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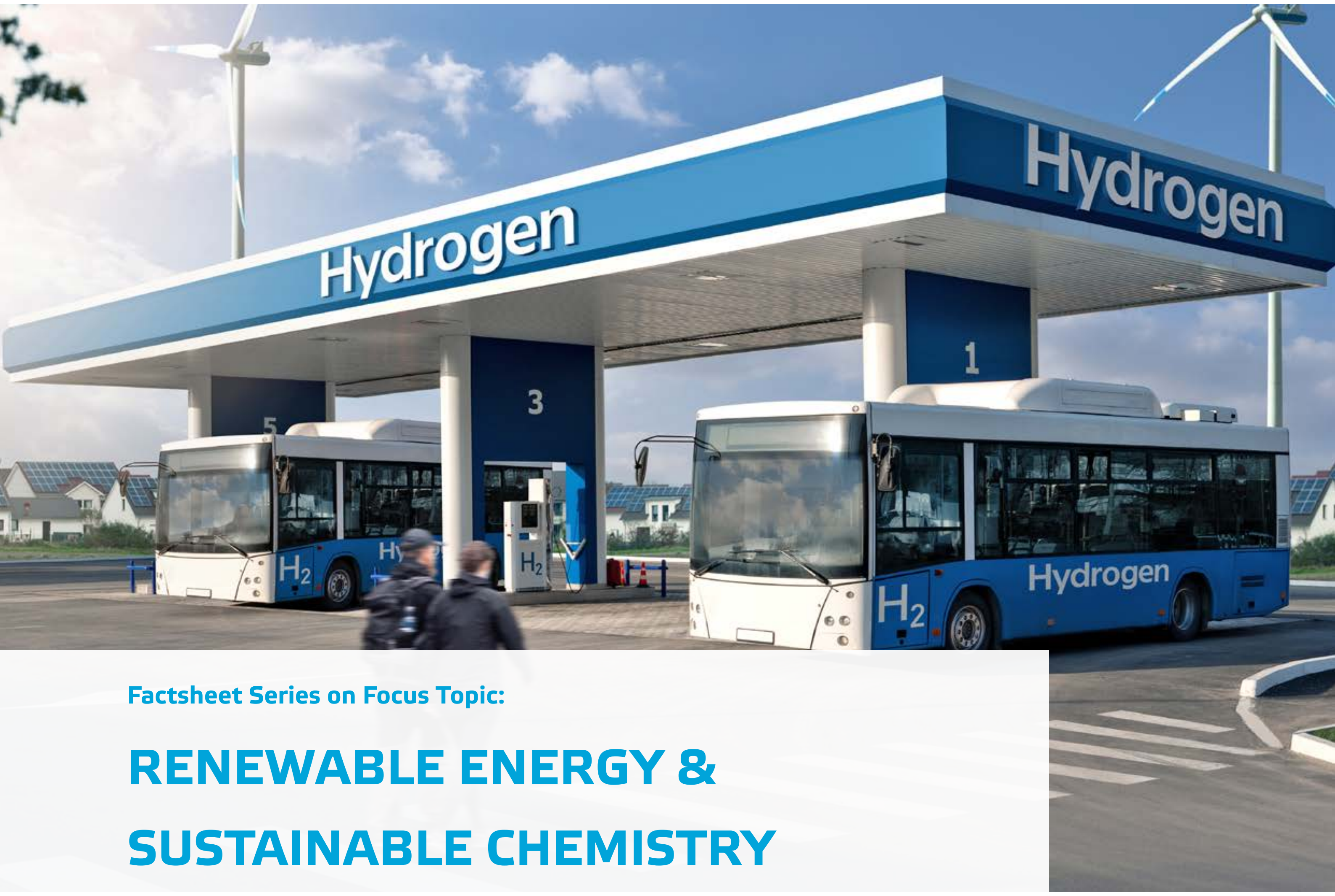


Factsheet Series on Focus Topic:

RENEWABLE ENERGY & SUSTAINABLE CHEMISTRY

Towards a sustainable PtX roadmap for Uruguay

Stakeholder dialogue: Results and strategies for implementation

Key findings:

Renewable energy can be used in the Power-to-X (PtX) process to produce chemicals such as hydrogen, ammonia, methanol, and methane. The process and technology come along with side effects in all dimensions of sustainability – those are foreseeable and can be diminished. Managing water use, designing for the reuse and recycling of rare metals, and creating social benefits are examples of essential considerations for countries aiming for sustainable PtX products.

Plain language:

When chemicals are produced, nature and people can be harmed. It is better to use electricity from wind or sun. The machines for this electricity also cause problems. The ISC3 advisors talk to people about the problems in their region. Solutions are developed for these problems.

The International Sustainable Chemistry Collaborative Centre ISC3 asks: How can energy from renewable sources be used in a sustainable way for chemical applications and vice versa? How can sustainable chemistry be used to advancement of a sustainable energy supply?.

In a consultative process, ISC3 and PtX- Hub assisted MIEM[1] and other stakeholders from Uruguay and Latin America, e. g. ANCAP[2], UTE[3], OLADE[4], with an in-depth analysis of the possible negative and positive social, economic and environmental impacts of green hydrogen and PtX production. In this consultative process, general but also local side effects of PtX were addressed and sustainability criteria were identified that need to be considered in order to avoid harmful impacts and foster positive aspects. Strategies for favourable and prosperous development were derived from a SWOT analysis.

H_2O **+**

a) $N_2 = NH_3$
b) $CO_2 = CH_3OH$

Power-to-X (acronym PtX) is the conversion of (renewable) electricity into molecules that can be used as fossil-free fuels and feedstocks in industry and transport. Typically, these molecules are gaseous (PtG, such as methane) or liquid (PtL, such as synthetic jet fuel).

The initial step is the production of so-called green hydrogen, which is generated by splitting water in an electrolyser using power from renewable energy sources. Hydrogen itself is a gaseous energy carrier and can be used directly for several industrial processes.

Energy from Renewables

Hydrogen Economy & PtX

Sustainable Chemistry

The PtX process can help to store or transport energy bonded into other substances, e. g. gases. Hydrogen is synthesised with other elements because these chemical compounds, such as ammonia (as a storage for hydrogen), are directly used for further industrial processes, for example the production of fertilisers or as energy carriers. The whole process requires energy, water and further elements, such as carbon dioxide or nitrogen, as input. The process for generating the PtX molecules also requires chemical plants as well as storage and transport infrastructure. Using existing infrastructure (brownfield industry plants) is one of the success factors that limits dissipation of resources.

PtX are technologies for a successful transition towards a climate-neutral, de-fossilised economy and society. However, this energy transition must be designed in a way that contributes to economic prosperity, social justice and environmental integrity. The domestic use as well as the export of hydrogen and its derivates and the related effects need to be considered. This includes limited resources and possible conflicts as a consequence, emissions, waste, and increased electrical energy demand for sector coupling. Possible transport hazards need to be avoided and challenges with output substances considered. The key question is how to avoid economic, environmental or social disruptions when phasing out energy systems based on fossil fuels.

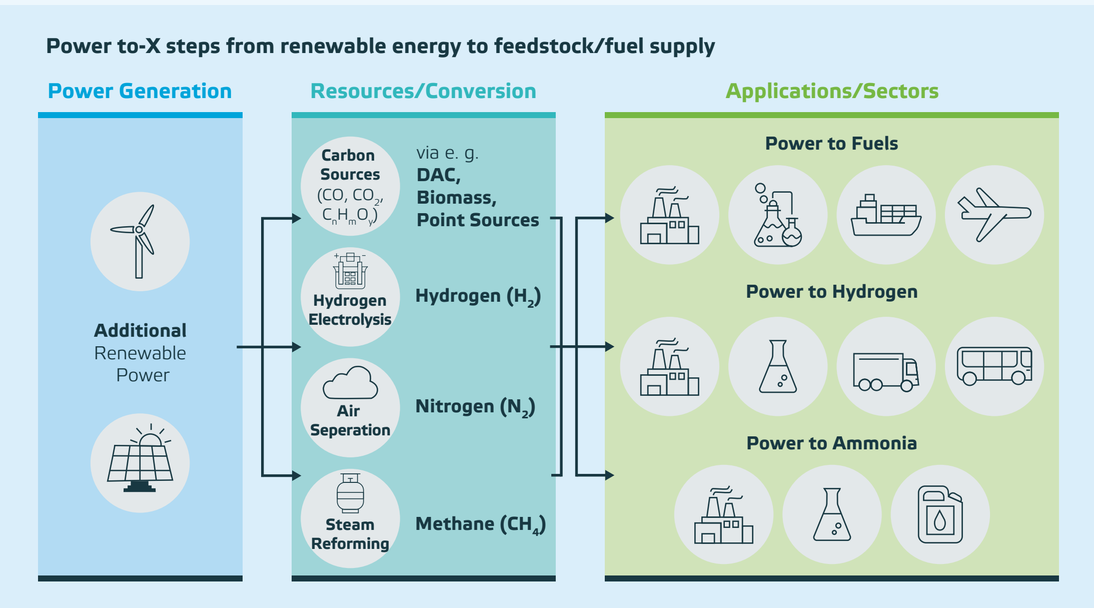


FIGURE 1: Overview of PtX Value chain showing the inputs (resources) and outputs (applicaitons)

9 t H_2O for 1 t H_2

Water use:

9 tonnes of water are required to produce 1 tonne of hydrogen

URUGUAY: STATUS QUO AND CHALLENGES

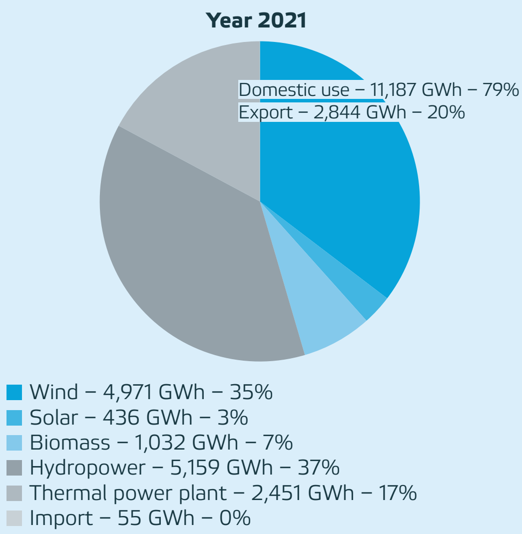


FIGURE 2:
Uruguay Power Sources in 2021

Source: https://www.adme.com.uy/controlpanel.php

Uruguay as an electricity exporter at the beginning of energy transition stage 2

Compared to 2020, Uruguay increased its energy exports by 148% in 2021 to 2,844 GWh, according to the National Energy Balance compiled by MIEM.

During the first stage of its energy transition, Uruguay achieved a high percentage of renewable energy and is now seeking to de-fossilise various sectors during the second stage of the transition towards green hydrogen, developing actions that include, among other things, the ongoing call for the construction of the first H_2 pilot project.

Renewable energy

98% of Uruguayan electricity was generated by renewable energies in 2019

98%

In its first energy transition phase, URY pushed renewables to this exceptionally high level and **was able to export 2,844 GWh in 2021**

Hydropower and thermal power

5.2 TWh **2.5 TWh**

5,159 GWh come from hydropower and **2,451** GWh from thermal power

According to MIEM, renewable energy sources accounted for 85% of electricity generation in 2021. This figure represents a decrease compared to 2020 (94%) and previous years (98%). The reason is more exports of conventional fossil electricity to neighbouring countries Brazil and Argentina.

Wind

5.0 TWh

4,971 GWh come from wind power

Uruguay has excellent wind resources in the north-western part of the country and in 2021 about 35% of all electricity was generated by wind power plants. ANCAP is considering building offshore wind parks that could produce green hydrogen and PtX on-site.

Solar

436 GWh

436 GWh come from solar power

One highlight of the National Energy Balance 2021 is the growth of installed solar capacities (MIEM 2022a). The amount of electricity generated by photovoltaics (PV) increased to 3% and 436 GWh in 2021 and is still at an early stage – there is a huge untapped potential. Excellent solar irradiation values in Uruguay make PV and Concentrated Solar Power (CSP) projects attractive by allowing low Levelised Cost of Electricity (LCOE) values.

Biomass

1.0 TWh

1,032 GWh come from biomass power

At the same time, the primary energy supply matrix is 57% renewable, an excellent figure by international standards. MIEM highlights that 40% of the primary energy comes from biomass, of which 75.5% is extracted from waste. While in 1990 87% of the biomass for energy production in Uruguay came from firewood (which in turn constituted 21% of the primary energy supply), in 2021 this energy source accounted for 21% of the biomass consumed.

H_2/PtX Roadmap Targets for Uruguay

The following potential has been identified in the Green Hydrogen & PtX Roadmap for Uruguay:

- Renewables that enable competitive hydro-gen production are abundant and complementary wind and solar resources are available – using both technologies will in-crease the total capacity factor, resulting in a more stable energy supply.
- At very favourable locations (Tier 1 locations) an additional renewable power generation capacity of more than 90 GW with competitive cost projections is feasible.
- Uruguay's RE resources can reach LCOE of 16 to 19 USD/MWh by 2030, with a total development capacity of about 60 GW solar and 30 GW wind for Tier I resources. At scale, hydrogen production costs will reach about 1.2 to 1.4 USD/kg by 2030, placing Uruguay in a competitive position worldwide.
- By 2040, a total addressable market of about 3 to 10 billion USD is estimated for green hydrogen and its derivatives; downstream products are predicted to add a further 11 billion USD.
- Local use of hydrogen is possible in transportation, fertilisers and industry.

Sustainability can only be achieved if the three dimensions – environmental, social and economic – are respected.

3D

Sustainability can only be achieved if the three dimensions – **environmental, social** and **economic** – are respected.

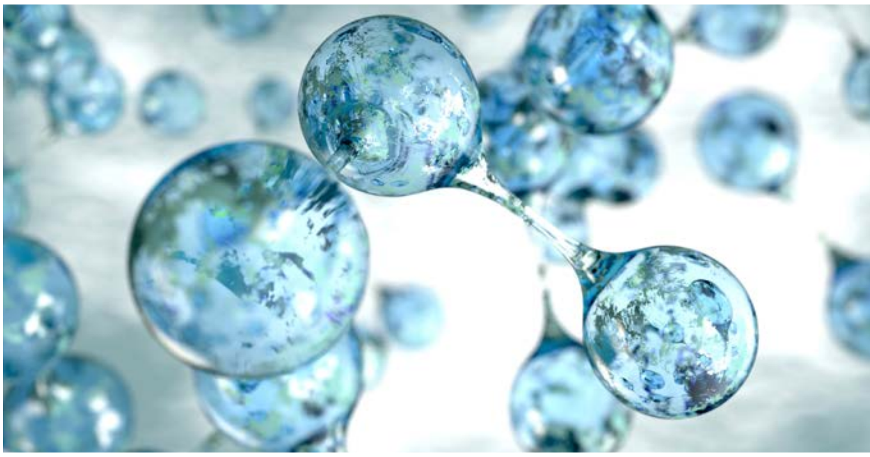
STAKEHOLDER DIALOGUE ON SIDE EFFECTS: OUTCOME IN A NUTSHELL

In expert groups, a SWOT analysis was conducted and strategies were derived from the outcome. Some insights are provided in the following table. For more detailed insights, please refer to our white paper (link to ISC3 website). The group focused on the EESG aspects and derived the classical SWOT strategies "Avoid, Safeguard, Implement and Expand":

Environmental	Governance
Safeguard future challenges: Design PtX plants and plant parts for recycling at end of life. Consider environmental stakeholders by involving NGOs. **Avoid** using rare metals as well as toxic and harmful substances or substitute these by less critical ones. Transport risks for hydrogen, ammonia, etc. need to be considered. Avoid conflict-bearing resources. **Implement** resource and waste management. Use CO_2 sources that are available in the next decades. **Expand** recycling capacity of rare metals or critical substances.	**Avoid** trade barriers or inequities in order to support domestic industry in international competition in its efforts to become more sustainable. **Safeguard** additionality of renewable energy for production of green hydrogen and PtX. The guarantee of origin must be regulated in order to be designated as green. **Implement** support policies and regulations to allow all stakeholders to participate and benefit from the transition to a green hydrogen economy. **Expand** and foster collaboration with neighbouring countries in energy trade, research and complementary production. As an example, the EU carbon offset mecha-nism allows fair conditions for all countries in Europe
Economic	**Social**
Avoid investments in greenfield plants – it is better to retrofit existing brownfield plants. **Safeguard** that rebound effects are considered and taken into account, i. e. savings from innovative technologies that increase efficiency of resource use can be lower than expected because of behavioural or other systemic responses that lead to an increase in the use of such resources. **Implement** the use of oxygen generated by electrolysis (e. g. for hospitals, bleaching or chemical processes). **Expand** renewable energy capacity such as solar, wind, hydropower and (waste) biomass extensively in a way that enables a maximum capacity factor and least cost.	**Avoid** a rise in national energy prices, land use, soil salination. Countermeasures should be planned and implemented and their effectiveness tracked. **Safeguard** employment in industry or expand higher-value sustainable industrial jobs for local skilled workers. **Implement** a continuous dialogue with social groups concerned about issues such as environmental protection and working conditions so that undesirable developments can be recognised and counteracted early. **Expand** education and capacity building already at an early stage to ensure that sufficient qualified professionals are available. Well-trained teachers are needed for academic education as well as for vocational schools to satisfy training needs from industry and the research sector and thus avoid recruiting only people from abroad.

In terms of the foreseeable developments, a differentiation is made between necessary, conducive and obstructive, and strategies are derived from this in order to steer in a desired direction with suitable measures.

- The environmental implications should be carefully analysed, and a systematic risk assessment and environmental impact assessment (EIA) are recommended.
- Compliance with national and international standards as well as certification schemes should provide proper regulatory frameworks for PtX markets and trade. Clear policy commitments, empowerment and participation of stakeholders are essential.
- PtX production and trade should contribute to improving economic prosperity and well-being. The 'low-hanging fruits' should be selected first.
- To create a 'Just Energy Transition', social implications must be taken into account, as well as adherence to high health and safety standards. Access to affordable energy for all is required and the development should not lead to job cuts but instead create additional attractive employment for skilled workers.



45x

The electrical energy needed to produce green hydrogen and transport it via pipeline is 45x higher than with natural gas.

Storage of H_2 at 350 bar or -253º

350 bar
-253º

3,500 to 5,000 km

Transport via pipeline = 3,500 – 5,000 km. Major investments in renewable power plants, electrolysers and PtX production are also needed. Resource demand is high.

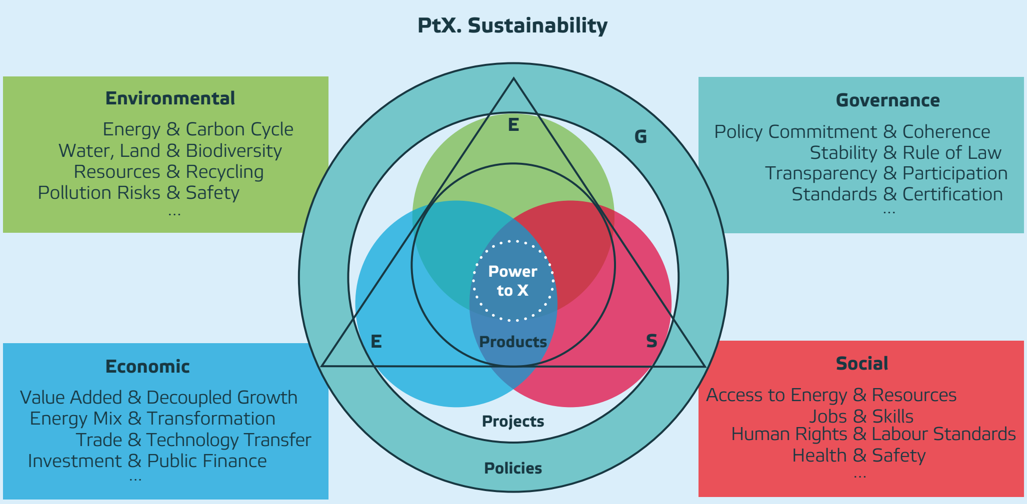


FIGURE 3:
EES criteria to asess PtX
Source: PtX HUB

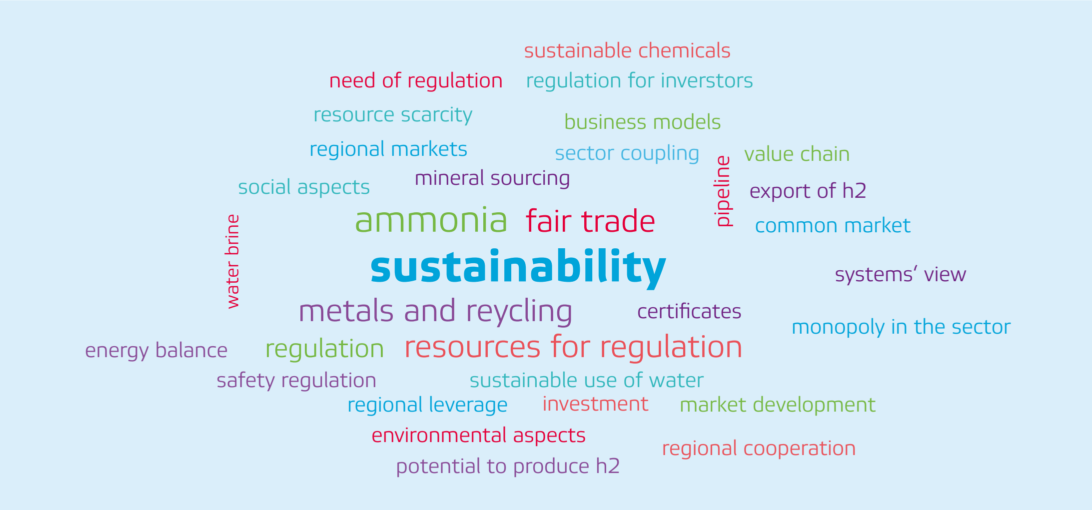


FIGURE 4:
Topics considered important by the participants of the online workshop on 29.10.2021 (Mentimeter results)

Outlook

The current findings cannot be applied to every country due to different conditions. ISC3 is also investigating PtX in Morocco. For example, Uruguay has abundant water resources and biomass plays a significant role, meaning that biofuels and biogas can be an additional source for producing green hydrogen as well as a possible CO_2 source. Morocco is arid and has limited fresh water sources. That is why seawater desalination plays a substantial role there. Morocco is situated strategically close to the EU and has its own chemical off-taker industry. A gas pipeline is already in place that can also be used to transport hydrogen or gaseous derivates (PtG) to Europe. Stay tuned for further factsheets in this series!

ISC3 is an international centre that promotes the transition of the chemical and related sectors to sustainable chemistry. The centre takes a multi-stakeholder approach, targeting policymakers, the public and private sectors, academia and civil society. ISC3 contributes to international chemicals policy, offers advisory services, fosters innovations, supports entrepreneurship and conducts research. The centre deliberately targets vocational training – especially the strengthening of capacities in developing and emerging economies.

The ISC3 is hosted by the German GIZ (Gesellschaft für Internationale Zusammenarbeit) in cooperation with Leuphana University Lüneburg as ISC3 Research & Education Hub and DECHEMA e. V. (Society for Chemical Engineering and Biotechnology) as ISC3 Innovation Hub. The centre was founded in 2017 on the initiative of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU now BMUV) and the German Environment Agency (UBA).

Websitepage: https://www.isc3.org/

1 **MIEM:** (**M**inisterio de **I**ndustria, **E**nergía y **M**inería) is committed to the global decarbonisation targets for 2050, both with regard to the energy sources used and the use of raw materials consumed in different industrial processes. A roadmap was drawn up at the end of 2021 (MIEM 2022b): https://www.gub.uy/ministerio-industria-energia-mineria/

2 **ANCAP:** (**A**dministración **N**acional de **C**ombustibles, **A**lcoholes y **P**ortland) is a state-owned company in Uruguay. It is involved in the production of petroleum products, Portland cement and alcoholic beverages. It operates Uruguay's only oil refinery: https://www.ancap.com.uy/

3 **UTE:** (**A**dministración **N**acional de **U**sinas y **T**rasmisiones **E**léctricas) is the state-owned electricity supplier: https://www.ute.com.uy/

4 **OLADE:** (**O**rganización **L**atinoamericana **D**e **E**nergía) is a public intergovernmental organisation for cooperation, coordination and technical advice, established in 1973 through the signing of the Lima Agreement, ratified by 27 Latin American and Caribbean countries, with the region's energy resources in focus: https://www.olade.org/en/

Further information

Link to white paper: https://www.isc3.org/cms/wp-content/uploads/2022/07/ISC3-White-Paper-PtX-UY.pdf.
If you are interested in promoting sustainable chemistry for the purpose of climate protection e. g. by implementing the above-mentioned formats, please contact us at: info@isc3.org.

Publications

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