Sharing experiences in applying innovative solutions to achieve 100% renewable power systems

Minutes of the online workshop of 10th October 2019, 16:00 (GMT+2)

I. Context

The workshop on '*Sharing experiences in applying innovative solutions to achieve 100% renewable power systems*' has been held online by the IRENA Innovation and Technology Center (IITC). It is the third activity performed under the **'Experience-sharing programme on innovative solutions for very high shares of renewable power by mid-century'** that takes 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 third workshop convened and connected representatives from four different countries, namely Costa Rica, Denmark, Uruguay and Sweden to share their *experience in applying innovative solutions* to achieve renewable-powered futures. In this context, best practices, lessons learnt as well as next steps have been explored from pilot projects conducted in these countries. Participants were further encouraged to present innovative solutions that have been implemented or are ongoing, that combine some of the 30 innovations proposed in the '*Innovation Landscape Report for a Renewable-Powered Future: Solutions to Integrate Variable Renewables*' (IRENA, 2019)[1].

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

- Alfonso Herrera – Ministry of Environment and Energy (Costa Rica)
- Manuel Barboza- Electrical Engineer, Energy Efficiency Specialist, Costa Rican Electricity Institute, ICE (Costa Rica)
- Isaac Rojas - Costa Rican Electricity Institute, ICE (Costa Rica)
- Kenneth Hansen – Advisor, Danish Energy Agency (Denmark)
- Hanna Ek-Fälth – Renewable Energy Analyst, Swedish Energy Agency (Sweden)
- Sara Grettve– Project Manager, Swedish Energy Agency (Sweden)
- Wilson Sierra – Manager of the Renewable Energies Department, Ministry of Industry, Energy and Mining (Uruguay)
- Martín Scarone – Ministry of Industry, Energy and Mining (Uruguay)
- Arina Anisie – Associate Programme Officer, Renewable Energy Innovation (IRENA)
- Emanuele Bianco – Associate Programme Officer, Knowledge and Policy (IRENA)
- Paul Durrant – Programme Officer, Renewable Energy Innovation (IRENA)
- Elena Ocenic – Programme Officer, Innovation Networks (IRENA)

The invaluable information gathered within these international dialogues will feed into the broader IRENA initiative on '**Enhancing Dialogue among Countries with High Renewable**

[1] Also referred to as the '*Innovation Landscape Report*' available at: https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future.

Shares in their Energy Systems'. The first dialogue, enacting this joint commitment to drive renewable energy growth in a context of international collaboration, will take place as a side-event during the **18th IRENA council** in Abu Dhabi, taking place from the 5th until the 6th of November 2019.

II. Highlights of the discussion

1. Welcome speech and introductory remarks

A welcoming speech by Mr Paul Durrant and introductory remarks by Ms Elena Ocenic opened the meeting. The rationale as well as value of these informal exchanges between nations, either striving towards or already operating power systems with high shares of renewable energy sources, has been reiterated. Ms Arina Anisie provided a concise overview of the concept of *systemic innovation*. The idea that on-the-ground solutions result from innovations combined across four different dimensions has been illustrated with three examples of innovative solutions derived from the '*Innovation Landscape Report for a Renewable-Powered Future*' report.

2. Presentation of examples of innovative solutions from participating countries

2.1 Denmark

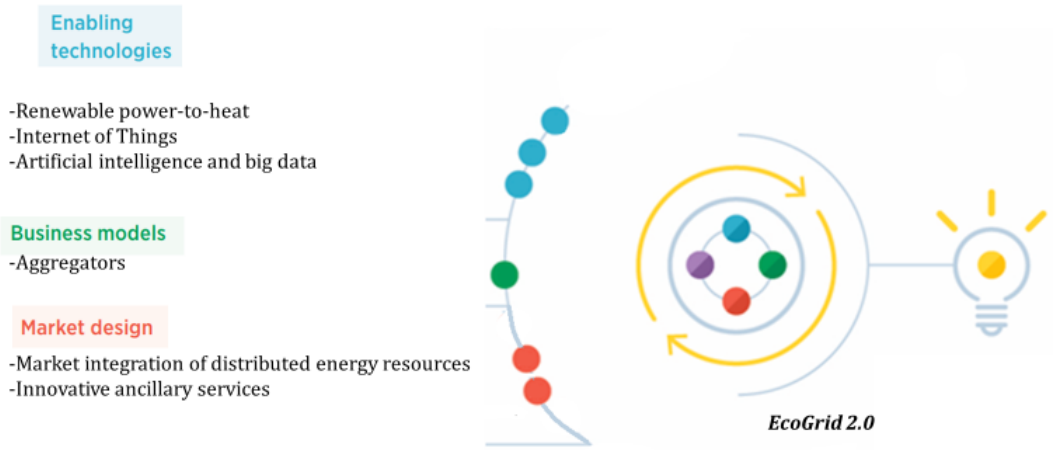
Mr Kenneth Hansen's presentation started the conversation on innovative solutions that are currently being implemented within the experience-sharing programme's participating nations. Mr Hansen, representing Denmark, provided a thorough overview over three innovative Danish projects, namely *EcoGrid 2.0*, *Energy Hub in Nordhavn* and *BioCat*.

EcoGrid 2.0

- *EcoGrid 2.0* is an innovative smartgrid R&D project which has been launched three years ago on a Danish island. The project focuses on the power grid whilst also tackling the heating and transport sectors. EcoGrid 2.0's goal is to harness flexibility through the remote controlling of private households. As part of its demonstration phase, an aggregator controlled the energy usage of 1000 participating households and buildings that own heat pumps and electric heaters. The aggregator, which was allowed to bid into the electricity market, matched consumption with grid flexibility needs for upward and downward regulation. The project has been predominantly funded through governmental R&D funds and partners include local universities, utilities and private companies. Key innovations comprise power-to-heat, an aggregator selling flexibility on the market on behalf of consumers and digital technologies such as machines learning, artificial intelligence (AI) and big data.
- Key lessons include that this solution proves to be successful for upward and downward regulation but that a prerequisite to this success is a good relation between private household and the aggregator. It has been found that consumers are willing to give control over their heating with the condition that there is a threshold and that benefits (such as the optimisation of their heat pumps) are received in return. Overall, such configuration has been found to not only reduce consumers' bills but also CO2 emissions while providing flexibility to integrate larger shares of renewables. Considering these

numerous success stories, these tested tools and market solutions are currently being developed for commercialisation.

Figure 1: Innovations combined in the project EcoGrid 2.0 (Denmark)



Energy Hub in Nordhavn

- The *Energy Hub in Nordhavn* has been over the past four years a laboratory for new energy solutions to increase flexibility for renewable energy integration. Demonstration projects revolve around the power sector but also focus on heating, transport and buildings. For example, tests have been carried out on using battery storage on grid scale, on electric vehicle (EV) smart charging as well as on renewable power-to-heat. Demand-side response technologies and solutions have been also scrutinised. The focus is always placed on assessing business cases for the developed solution. Moreover, research also concentrates on market and sector coupling, for example on how to develop *markets for multicarrier energy* that go beyond the electricity market and create synergies between power, transport, heating, gas and cooling markets. Funding stems predominantly from the Danish governmental R&D fund and partners include universities, developers, local municipalities and utilities as well as private companies.
- Learnings shed light on the importance of data and that sector coupling is key for renewable energy integration since technologies such as heat pumps can provide flexibility in both heating and power systems. The importance of stakeholder engagement and collaboration to combine competencies from different fields was further a crucial lesson. A final report with 28 recommendations on tax systems and regulations is due to be published soon.

BioCat

- *BioCat* will be world's largest power-to-gas plant based on biological methanation. This demonstration project consisting of alkaline electrolysers generating methane that can be either injected in the natural gas grid or can be stored, is about to go online soon. CO2 from biomass sources will be used to methanise hydrogen. The solution is expected to increase power system flexibility by offering ancillary services to the grid operators. The project is based predominantly on government funding for R&D. Considering the early

stage of this innovative project, key learnings will only start to be shared within the upcoming six months.

2.2 Costa Rica

Costa Rica's electricity system is based almost entirely on 100% renewable energy and is operated by eight utilities, the main utility being ICE. Therefore, Mr Barboza and Mr Rojas, both working for ICE, have been deemed as most knowledgeable to share the Costa Rican experience in applying innovative solutions to reach high shares of variable renewable energy (VRE) sources. Both representatives shared several insightful and diverse projects during the workshop, which span over the transport, power and heating sectors.

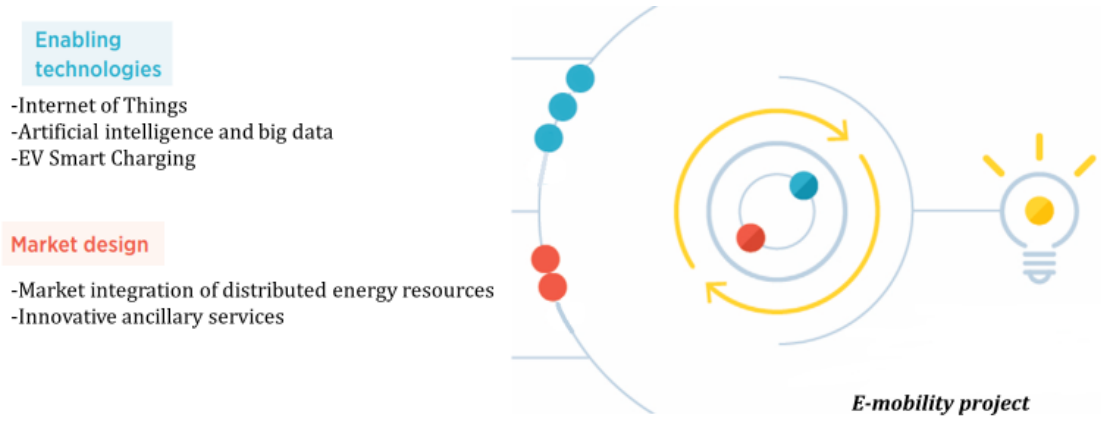
Solar Energy Project

- Costa Rica's project on Solar Energy to test the technology and analyse effects on the grid and on power quality, especially on frequency, has been implemented as early as in 2009. One of the project's rationale was to develop effective regulations to promote the technology and encourage companies to implement the technology in-house. An emphasis has been placed on maintaining power quality in the grid and on analysing the use of storage technologies in such systems. An important aspect was also determining adequate present and future installed capacity.

E-mobility project

- The purpose of this project is to create a *network of EV chargers* spanning over the entire country under a public/private partnership. This has been initiated by the central government by establishing an obligation to install such chargers on utilities responsible for electricity distribution. The project is currently in its deployment phase with different types of technologies and connectors being tested in different vehicles. An important aim of this initiative is to create a market push for electric buses. A key lesson so far has been that the new stable laws greatly contribute to the creation of favourable market conditions for electric vehicles, for both private and public transportation. Next steps include the deployment of a national charging grid, increasing R&D efforts, for example on protocols, charging systems and on connecting different types of charging technologies developed in all parts of the world to the Costa Rican grid.

Figure 2: Innovations combined in the E-mobility project (Costa Rica)



Energy decarbonisation project

- An important project targeting *energy decarbonisation* via substituting natural gas by electricity has been initiated by ICE by establishing a strong partnership with the private sector. The goal and focus of this project are the installation of boilers, heaters and cooking systems that are usually energised by gas to reduce emissions and to subsequently decarbonise the country. R&D on the development and deployment of innovative technologies replacing the use of gas is ongoing. Key lessons include the importance of fruitful partnerships with the private sector to develop effective solutions and the need to foster healthy relationships with customers.

Smart-meter project

- Costa Rica is currently in the process of deploying a state-of-the-art *advanced metering infrastructure* by replacing 850.000 old meters over a period of seven years until 2025. The project began as a trial to test different technologies and a key aim is to build a platform for electricity customers. Therefore, the use of digital enabling technologies, including Internet of Things (IoT), is crucial to enable the provision of different demand-side services for end-customers and create revenues to partially cover the cost of installing smart-meters. This is of utmost importance in light of the fact that metering and storage technologies are generally more expensive than the cost of generating electricity in Costa Rica.

2.3 Sweden

Ms Hanna Ek-Fälth started her presentation by providing a brief overview of the Swedish Energy Agency which she represents. The role of the Swedish Energy Agency as the national authority for energy policy issues is to fund innovative solutions to promote sustainable energy systems rather than implementing these. By looking at annual research and innovation funding, it became evident that the Agency's predominant focus is on the power, industry and transport sectors.

Hybrit

- *Hybrit*, the first example presented by Ms Ek-Fälth, targets the electrification of the steel industry. The pilot project's aim is to replace coal with renewable hydrogen and generate as a bi-product water instead of CO2. Since the steel industry in Sweden is very significant, this could reduce total CO2 emissions in the country by 10%. However, this would also increase power demand, which is why flexible demand-side management is also required. Innovations in this innovative pilot project therefore not only include renewable power-to-hydrogen but also time-of-use tariffs to connect to demand-side management and to increase VRE use in the system. The project is funded by three major steel and power sector industries along with funding provided by the Swedish Energy Agency. The pilot further envisages hydrogen storage as a source of power system flexibility. The plan is to start the project in Lulea in 2020. Therefore, no lessons can be shared at this stage although in theory Hybrit could contribute in integrating significant shares of VRE if managed the right way,

Figure 3: Innovations combined in the Hybrit project (Sweden)

Hydropower plant combined with batteries

- This project is entirely privately conducted by Swedish utility Fortnum. It connects a battery park to a hydropower plant and acts as one unit in the market. This enhances the hydropower plant's balancing role on the electricity market which is crucial since electricity market balancing is realised to a very large extent by hydropower plants in Sweden. Interestingly, the pilot project started initially at a combined heat and power (CHP) plant in 2017 and positive findings paved the way to the current hydropower installation in Forshuvud. The configuration contributes to grid stability and reduces maintenance costs by decreasing turbine wear and tear. It must be noted that the project is funded in its entirety by Fortnum, without any special incentives. The utility holds the view that the project is economically feasible, not only thanks to reduced maintenance costs but also thanks to the batteries' fast response, which leads to better remuneration of the hydropower plant on the frequency regulation market.

CoordiNet

- *Coordinet* is a EU Horizon 2020 project and is carried out on a national scale by Sweden's Transmission System Operator (TSO) Svenska Kraftnät along with two Swedish Distribution System Operators (DSOs), namely the distribution segments of Vattenfall and E.ON. The aim is to create a platform optimising TSO-DSO coordination to handle different constraints in the power grid in order to integrate VRE in flexibility markets. This project started in 2019 and is currently being trialled in different areas, such as Uppland and Gottland, until 2022. Since the pilot only started, there are not many results and conclusions that can be drawn at this stage. However, flexibility in local markets is expected to increase from effective collaboration between TSOs and DSOs.

2.4 Uruguay

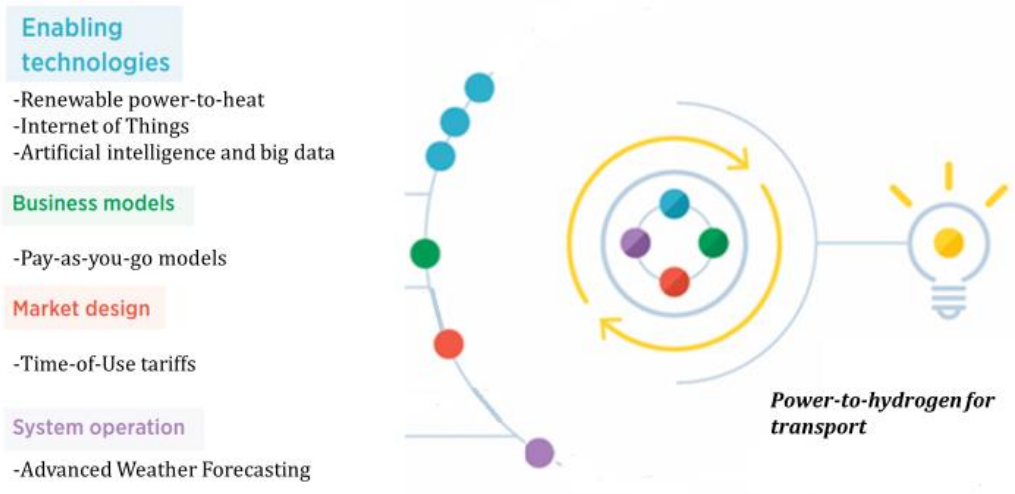
Mr Martin Scarone, working and representing Uruguay's Ministry of Industry Energy and Mining, started his presentation by highlighting that in Uruguay, almost 100% of electricity comes from renewable energy (97% in 2018). In the primary energy mix, 62% comes from renewable energy. The challenge is to decarbonise the remaining 38% fossil-fuel share, of which 68% is associated to the transport sector's energy demand. Addressing the transport sector in Uruguay is therefore key. Battery EVs have been promoted since 2010 along with the expansion of charging stations and incorporation of electric buses in the country's public transport fleet. A pilot project on fuel

cell EVs for heavy duty vehicles and coaches will be also rolled out in 2020. However, also other innovative pilot projects and solutions targeting the **demand**-, **grid**-, as well as **system dimension** of the power sector are currently implemented in Uruguay. Mr Scarone provided an overview.

System-wide: Power-to-hydrogen for transport (heavy duty and coach buses)

- In this project *addressing the power sector as system* and to take advantage of the high penetration of renewables in Uruguay's power generation matrix, hydrogen will be produced with electricity from the grid, which is 98% renewable. A public company will administer the use of hydrogen whilst Uruguay's public utility will operate remotely the electrolyser the most convenient for electric system 19 hours per day. A hydrogen fuelling station for heavy duty vehicles and coaches will be located in Montevideo. There is a possibility to produce hydrogen only from renewable energy surpluses in electricity generation but there is the need to enable hydrogen storage to cover hydrogen demand for transport. After implementing this pilot, the levelized cost of hydrogen and cost evolution of operating coaches and buses with hydrogen will be evaluated. If the findings are promising and when the time is right, the pilot will be scaled up. A research focus of the project is also assessing the complementarity between solar and wind generation for hydrogen production. Key innovations include renewable power-to-hydrogen, IoT, AI and big data, pay-as-you-go models, time-of-use tariffs and advanced weather forecasting.

Figure 4: Innovations combined in the renewable power-to-hydrogen project for transport (Uruguay)



System-wide: Decarbonisation of heat via renewable power-to-heat

- Renewable energy surplus equates in Uruguay to about 18% of domestic demand. Therefore, ongoing analyses assess cost-effective uses of these significant surpluses to satisfy industrial demand instead of curtailing renewable power generation. An interesting *system-wide pilot project* and business model have been recently developed in Uruguay targeting this challenge: A utility works with an industrial customer and ensured for a number of hours the sale of energy surpluses at a fixed price over the next 7 years. In turn, the industrial customer installed a secondary heat production unit to produce steam or electric resistance to heat air to dry products. This secondary heat production will replace sources such as natural gas, fuel oil and propane as its 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. Thanks to this price difference, the industry will be able to recover the investment of installing electric boilers and electric resistance. The latter will be further connected to the public utility so that power can be turned automatically on and off depending on the availability of electricity surpluses. To realise this, a new connection with new tariffs and separate metering is necessary. Uruguay's public utility UTE has initiated the project but partnered with private companies, especially for the management of electric boilers and electric resistance. Next steps include the scale-up of this pilot project as well as gathering and sharing learnings from this experience. Key innovations include renewable power-to-heat, IoT, AI and big data as well as advanced weather forecasting.

Demand-side: Achieving 100% smart-meter rollout

- Today, Uruguay has 100.000 smart meters installed and aims to install 100% of customers by 2022. This has been deemed crucial to unlock demand-side flexibility. A project is conducted for demand management with electric water heaters with utility remote control (95% of houses use electric heaters in Uruguay).

Grid-flexibility

- It must be noted that besides the ongoing innovative projects, there are strong interconnections with neighbouring countries which could further *enable grid flexibility.* Uruguay has strong interconnections with Argentina (equivalent of 100% of the historical peak demand) and Brazil (25% of the historical peak demand).

3. Innovations beyond IRENA's Innovation Landscape Report

When asked whether there are any other innovations that are not captured within IRENA's Innovation Landscape Report, the participants provided valuable ideas and insights. Costa Rican representatives for example highlighted the need to go beyond EV smart-charging to further include the electrification of public transport, especially the electrification of buses which require different charging technologies. Representatives from Uruguay also highlighted the need to go beyond innovations for VRE integration to innovations for the efficient use of VRE surpluses. In a similar vein, Mr. Hansen from Denmark reiterated the importance of sector coupling and understanding energy multicarrier systems creating synergies across multiple sectors as innovative solutions.

4. Regulation and market design

As part of this online debate, participants were further encouraged to consider *adequate organisational structures* and *appropriate market design* for a transition towards renewable energy-based power system. This is an important topic as more and more market structure issues are expected to emerge as VRE shares increase across different power systems. Considering the complexity of the matter, this online workshop's aim was to start the conversation on this topic to encourage in-depth discussions in the future.

In this context, Mr Hansen from the Danish Energy Agency made a valuable contribution by highlighting the current debate in Denmark on changing the current tax scheme in order to meet the government's very ambitious CO2 reduction targets by 2030. Mr Hansen also mentioned other future challenges related to regulation and market design in Denmark. Considering Denmark's role as a frontrunner in wind power deployment, it has been possible, thanks to

numerous interconnections with neighbouring countries, to export the country's excess wind power. However, neighbouring countries such as Germany and Sweden are currently rapidly expanding their respective wind power capacity, which is expected to lower the export opportunities for Danish wind generators. Therefore, the most cost-effective use of excess VRE generation may become more complex and more important in the future. This is of utmost importance since Denmark is already witnessing negative prices on their electricity market during few hours with significant wind power generation. On the other side of the spectrum, in periods of low VRE generation, ensuring sufficient levels of back-up power is also challenging, especially since Denmark does not own any hydropower assets and has access to balancing services from the common Nordic electricity market. Nonetheless, it remains unclear whether changes in regulations (e.g. capacity payments) or new markets (e.g. a capacity market) are required to address this growing complexity.

III. Past and future activities

Type of workshop	Tentative date	Description	Location
Online	6th June 2019	Focus on sharing national objectives for renewable power and expected/experienced **challenges**	Remote
In-person	17th July 2019	Focus on **innovative solutions for 100% renewable power systems by mid-century** by exchanging perspectives, plans and good practice in working towards very high levels of renewable power. Workshop takes place back-to-back with the **IRENA Innovation Day** (15-16th July).	Montevideo, Uruguay
Online	10th October 2019	Focus on sharing national **experiences** with the application of innovative solutions	Remote
Online	**28th November 2019**	Focus on **disruptive innovative solutions** enabling 100% renewable power systems	Remote

More information about the previous online and in-person workshops is available here:

- 06.06.2019 - Online Workshop on Challenges: https://www.irena.org/events/2019/Jun/Online-workshop-on-identifying-challenges-for-achieving-100pc-renewable-power-systems-by-mid-century
- 17.07.2019 – In-person Workshop on Solutions (Uruguay): https://irena.org/events/2019/Jul/Workshop-on-Innovative-solutions-for-achieving-100pc-renewable-power-systems-by-mid-century

IV. Next steps

As part of the experience-sharing programme on innovative solutions for very high shares of renewable power by mid-century, the next online workshop on "**Disruptive innovations enabling 100% renewable power systems**" will take place on **28th November 2019** at 4PM (GMT+2).