

Disruptive innovative solutions enabling 100% renewable power systems by mid-century

Minutes of the online workshop of 28th November 2019, 16:00 (GMT+2)

I. Context

The workshop on ‘*Disruptive innovative solutions enabling 100% renewable power systems by mid-century*’ has been held online by the IRENA Innovation and Technology Center (IITC). It is the fourth and final activity performed under the ‘**Experience-sharing programme on innovative solutions for very high shares of renewable power by mid-century**’ that took place throughout 2019. This programme is supported by the government of Sweden and benefited from the active engagement of numerous member countries within past exchanges of perspectives and plans in striving towards high levels of renewables in their power systems.

This fourth workshop convened and connected representatives from Spain, Sweden and Uruguay which discussed the most disruptive innovations to achieve renewable-powered futures, with a focus on **direct and in-direct electrification of end-use sectors**, as well as sector-coupling. Based on the outcome of previous workshops, the participants were encouraged to consider additional dimensions of innovations, including ‘*social innovation*’ and ‘*regulatory sandboxes*’, to achieve successful and inclusive renewable energy transitions.

This document summarises in chronological order the highlights from this activity, to which the following speakers participated:

- Hugo Lucas Porta - Institute for Energy Diversification and Saving (Spain)
- Hanna Ek-Fälth – Renewable Energy Analyst, Swedish Energy Agency (Sweden)
- Sara Grettve – Project Manager, Swedish Energy Agency (Sweden)
- Virginia Echinope – Manager of the Electric Power Department, Ministry of Industry, Energy and Mining (Uruguay)
- Wilson Sierra – Manager of the Renewable Energies Department, Ministry of Industry, Energy and Mining (Uruguay)
- Stephanie Grunvald - Ministry of Industry, Energy and Mining (Uruguay)
- Martín Scarone – Ministry of Industry, Energy and Mining (Uruguay)
- Paul Durrant – Programme Officer, Renewable Energy Innovation (IRENA)
- Elena Ocenic – Programme Officer, Innovation Networks (IRENA)
- Nina Litman-Roventa – Intern, Stakeholder Engagement in Renewable Energy Innovation (IRENA)

The invaluable information gathered within these international dialogues will feed into the broader IRENA initiative on ‘**Enhancing Dialogue among Countries with High Renewable Shares in their Energy Systems**’. A preliminary discussion, enacting this joint commitment to drive renewable

energy growth in a context of international collaboration took place as a side-event during the **18th IRENA Council** in Abu Dhabi.

The next dialogue will take place in the framework of the **10th IRENA Assembly** on the **10th of January 2020**. During this event, Member Countries are invited to provide feedback on the implementation approach of such multi-stakeholder platform and to actively participate in a panel discussion on *'Innovation'*.

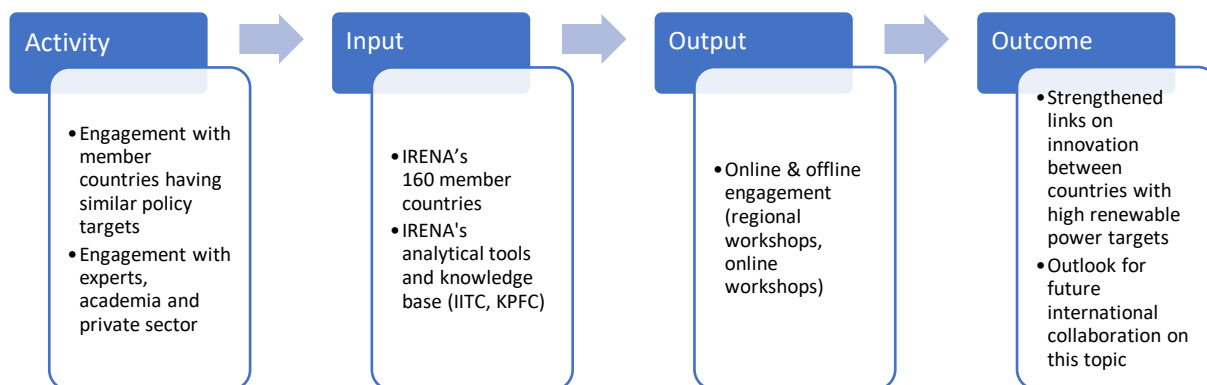
II. Highlights of the discussion

1. Welcome speech and introductory remarks

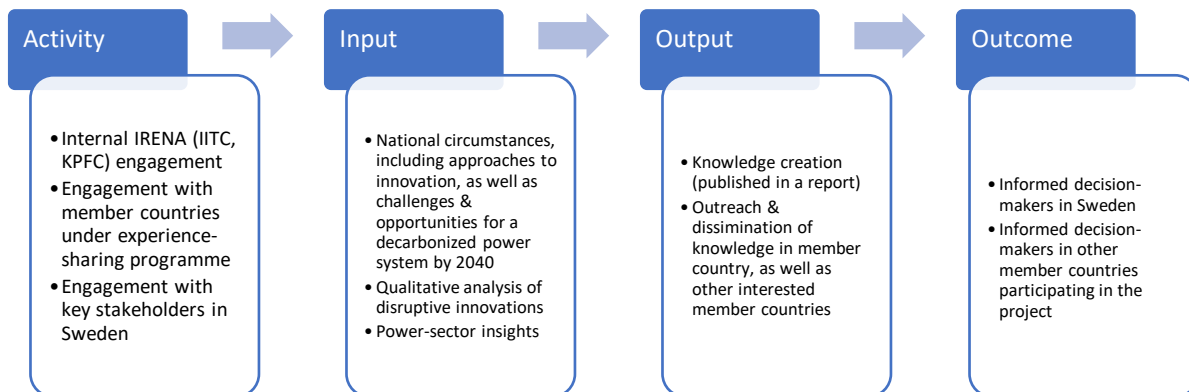
A welcoming speech by Mr Paul Durrant and introductory remarks by Mrs Elena Ocenic as well as Ms Nina Litman-Roventa opened this fourth and final online workshop. Mr Paul Durrant placed the *'Experience-sharing programme'* within a wider context and highlighted parallel IRENA discussions and broader initiatives on achieving high shares of renewables shaping up, thanks to Member Countries' increasing interest on this topic. Preliminary conversations at the previous IRENA Council as well as a future event planned for the upcoming IRENA Assembly are building on the excellent discussions and insights collected during the past online and in-person workshops conducted throughout 2019.

Mrs Elena Ocenic reiterated the rationale and value of the previous dialogues between nations, either striving towards or operating power systems with large shares of renewables and further presented the programme's participating nations. Mrs Ocenic also provided an overview of the two parallel and mutually reinforcing workstreams pursued as part of a Voluntary Contribution from Sweden.

Workstream 1: Connecting countries with targets for high shares of renewable power



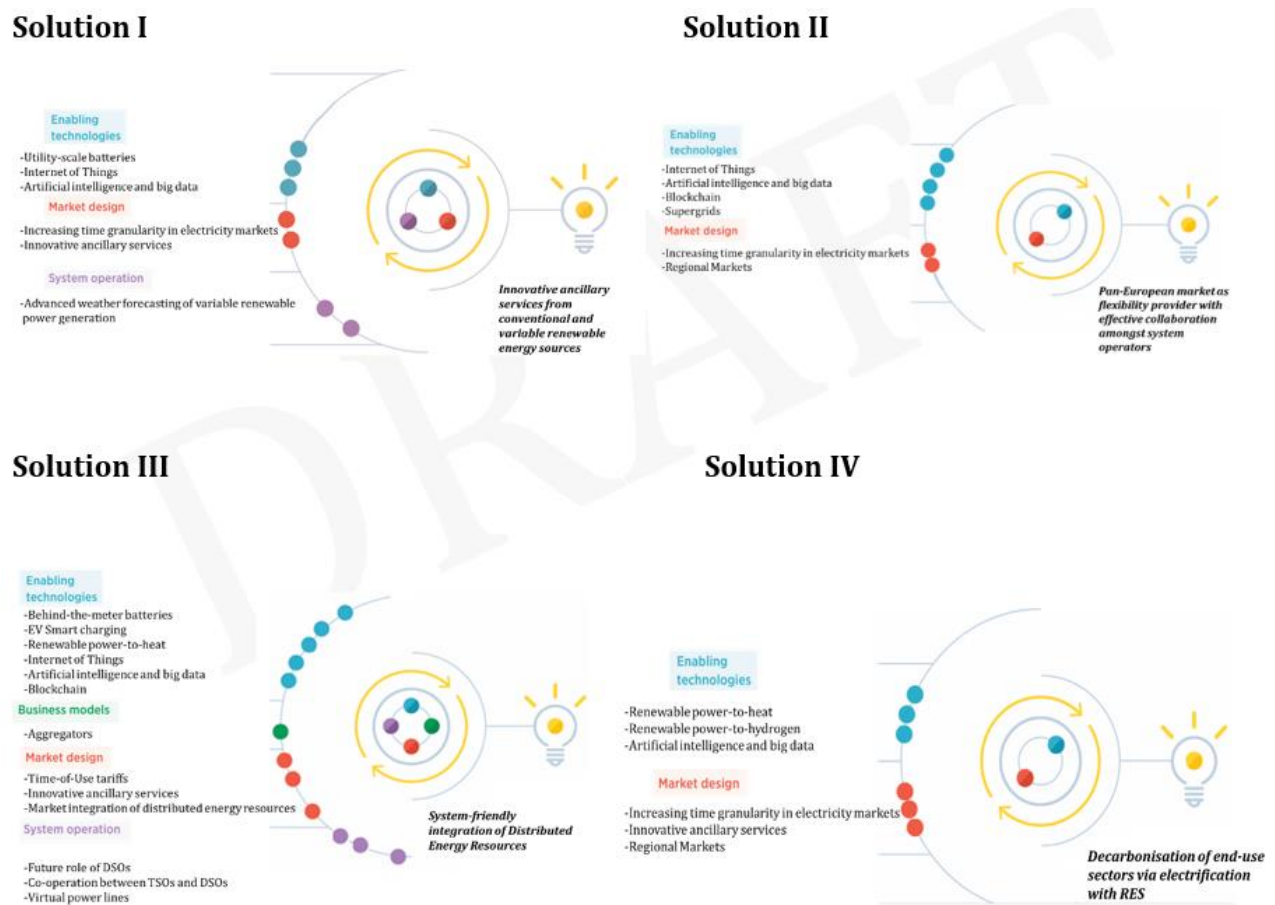
Workstream 2: Swedish country-level innovation study



Workstream 1 refers to the online and in-person workshops to facilitate exchanges between countries on innovative solutions to integrate higher shares of renewable power. Workstream 2 entails a country-level study on how to integrate larger shares of variable renewable energy (VRE) in the Swedish power system. As part of this study and based on the systemic innovation approach and 30 innovations from the *“Innovation Landscape for Renewable-Powered Future”*¹ report, four different innovative solutions have been developed to help Sweden in meeting its policy goal of 100% renewable power by 2040, as shown in Figure 1. Mrs Ocenic further noted that the report on the Swedish case study, in which all solutions are illustrated in more depth, will be published in January 2020.

¹ <https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future>

Figure 1: Innovative solutions for Sweden's power system



Ms Nina Litman-Roventa provided details on Solution IV referring to the decarbonisation of end-use sectors with renewable energy sources via direct and indirect electrification. As this topic has been addressed frequently in past workshops and since the fourth workshop focusses on disruptive innovations, it was deemed relevant to further engage on this subject.

2. Presentation on most disruptive innovative solutions from participating countries

Spain

Overview

Mr Hugo Lucas Porta from the Institute for Energy Diversification and Saving (IDAE) started his presentation by highlighting the importance Spain attributes in decarbonising electricity generation, which is exemplified with their target of increasing renewables' share in power generation to 74% by 2030. This implies a massive deployment of renewable energy capacity and the necessity of a cost-

effective integration into the power system as well as a paradigm shift from base and peak to variable and flexible power generation. Measures to provide the increasing flexibility needed entail demand side management, distributed generation and storage but also interconnections and grid reinforcements. Mr Lucas Porta particularly emphasised the growing importance of the role of prosumers in Spain, with 4-11 GW of distributed solar photovoltaic (PV) capacity expected by 2030 (compared to 900 MW today) depending on the scenario. More flexibility in the Spanish power system is also expected by increasing the installed capacity of pure pumping (3.5 GW by 2030) and storage (batteries) linked to generation (from 0 to 2.5 GW). It is worth noting that an increasing number of hybrid projects are expected in the future as the lowest levelized cost of electricity (LCOE) in Spain is for hybrid wind/PV plants. By 2050, renewable gas and power-to-X to reduce curtailments and enable seasonal storage as well as sector coupling are perceived as effective measures on the longer term. These flexibility measures all require an adequate policy framework.

In terms of challenges to achieve a successful transition, Mr Lucas Porta emphasised particularly technological and market design challenges. According to Mr Lucas Porta, designing an adequate electricity market is not only of utmost importance in Spain but across entire Europe. From a technology perspective, Mr Lucas Porta mentioned challenges associated with network capacity, variability as well local inertia problems due to the planned phase out of coal in Spain by 2030 and loss of inertia due to less base load capacity. The key challenge on the longer term however refers to seasonal storage, especially by 2050 when 100% renewable sources are expected to make up the country's electricity mix.

Mr Lucas Porta also mentioned issues related to human resources and the growing challenge of finding the necessary skillsets and knowhow. Territorial challenges related to local social acceptance and making use of territories to deploy location-bound renewable energy sources (i.e. solar and wind) need to be equally addressed.

Examples of pilot projects

Mr Lucas Porta provided insights into projects and examples addressing the aforementioned challenges. There are currently five ongoing pilots in Spain at the distribution level targeting the use of demand side management, for instance the reduction of electricity demand in cooling systems in households and supermarkets, prosumers, storage and e-mobility, to provide services to the distribution grid. The pilots' overarching goal is to benefit from new players (aggregators) in the energy transition by incentivising consumers to change their behaviour and enable their provision of services at the network level.

Mr Lucas Porta further highlighted the growth of heat pumps and that heat pump electricity consumption is expected to increase six-fold between 2020 and 2050. The importance of a high coefficient of performance (COP) has been underscored.

Pilots in e-mobility are also currently being implemented, for instance in the Basque country where the charging infrastructure is already in place, enabling the provision of ancillary services at the distribution level. This is pushed by a company providing batteries and aggregation systems. The main objective of this and other trialed projects and pilots is to find out how to design local electricity markets for flexibility.

Another noteworthy example is a 100% renewable hydrogen project, which started recently in Mallorca. In this pilot, hydrogen will be produced from solar PV generation and will be employed for the local bus fleets as well as for energy supply and stationary uses in hotels in the area.

Sweden

Overview

Ms Sara Grettve from the Swedish Energy Agency opened her presentation by noting that although there are no specific targets for renewable power-to-X and sector coupling in Sweden, there are other targets in place having a direct effect on electrification and decarbonization. These include for instance achieving no net greenhouse gas (GHG) emissions by 2045 and reducing GHG emissions from domestic transport by 70% by 2030 from a 2010 baseline. As such, these objectives are driving significant interest in decarbonizing and electrifying end-use sectors, especially industry and transport. A bonus-malus system is for instance in place to create incentives and increase investments in clean transport, such as electric vehicles and biofuels. Another noteworthy example of transport electrification is also the electrified roads pilots with highways recharging batteries of vehicles and trucks driving on these. There are also ongoing pilots to electrify and decarbonize the Swedish industry, such as the 'Hybrit' project which targets the decarbonization of steel making.

When discussing the feasibility of decarbonising end-use sectors with renewable energy sources via direct and indirect electrification, Ms Grettve stated that such solution is of interest and feasible to implement but some factors may represent barriers that need to be overcome. Firstly, increasing electricity use implies the need to satisfy a more significant electricity demand and hence the necessity to increase electricity generation. It must be noted that Sweden is currently a net exporter of electricity. However, nuclear power plants are expected to reach the end of their economic lifetime by the 2040s and to be replaced by variable renewable energy (i.e. mainly wind but also solar PV) as well as combined heat and power (CHPs) plants powered by biomass. This further engenders challenges to cope with the variability of power generation and the loss of inertia, which was also highlighted by Mr Porta's presentation. Ms Grettve also mentioned challenges associated with social acceptance due to the deployment of wind parks as well as with grid capacity, as some urban areas are already facing grid constraints which represent barriers with increasing electrification. Prosumers and demand-side flexibility are also deemed in Sweden as a solution in handling the variability of power generation. However, the challenge remains in activating and unlocking this significant potential. This is partially explained by missing price incentives as nuclear and hydro power plants provide balancing services which leads to stable electricity prices.

Examples of pilot projects

As many examples of decarbonizing end-use sectors via electrification in Sweden have been circulated prior to the workshop with the participants, Ms Grettve referred to the agenda's annex where ongoing pilots are presented (see examples below). Ms Hanna Ek-Fälth, added the fact that the Swedish Energy Agency is currently developing an Electrification Strategy. This will entail a

detailed analysis of the increase in electricity demand which will help in identifying more specific challenges in decarbonizing the electricity sector as well as the more broader energy system.

Renewable hydrogen in the housing sector – developing the world’s first self-sufficient hydrogen housing complex, Sweden

Since 2018, the world’s very first off-grid, energy-sufficient housing complex combining on-site solar generation and hydrogen fuel cells, is being developed in the Vårgårda Municipality of Sweden. This innovative project is realized by municipal housing company Vårgårda Bostäder, alongside Danish firm Better Energy and Sweden-based Nilsson Energy. All 172 apartments across six blocks will meet their electricity and heating needs thanks to onsite PV systems (659 kWp) and hydrogen storage.

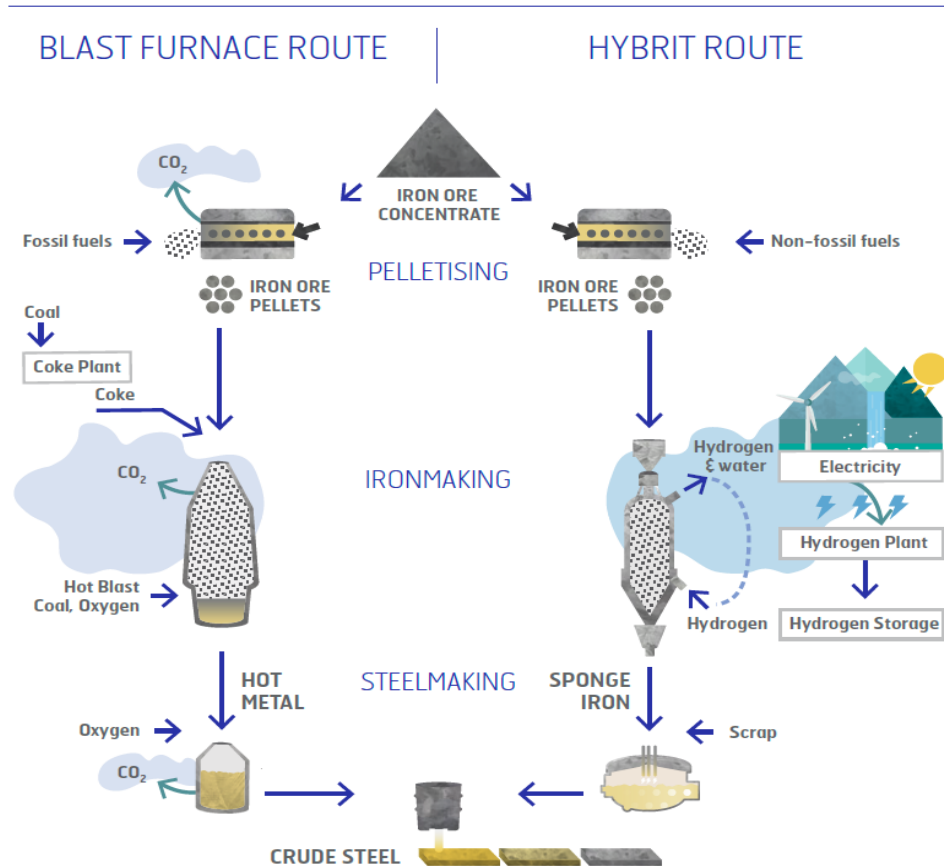
Surplus energy and overproduction in summer from the residential solar systems pass through through an inverter and is stored in a battery, that powers an electrolyser which produces hydrogen through electrolysis. The hydrogen is then compressed to 300 bar and stored in a pressure tank. When power is required for consumption, especially in winter months, the hydrogen can be converted back into electricity through fuel cells, with the only emissions being oxygen and water vapor. Benefits of this solutions not only include zero emissions and high reliability of power, but also unlocks opportunities for long-term storage and seasonal flexibility.

Renewable hydrogen in the energy-intensive industries (iron and steel) – HYBRIT project, Sweden

With the increasing availability of low-cost renewable power, significant opportunities emerge to reduce CO₂ emissions in iron and steelmaking processes using renewable hydrogen. In fact, there are increasing efforts in the global steel industry focussing on renewable hydrogen production to achieve mitigation and decarbonisation². One of such efforts to decarbonise the steel industry is for example the ‘HYBRIT’ project in Sweden, which stands for *Hydrogen Breakthrough Ironmaking Technology*. This innovative project aiming to substitute coal with hydrogen is conducted through the consortium of Swedish steelmaker SSAB, power utility Vattenfall, and LKAB, Europe’s largest iron ore producer. The Swedish government provided a 50-60 million Euro subsidy for a demonstration plant. The goal is to have a pilot plant (proof of concept) operational by 2020 and a demonstration plant post-2024. Hydrogen production and storage is also expected to contribute to power system flexibility and thus facilitate VRE integration in power generation. According to the consortium, HYBRIT could not only help meet Sweden’s national target to achieve zero net emissions by 2045 but also, “*if realised on an industrial scale, the technology could make Sweden the world’s first country to produce fossil-free ore-based steel*” (HYBRIT , 2018). Currently, the steel industry accounts for approximately 7% of global CO₂ emissions and 10% of Swedish CO₂ emissions, respectively.

² Iron production with renewable hydrogen is expected to become the least-cost supply option at a CO₂ price of approximately USD 67 per ton by 2050.

Figure 2: The HYBRIT concept compared to the conventional steelmaking process



Source: (HYBRIT, 2018)

Uruguay

Overview

Ms Echinope drew on the examples on direct and indirect electrification provided by Uruguay during the previous online workshop on experiences in applying innovative solutions³. This time the Uruguayan representative provided additional details on the challenges and identified barriers in developing these projects.

In-direct electrification

Ms Echinope firstly talked about in-direct electrification by drawing on the ongoing hydrogen pilot to decarbonize the transport sector in Uruguay. In this project, hydrogen will be produced with electricity from the grid, which is almost 100% renewable (97% in 2018). Hence, this pilot truly takes advantage of the significant penetration of renewables in the country's power generation matrix. An

³ <https://www.irena.org/events/2019/Oct/Online-workshop-on-sharing-experiences-in-applying-innovative-solutions>

electrolysis unit as well as a hydrogen fueling station for 10 heavy duty vehicles and coaches will be located in the city of Montevideo. Uruguay's public oil company will be in charge for administering the use of hydrogen whilst the public electricity utility will be operating the electrolyser remotely for 19 hours per day.

The identified barriers are complex and multifaceted. Firstly, there are no commercial coach buses in Uruguay, but only urban ones. It is further difficult to purchase fuel cell trucks as Uruguay is too small to be considered as attractive enough as a country for market entry to start the sales of these technologies. From a technological perspective, it is also complex to store hydrogen as there are no salt mines in Uruguay. Liquid organic hydrogen may represent a solution in the future and remains to be further explored. Besides the need to develop the novel and expensive infrastructure required and enable the costly grid connection, subsidies will be also until renewable hydrogen will be cheaper than producing fossil fuels (which is expected by 2030). Last but not least, addressing negative security perceptions of hydrogen will be also key. According to the Uruguayan representative, this represents an issue that should be ideally tackled at international scale.

Direct electrification

The second part of Uruguay's presentation focused on direct electrification, where Ms Echinope provided insights on challenges encountered in an ongoing renewable power-to-heat project. In this pilot, energy surpluses are used to decarbonize the local industry instead of being curtailed. It must be noted that energy surpluses in Uruguay amount to 18% of the country's domestic demand in mean terms. This is due to the country's structure of the electricity system, which is almost entirely renewable powered as well as due to increasing shares of variable renewable energy. In the ideal case, energy surpluses are exported to neighboring countries, including Argentina and Brazil. However, in other cases renewable electricity generation needs to be curtailed.

In the example provided by Ms Echinope, a secondary heat production unit, installed by a local industrial customer, is used to generate steam or electric resistance to heat air to dry products by employing solely renewable energy surpluses. Hence, fossil fuels such as natural gas, fuel oil and propane will be replaced as demand will be covered instead by renewable energy surpluses, which will be sold at \$30/MWh instead of the regular price of \$50/MWh for natural gas or fuel oil. The installed electric boilers and electric resistance will be also connected to Uruguay's public utility so that power can be turned automatically on and off depending on the availability of electricity surpluses.

In terms of challenges and barriers, Ms Echinope highlighted the fact that energy surpluses are not equal every year. Hydropower's share in electricity generation is around 50%, however there is high annual variability. Therefore, the public utility UTE administering this project can only guarantee to the industrial customer only a certain quantity of surplus hours in 7 years (14000 hours), which could represent a limiting factor. Moreover, the connection to the grid is also costly and UTE needs further direct access to this installation. These factors highlight the need to further examine and reconsider some elements in market design.

Q&A after presentations

In a conversation following the presentations, participants reiterated that economic, technical and regulatory challenges in both direct and indirect electrification remain to be addressed. Mrs Ocenic also mentioned that there could be also positive spillovers from such energy transition and that new opportunities may emerge beyond power sector applications. The possibility of exporting green hydrogen (for instance from Australia to Japan) has been used as an example to illustrate this point.

Ms Echinope further highlighted that the lack of available technologies represents a key issue which engenders delays in implementing innovative green hydrogen pilot projects and proofs of concept. The low cost of fossil fuels is also a significant barrier.

Views on negative security perception of hydrogen have been also shared by both Uruguay and Spain. When deploying renewable energy capacity in Uruguay, there have not been any problems associated with perceptions of safety. However, security perceptions are more negative with regards to hydrogen transportation and production. Spain is facing similar challenges with the perception of hydrogen being dangerous, exacerbated by the inability of seeing or smelling it. Mr Lucas Porta added that the approval of hydrogen infrastructure is required at the municipal level. However, due to current knowledge gaps on how to best address security aspects, it is complex to get a license which in turn hinders the development of a hydrogen economy. Mr Lucas Porta further mentioned that in Spain, hydrogen will rather target the decarbonization of building stocks to achieve net zero energy buildings rather than for the decarbonization of the transport sector, which will be tackled by direct electrification, with the exception of heavy vehicles.

3. Social acceptance and 'regulatory sandboxes'

According to Mr Lucas Porta, **social acceptance** is becoming an increasingly important topic in Spain in order to place citizens at the centre of the energy transition, as recommended by the European Commission. Therefore, specific measures and mechanisms to promote proactive roles of citizens are being implemented in Spain. For example, Spanish citizens are already able to proactively buy 100% renewable electricity as well as produce renewable power. To further encourage citizen-driven and community renewable energy projects, there are ongoing discussions in Spain to implement for such projects an accession mechanism which is offering contracts for renewable power production, after an auction is implemented. In this context, quotas will be established for **citizen-driven projects**, which will be further awarded with a Feed-in-Tariff and which will benefit from financial guarantee provided by the government. The Feed-in-Tariff will be based according to the results of the auction to conform with EU competition rules. To further support community-scale renewable energy undertakings, crowdfunding platforms for citizens will also be established, in which IDAE will invest. Mr Lucas Porta also praised the inclusion of citizens in renewable energy projects by Uruguay's public utility UTE. A model which is, nonetheless, difficult to implement in a European context with mainly private utilities.

Mr Lucas Porta also provided some insights on **regulatory sandboxes** in Spain. These are particularly needed to develop and implement the local flexibility markets presented earlier on in the workshop, but also when conducting innovative projects on islands. Mr Lucas Porta added that

such regulatory sandboxes are frequently expected to not bear any additional costs in the system, which is however more challenging in practice. Hence, this may represent limiting factors when developing and implementing different innovations. The necessity of dialogues with the energy regulatory authority to address this has been stressed.

Following Mr Lucas Porta's presentation, participants exchanged on the importance of data in the energy transition, especially at the distribution level with the emergence and increasing number of prosumers and distributed energy resources. **Data hubs** in the Nordic countries are already at a well-advanced stage. Ms Sara Grettve from the Swedish Energy Agency provided additional information on the implementation status in Sweden and on ongoing discussion of what data and statistics shall be gathered and included. Uruguay also fosters a tradition of information availability by providing very high levels of transparency of power generation. As such, all data related to production and consumption is publicly available.

4. Future engagement and the role of IRENA

As this online workshop was the last planned activity under the experience-sharing programme, Mrs Ocenic asked the participants on which topics they would like to be further engaged in the future as well as on IRENA's role in accelerating innovation in renewable power.

When discussing future topics, Mr Lucas Porta emphasised Spain's challenge when drafting their 2050 Decarbonisation Strategy on assessing costs on technologies and innovative approaches such as green refineries and power-to-X for the decarbonisation of industrial applications. In this sense, Mr Lucas Porta highlighted the need to gather and make available more information related to the costs of such processes in order to support countries in making well-informed decisions. Although there is no great interest in carbon capture utilisation and storage (CCUS) in Spain at the moment, it would be still useful to know the costs. Ms Grettve added that it may bring value to map CCUS efforts on an international scale as it may represent an option to decarbonise the cement industry in Sweden.

In terms of IRENA's role in accelerating innovation, Ms Grunvald from Uruguay suggested to continue collaboration efforts, especially in order to facilitate the implementation of innovative projects pursued by Uruguay presented during the series of workshops. Ms Grunvald highlighted Uruguay's interest in accessing the Abu Dhabi fund for development in order to access technologies which would accelerate the implementation of these innovative renewable energy projects.