 11. *Hydrological regions of Veracruz (image courtesy of SINA 2020).*

The three hydrological regions that make up Veracruz are [28]: Veracruz North-hidrological regions (Figure 12), Papaloapan region (Figure 13) and Coatzacoalcos region (Figure 14).

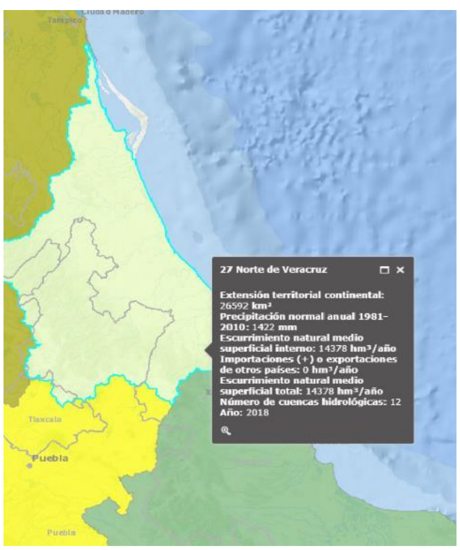

Figure 12. *Veracruz North-hidrological regions (image courtesy of SINA 2020).*

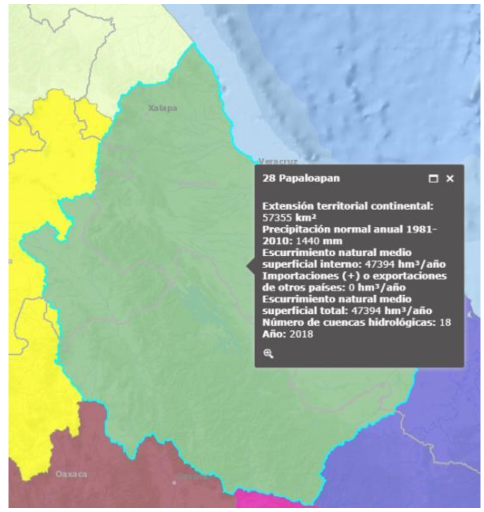

Figure 13. *Papaloapan-hydrological regions (image courtesy of SINA 2020).*

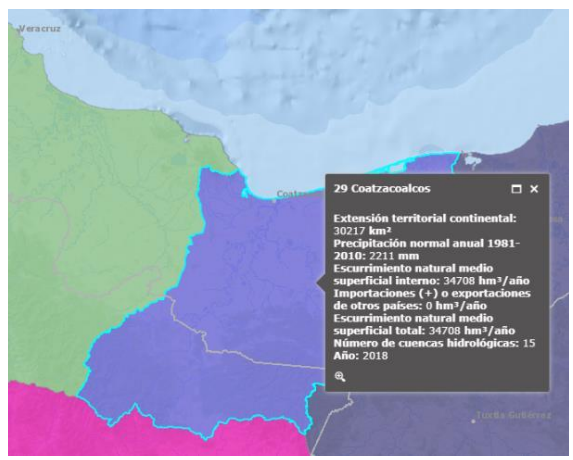

Figure 14. *Coatzacoalcos-hydrological regions (image courtesy of SINA 2020).*

Veracruz therefore has large hydrological resources to use them sustainably, and thus be able to generate a green economy and reduce the climate change. Now the global trend is to favor projects and investments that boost the green economy, and Veracruz could take advantage of it, driving an economy based on sustainable money. Veracruz currently bases its economy on technologies based on fossil fuels that generate greenhouse gases (GHG), and the energy transition based on renewable energies is not yet promoted on a large scale. It's necessary to promote public or private investments that reduce the use of fossil fuels at regional and national levels. Hydrological variables will be analyzed by region, of which they make up Veracruz. Below are defined some variables to analyze:

Distribution of normal rainfall

Normal precipitation is the calculated average of uniform period with at minus 30 years of information registration. For the period 1971-2010, the average normal rainfall of the country was 760 millimeters per year Table 1 and Figure 15.

Table 1. *Hydrocarbon degradation at different percentages.*

RHA	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	Anual
I Península de Baja California	23	22	17	4	1	1	9	23	24	12	12	21	169
II Noroeste	25	23	13	5	5	18	111	107	56	28	20	33	445
III Pacifico Norte	27	12	5	5	8	62	188	193	136	54	29	28	747
IV Balsas	15	5	6	14	52	186	198	192	189	83	16	7	963
V Pacífico Sur	9	8	8	20	78	244	205	225	249	111	21	9	1 187
VI Río Bravo	16	12	10	16	31	50	75	81	81	36	15	17	438
VII Cuencas Centrales del Norte	16	6	5	12	27	59	87	86	72	32	13	15	430
VIII Lerma-Santiago-Pacífico	22	6	3	6	23	131	201	185	150	59	18	12	816
IX Golfo Norte	27	17	21	40	76	142	145	130	176	82	30	29	914
X Golfo Centro	45	34	30	41	85	226	255	253	281	161	88	61	1 558
XI Frontera Sur	60	52	38	52	135	278	219	266	332	222	114	77	1 846
XII Península de Yucatán	48	31	29	38	83	172	158	173	212	147	76	52	1 218
XIII Aguas del Valle de México	10	8	13	28	56	105	115	104	98	50	13	7	606
Total	**25**	**17**	**13**	**18**	**41**	**105**	**136**	**140**	**136**	**70**	**31**	**27**	**760**

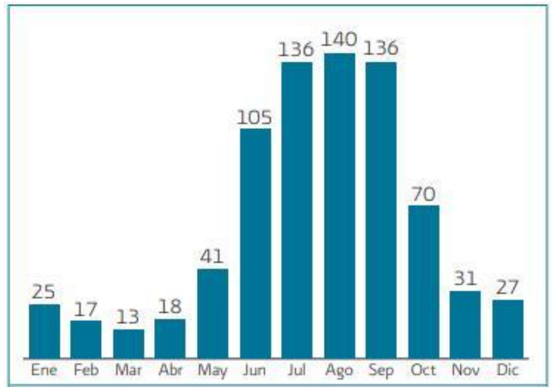

Figure 15. *Normal monthly rainfall in Mexico, 1971-200 data from table 1 (image courtesy of CONAGUA 2011).*

In Mexico, 68% of normal rainfall monthly occurs between June and September. Considering whereas the renewable water resources of a region or country refer to the maximum amount of water that is feasible to exploit annually that is, the amount of water that is renewed by rain and by water from other regions or countries (imports). Renewable water is calculated as the annual internal average surface natural runoff, plus the total annual recharge of aquifers, plus water imports from other region or countries, minus water exports to other regions or countries [29].

In the case of Mexico, for the Annual internal average surface natural runoff (Figure 16) and aquifer recharge, the average values determined from the studies carried out in the region are used [30].

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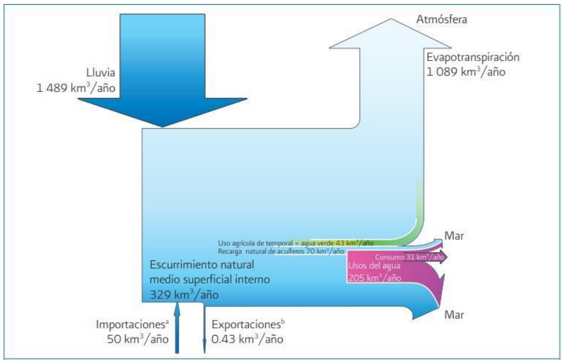

Figure 16. *Average anual values of the components of hydrological cycle of Mexico, billions of cubics meters Km^3 (image courtesy of CONAGUA 2011).*

The rivers and stream of the country constitute a hydrographic network of 633 thousand kilometers in length, in which fifty main rivers stand out (Figure 17) for that flows 87% of the country´s surface runoff and whose basin cover 65% of the territorial surface continental of the country.

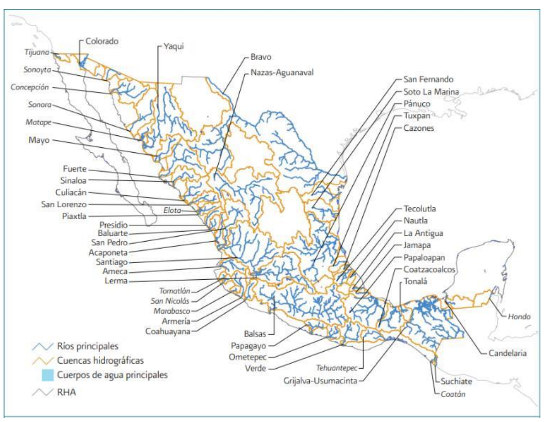

Figure 17. *Main rivers with their river basin(image courtesy of CONAGUA 2011).*

Two thirds of surface runoff it belongs to seven rivers: Grijalva-Usumacinta, Coatzacoalcos, Balsas, Pánuco, Santiago y Tonalá, while their basin they represent 22% of surface of our country (CONAGUA, 2011, p. 28).

Analysis of hydrological variables-rivers by región of Veracruz´s state

To have a more specific view of the hydrological resources of the three regions that make up Veracruz (SINA, 2020). The data obtained from the SINA Table 2, will be analyzed, in order to observe the correlation between the hydrological flows that enter and leave by region and their levels of increase or decrease in their normal annual rainfall, and in this way the hydrological region with the greatest potential for produce hydrogen in sustainable way.

Table 2. *Data collected from reports historical from 2013 of tree regions of Veracruz, Veracruz North, Papaloapan, Coatzacoalcos (SINA, 2020).*

Año	Hydrological region	Normal rainfall 1981-2010 (mm)	Internal surface medium natural runoff (Hm3/año)	Imports (+) and exports (-) from other countries (Hm3/año)	Total surface average natural runoff (Hm3/año)	number of basins	Area (Km2)
2013	Veracruz North (Tuxpan-Nautla)	1422	14378	0	14378	12	26592
2013	Papaloapan	1440	47394	0	47394	18	57355
2013	Coatzacoalcos	2211	34708	0	34708	15	30217
2014	Veracruz North (Tuxpan-Nautla)	1422	14155	0	14155	12	26592
2014	Papaloapan	1440	48181	0	48181	18	57355
2014	Coatzacoalcos	2211	34700	0	34700	15	30217
2015	Veracruz North (Tuxpan-Nautla)	1422	14155	0	14155	12	26592
2015	Papaloapan	1440	48181	0	48181	18	57355
2015	Coatzacoalcos	2211	34700	0	34700	15	30217
2016	Veracruz North (Tuxpan-Nautla)	1422	14378	0	14378	12	26592
2016	Papaloapan	1440	47394	0	47394	18	57355
2016	Coatzacoalcos	2211	34708	0	34708	15	30217
2017	Veracruz North (Tuxpan-Nautla)	1422	14378	0	14378	12	26592
2017	Papaloapan	1440	47394	0	47394	18	57355
2017	Coatzacoalcos	2211	34708	0	34708	15	30217
2018	Veracruz North (Tuxpan-Nautla)	1422	14378	0	14378	12	26592
2018	Papaloapan	1440	47394	0	47394	18	57355
2018	Coatzacoalcos	2211	34708	0	34708	15	30217

A graph was obtained with a correlation coefficient between normal precipitation and the internal surface medium natural runoff (hm^3/hora) from Table 2, the tendency obtained is positive Figure 18, which means that the hydrological volume positively increases both variables.

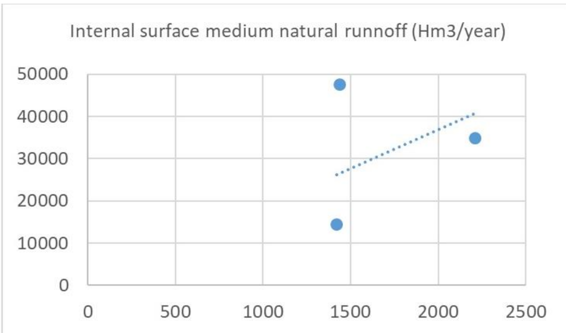

Figure 18. *Positive correlation between normal precipitation and internal Surface médium natural runoff from 2013-2013 from each hydrological región Veracruz (SINA, 2020).*

The next graph was obtained (Table 2) with a positive correlation coefficient between Total surface average natural runoff (hm^3/year) and area for each region in square kilometers (Figure 19).

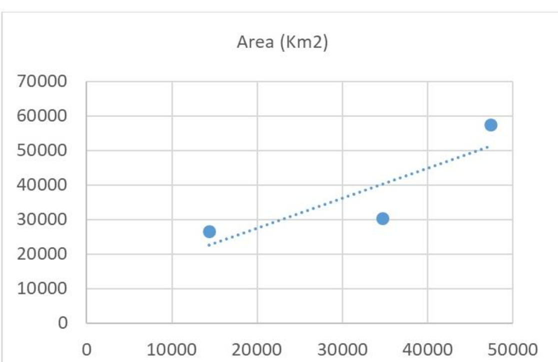

Figure 19. *Positive correlation between normal total Surface average natural runoff (hm^3/year) and area for each region from Veracruz in square kilometers from 2013-2013 from each hydrological region of Veracruz (SINA, 2020).*

The trends indicate that the total surface average is according with the extension of region in square kilometers (Area) by Veracruz´s hydrological region Figure 20.

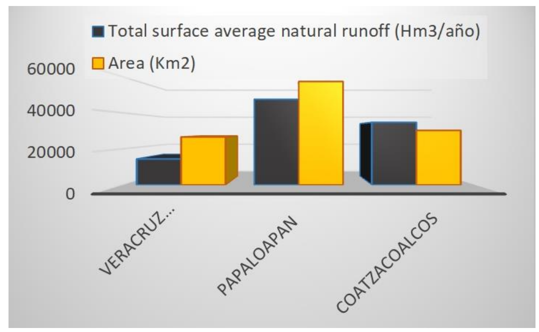

Figure 20. *Area and total Surface average natural runoff (Hm^3/year) each hydrological región of Veracruz (SINA, 2020).*

The region with most square area and hydrological volume is the hydrological region Papaloapan and the second place Coatzacoalcos. For the last one region is Veracruz North, with the less square area and total surface average natural runoff (hm^3/year):

*1 hectometer (hm^3/year)= 1000 000 000 litters

As we can see, the graph Figure 20 that show us, (last data obtained by year 2018), the most potential region to develop an economy based in

Hydrogen in Veracruz its Papaloapan and Coatzacoalcos.

Finally, we will analyze the 10 main rivers of Veracruz the following variables: Medium surface natural runoff (millions of m^3/year), Basin Area (Km^2) and River length (Km).

The Table 3, show the following variables:

*RHA= Administrative Hydrological Regions

$1hm^3$= million cubic meters

The average surface natural runoff data represent the average annual value of its historical record and include runoff from transboundary basin.The data of the average natural surface runoff and the area of the basin were obtained from the availability studies of hydrological studies. Source: Conagua Technical Subdirectorate, 2010.

The basin area and length refer only to the Mexican part.

Table 3*. The 10 main rivers from Veracruz´s hydrological variables, area and river length (SINA, 2020).*

No	River	*RHA	Medium surface natural runoff (millions of m3/year)	Basin Area (Km2)	River lenght (Km)
1	Papaloapan	X Center Gulf	44662	46517	354
2	Coatzcoalcos	X Center Gulf	28093	17369	325
3	Pánuco	IX North Gulf	20330	84956	510
4	Tonalá	X Center Gulf	11389	5679	82
5	Tecolutla	X Center Gulf	6095	7903	375
6	Jamapa	X Center Gulf	2563	4061	368
7	Nautla	X Center Gulf	2217	2785	124
8	La antigua	X Center Gulf	2139	2827	139
9	Tuxpan	X Center Gulf	2076	2076	150
10	Cazones	X Center Gulf	1712	1712	145

The graph Figure 21, show the main variable Medium surface natural runoff (millions of m^3/year).

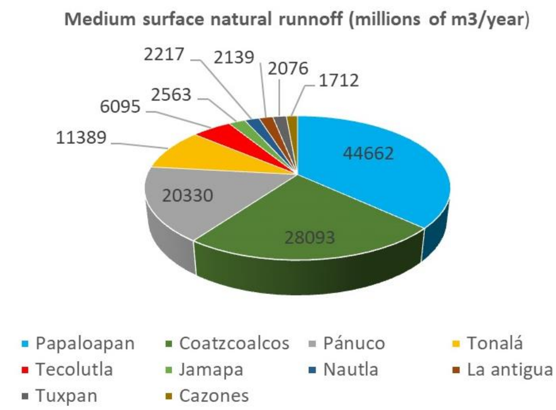

Figure 21. *Graph to show the Medium Surface natural runoff (millions of m^3/year) of the main Veracruz´s Rivers, data of Table 3, (SINA, 2020).*

The graph Figure 22, show the variable Basin Area (Km^2). Data were obtained from Table 3.

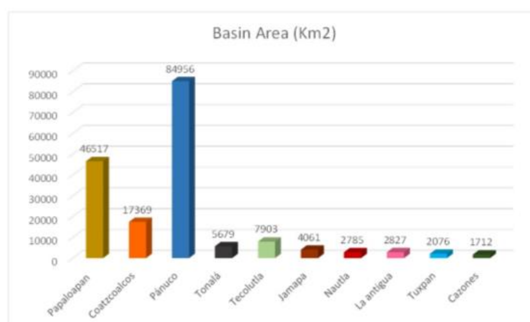

Figure 22. *Graph to show the Basin area (Km^2), of the main Veracruz´s Rivers, data of Table 3, (SINA, 2020).*

The graph Figure 23, show the variable River length (Km). Data were obtained from Table 3.

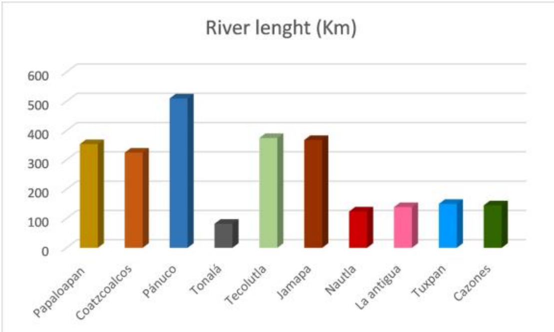

Figure 23. *Graph to show the River length (Km), of the main Veracruz´s Rivers, data of Table 3, (SINA, 2020).*

A correlation analysis was made between Medium surface natural runoff (millions of m^3/year) and Basin area (Km^2) (Table 4).

It is intended to know with this analysis, if the volume of millions of m^3/year is a dependent variable with respect to the square kilometers of surface area of each of the 10 main rivers of the state of Veracruz. If the correlation is positive or negative.

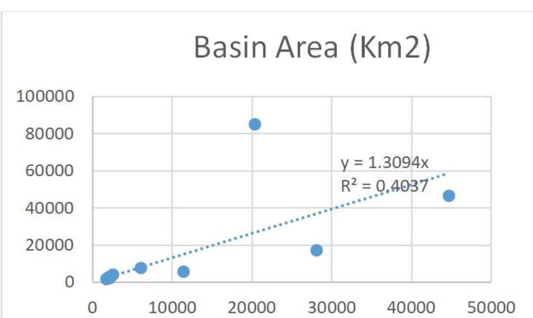

Figure 24. *Graph to show correlation of between Medium surface natural runoff (millions of m^3/year) and Basin area (Km^2) from the main Veracruz´s Rivers, data of Table 3, (SINA, 2020).*

As we can see, the graph from Figure 24, there is a positive correlation perfect between both variables, whose value is equal 1. The trend is positive and the volume increases with respect to the area covered by river basins.

There are three main rivers that have the largest volume of millions of m3/year (Figure 21), and their length (Figure 22), and surface area (Figure 23) are significantly greater than the rest of the other rivers. The Panuco, Papaloapan and Coatzacoalcos rivers with the highest hydrological values and as future prospects for the development of hydrogen as a sustainable energy resource.

STATEMENT OF LIMITATIONS

As it was seen at the beginning of the investigation, although hydrogen is not considered as a priority energy resource, within the objectives of sustainable development, promoted by the UN, as it is not yet established in Mexican regulation. There are limitations regarding specific technical information to develop hydrogen in a totally sustainable and economic way, as well as projects that are currently focused on taking advantage of the hydrological resources of the rivers of the Veracruz state.

Therefore, this research is intended as a first step, for future work on hydrogen research and its development in the Mexico´s southern regions, which have hydrological advantages, as saw a the beginning of the research.

CONCLUSIONS

We are in a global climatic emergency, today is when we must focus scientific research on the development of hydrogen as the most abundant sustainable resource in the universe. We must participate together with the government, private sectors and institutions of higher educations and develop joint projects. As the hydrological resources in the state of Veracruz were analyzed, we have potential rivers to detonate a sustainable hydrogen-based industry, and therefore a green economy. The future depends on what we to do today, we cannot delay the development of renewable energies, the end of fossil fuels will come soon and we must to work now, in the energy transition, towards a cleaner and more sustainable world.

“The future is uncertain and we cannot predict it, but we must be ready for its arrival” says Andreas Schleicher, director of Education and Skills of the Organization for Economic Cooperation and Development [31]. Over the next few year, cities across the planet will increase to 3000 million by 2030.

In 10 years, global food demand will increase 50%, energy demand 45% and water demand 30% according to a report published by the High Level Panel on Global Sustainability, designated by the UN. The world population will be mostly urban 60%, according to The Economist [32]. The digital government, the Internet of things (IoT), artificial intelligence and the 5G network revolutionize information technology (IT) services.

For example, technologies such as autonomous vehicles require adequate infrastructure that allows them to make decisions in the shortest possible time.

To satisfy this need, the IT industry is committed to edge or “border” technology that is, data minicenters near the place where information is generated and processed, details Herve Tardy, vice president of EATON, a US multinational management of energy.

“The trend will be hybrid infrastructure: what is more sensitive to latency (speed at which information travels from point to point) be closer and the rest will be distributed in public and private clouds and computers centers,” he says.

In addition, the industry should improve the uses of the temperature of the environment to obtain greater energy efficiency, increase both physical and digital security and grater intercom processing capacity says Juan Pablo Borray, director of Business Development at Panduit. IT services has grown at an annual rate of 14% since 2017 [33].

Experts says that this year (2020) will be the beginning of the association of all the leading technologies of the last decade to create fully coupled environments that can work autonomously in order to build companies, work spaces, smarter cities and interconnected capabilities

Artificial Intelligence (AI), the Internet of Things (IoT), automation, Machine Learning, 3D printing and 5G connectivity will be responsible for giving this momentum [34]:

- 30% of jobs will be automated by 2030.
- 15% of cars will be autonomous in the next decade.
- 125 million devices connected to the Internet of things will be in ten years [35].

According to estimates by the United Nations Organization (UN), in 2050 it is estimated that 68% of the world's population will live in urban areas, which would result in an increase of 2,500 million people.

In Mexico, the capital of the country will become the tenth most populous city in the world, with 23, 3 million inhabitants, according to projections of the Global Cities Institute.

The manufacturers of transport systems agree on two things: the mobility of these types of populations would be through electric and even autonomous modes. Autonomous and electrical systems and mobility policies would reduce emissions by 80%. Car manufacturers will continue with the electrification trend at an annual growth rate of between 28 and 37%, and within 30 year more than 200 million alternative vehicles could circulate in the world, according to estimates by Goldman Sachs and Bloomberg [36].

"We are not a company that is particularly thinking of self-employed but we have seen the trends and we know we have to there," said Lutz Meschke, appointed director of the board of directors and member of the board of finance and technology executives of Porsche AG (Chavez Gabriela, 2019, p. 80).

"In 2040, renewable energies will continue to gain ground and when combined with natural gas and emerging technologies, such as micro-networks, they will be able to create robust energy systems of high efficiency and low carbon emission. Advanced biofuels are envisioned through algae, carbon sequestration and new hydrogen-associate technologies," said

Enrique Hidalgo president of Exxonmobil Mexico [37].

"There is a dilemma and trend that will continue to determine the energy sector in following years and is the decentralization of energy. The probability that Mexico will become a country with energy deficit has increased in recent years, in a world where oil it is increasingly scarce and expensive. It is necessary to stop thinking that this input is necessary and to use it is strategically, and not as an economic and energy base. To achieve this objective, the country must consider all energy markets, including natural gas, electricity and renewable energy," said Enrique Gonzalez Haas, General Director of Schneider electric Mexico and Central America [38].

"In 50 years it will reach between 60 and 70% of the total electricity generation worldwide. But my personal impression is that the renewable plant has always broken forecasts and that this will be higher. We will see a quantum leap with Hydrogen that still has limitations, but it will be a disruptive and competitive technology against batteries to store energy (litio battery)," said Paolo Romanacci, CEO of Green Power Mexico and Central America [39]. The issuance of green bonds allows to finance sustainable projects, such as solar power plants, hydroelectric plants or saving buildings.

Richard Turnill, global head of Investment Strategies at Black Rock points out that sustainable investments are gaining popularity in the world.

"The issuance of bonds is due to the fact that the reception of investors has been favorable and there is an increasing interest in these instruments because the projects to which the green bond resources are destined are more adapted to the world that is coming," says Eduardo Piquero, director of MexicoCo2. For the manager, this type of bond decreases the financial risk that have to do with climate change. For example, investments in oil, gas o other fossil fuels will tend to lose value in the market, because the international trend is committed to other types of energy, "adds the specialist.

In Mexico there are still many areas of opportunity for these instruments to grow even more. According to the UBS investor Watch study, globally. Investors expect the proportion of sustainable investments to increase from 39 to 49% over the the next five years and a majority (58%) believe they will become the norm within a decade [40].

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