Citizens on the driving seat of Photovoltaics

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***Abstract* — A more collaborative, interdisciplinary, open, transparent and reproducible science begins to be required by Public Funding Agencies along the world. This contribution explains how a real project funded by the European Commission and researching in six innovative photovoltaic solutions, has embraced concepts of Open Science to foster innovation in our sector. In this paper we mainly focus on the concept of knowledge coalitions for sharing data and know-how. We aim at assisting and encouraging our colleagues to adopt such practices that entail the performance of a more responsible research aligned with the values and needs of our era.**

***Index Terms* — open science, public engagement, society, photovoltaic cells, novel concepts, irrigation, ageing, circular economy.**

I. INTRODUCTION

A traditional top-down model of scientific research has been and is still guiding the activity of many laboratories and groups, particularly those working in Engineering fields. The typical scheme where researchers line up their activity with the recommendations of their Governments and/or High-Experts Platforms, while collaborating with the industry to produce such innovative solutions, is being revealed as an incomplete approach [1]. That is, we are in a well-stablished routine where everybody is assuming what the final users want and preventing them from taking part in public funded activities. The voice of both, civil society considered as: NGOs, Consumers Associations, Foundations, etc.; and citizens is rarely considered when defining public research processes in Engineering in general, and in photovoltaics (PV) in particular. A more responsible model would not be the opposite, a bottom-up scheme, but rather a collaborative innovation process in which civil society organizations (including also citizens), industry, government and academia are committed to work together and share knowledge and data among each other and interested third parties. This is defined such as the quadruple helix of innovation [2]. The operationalization of such processes within the workflow of research laboratories is what GRECO Consortium is exploring in the field of Photovoltaics.

On the other hand, being more responsible with our research, according to the Responsible Research and Innovation (RRI) definition [3] not only involves more collaboration among all stakeholders, but also enabling science to be more transparent, reliable and reproducible. Thus, while collaborations are achieved through Public Engagement and Citizen Science processes; the rest of the requests imply to follow any of the processes on Open Science. The spectrum of available Open Science practices is so wide, that there are more than 400 procedures and tools already available [4]. GRECO have just selected a group of them for exploring its adequacy in our field of work.

However, that is also true that for some experts, Public Engagement and Citizen Science are not separate concepts from Open Science. They understand that the first openness and attempt to perform more responsible science is carried out through the operationalization of quadruple helix knowledge coalitions rather than using tools for open data, open papers, open software, etc...

Therefore, three main photovoltaic research lines at different technologies readiness levels (TRLs) converged in GRECO with the objective of demonstrating to our counterparts that public funded science can be performed in a more responsible way. The pilot on Open Science Methodologies into Practice, is being tested in a research line related to the ageing modelling, characterization and repairing of PV systems; in a second one devoted to irrigation PV solutions and; for a third one related to next generation PV concepts, that includes: PV-Heat Pumps, novel solar cells and micro-Concentration PV systems (μ-

CPV). In this contribution, we will explain our experience in the Pilot regarding the participation of civil society and citizens.

II. PUBLIC ENGAGEMENT IN PHOTOVOLTAIC SCIENTIFIC ACTIVITIES

There are three main questions when thinking of public engagement in science. The first is to know how citizens can benefit my research and speed-up innovation. The second is to elucidate them how they are going to be benefited. And the last one, to define how scientific teams can organize such participatory processes successfully.

The responsible model explored by GRECO for planning research activities from the quadruple helix point of view, implies two steps. Firstly, we encourage our GRECO researchers to leave their ivory tower and provide answers to the two first inquiries stated in the previous paragraph, concluding with new research objectives. While in a second step, we define the processes by which such public engagement is going to be conducted. One important point to notice for researchers that are not familiar with these activities, is that the majority of participatory processes are affected by Ethical Issues, such as: management of personal data, data import/export, minors' participation, etc. Next, it will be explained the full experience of GRECO regarding Public Engagement Processes in each of the three research lines.

A. Ageing Modelling, Characterizing and Repairing of PV Systems

We know that 97% of PV power installed today worldwide are installations younger than 10 years old, while less than 3% are 10-15 years old, less than 1% are today 15-20 years old; and less than 0,5% of all installations are older than 20 years. Despite of that, everybody is assuming production models for 25 years that have not been validated against real data. Within this framework, GRECO researchers thought that finding those installations with the longest lifetimes (older than 10 years) and characterizing them in order to have data for the validation of a more reliable ageing model would be a nice practical example on how civil society and citizens can be engaged with scientific process. In this case, furthermore, researchers by planning this research are filling a gap of information that could not be bridged without operating such knowledge coalitions with the civil society and other stakeholders interested in sharing their older installations data.

For this specific case, GRECO has launched an open call that is being distributed around the world trying to find the installations. The call, recently launched in January 2019, will be open until September 2019. Then, the selection of the most interesting plants will be carried out, they will be characterized and analyzed, and later will validate the developed ageing models.

There are two main benefits for the society for taking part in such a knowledge coalition. The first for the owners of such plants. They will receive a detailed report about the «health condition» of the installation. In case of defective PV modules, we could consider to substitute them while we try to repair them. And the second one for banks and investors. We are sure that providing financial actors in charge of due diligence projects with evidences for a major profitability that is predicted by current production models of PV installations, is another small step for supporting the major deployment of Photovoltaics.

B. PV-Irrigation Systems

This research activity is really close to market, so in principle thinking about how to integrate end-users in the scientific activity was easier than for the other research lines. In this case, we found that the traditional model in which they were working implied a decision more or less agreed among industries and researchers for developing technical products, using end-users for testing prototypes and then transferring to companies the solution for production and commercialization. When exploring how to perform more collaborative science, we envisage that GRECO can explore processes of Open Innovation [5] where civil society and Water Departments from Governments should be in the spotlight from the planning phase of a new research process.

GRECO performed an exercise of Open Innovation devoted to gathering insights. This practice was selected because it allows researchers to immerse themselves in the problem space to better understand end-users and market. At the end, this entails to build empathy and generate products and services that people need and want, and governments support.

GRECO contacted civil society through 400 representatives from Irrigation Communities, 3 Representatives of National Water Users' Associations (Portugal, Italy and Bulgaria) and several farmers; delegates of 20 Governments belonging to The Intermediterranean Commission Working Group on Water & Energy; and representatives of 28 SMEs from the irrigation field. We did not organize ad-hoc meetings, but we took advantage of Congresses, Conferences and Annual Meetings for organizing 4 different sessions of this Open Innovation activity. In addition, face-to-face interviews and some phone meetings were also conducted.

Exercises led by a moderator consisted of two phases. The first one, where participants discussed about the Challenges that the sector needs to address to be more competitive and analyzed the market products that are trying to solve such challenges from different perspectives (technical performance, warranties, environmentally friendship, return on investments, etc.). This phase let us share background,

knowledge and know-how with relevant stakeholders, listen to them and understand better the interests and difficulties they experience. In a second phase, we presented them three suitable solutions that researchers had though could be useful for the sector: (1) PV irrigation solutions for the use of salty waters that are near the coast. (2) PV irrigation solutions for big Irrigator Communities; and (3) the use of batteries for the robustness of PV irrigation systems against intermittences. Participants were discussing every solution on the basis of time and needs alignment. They agreed on the expectations of each of them in terms of capabilities, costs, warranties, etc. In general terms, all groups of stakeholders prioritized solutions in almost the same order: 2, 3 and 1. But there was a large disagreement on the selection of the most urgent and useful solution for the sector when performing the analysis of the answers disaggregated by geographic region. This is a clear and useful indicator for researchers when thinking of technological transfer processes. These 4 activities concluded with the specific challenge of developing an ad-hoc solution for PV irrigation systems with more than 20 PV modules in series and configurations for pumps of more than 400V. Once the first prototype is built, a validation phase is planned with end-users' experiences, prior transferring the solution to interested companies in commercialization.

C. Next generation PV concepts

Line 3 includes basic, novel and less known concepts for civil society: high efficiency solar cells based on perovskites, micro-Concentration PV systems (μ-CPV) and PV heat pumps. Such activities might be considered as the most difficult for understanding the common benefit of participatory processes of collaboration with representatives from the whole quadruple helix of innovation, because of their distant stage from a marketable product.

Any researcher working on Photovoltaic is aware of the difficulties that PV has because of the top-down regulatory electricity market in all countries. But we also know that PV is the unique energy source with a decentralized character, where citizens can start a change from a bottom-up decision scenario. Therefore, researchers must be aware of the specific role that citizens and civil society play to foster the deployment of PV. Society and citizens need to define what kind of product would they buy, while researchers need to know which research activities on "next generation" products would end-up into a drawer because of social constrains.

GRECO decided to perform Mobilization and Mutual Learning (MML) participatory processes. An MML is an action -activity or exercise- that gathers together people to learn through dialogue. It is based on the concept of mutuality. Therefore, the main discourse is decentralized. In MML activities, participants talk about futures, hopes and fears, uncertainties and alternative scenarios rather than about fixed knowledge and ideas. The aim of these activities is to bring together various groups of stakeholders - researchers, professionals, students, media, broader publics, etc. In contrast with traditional forms of deliberation like lectures or question-and-answer sessions for large audiences, MMLs innovative methods must be employed in order to stimulate in-depth dialogues. The methodology of MMLs is described in the guide "How to organize Mobilization and Mutual Learning Processes - Public Engagement in Science"[6].

GRECO has been performing this activity from March 2019 to May 2019. Meetings took place in Germany, Spain, Portugal, Bulgaria, the United Kingdom and Brazil with a main objective: How can research and development learn from different actors to improve the integration of photovoltaics in society?. Non-specialized people are not able to answer such question in the technically rigorous way we as scientists would want. So, we prepared dynamic, less ambitious sub-objectives to be answered in small group discussions.

The first was to identify how the different stakeholders can actively take part in the energy transition. This implies for instance questions about the actions that citizens could take to stop climate change, what could be necessary in the social dimension to ensure that PV becomes accepted and widely requested, who can foster the energy transition and the adoption of PV solutions. The second sub-objective aimed at identifying how could photovoltaic energy have a greater presence in the citizen daily life, dedicated to current or near future needs, expectations and the main concerns and worries of the society regarding energy. And, recognizing the requirements of a next generation of PV products from a social point of view forms the third sub-objective. It targeted to find out how PV solutions can be integrated into citizens' lives, where money should be invested and about the technical needs for the next PV products generation.

Participants in these activities had different and complementary backgrounds from all fields of the quadruple helix that, in addition to the different nationalities, ensured that the broader public opinion was obtained. About 100 participating stakeholders was reached ranging from consumer associations, PV installers, manufacturers of PV modules, local and regional policy makers, town councilors, university teachers, citizens, presidents of association of neighbors, specialized journalists, architects, ecologists, responsible banks managers, representatives of PV owners, sociologists, master students, researchers in the fields of PV materials, energy systems, optical materials and technologies, solid state physics, electro-chemistry, electronics and renewable energy, to one or more members of solar energy related companies, NGOs, the Fridays for Future movement, the human resources management of universities, big electric companies, Platforms for PV, companies providing consultancy services on energy, construction companies and PV distributing companies.

At the end, it was possible to gather a list of recommendations for researchers working on the next-generation products made by Citizens and the Civil Society, which will be announced publicly soon.

III. CITIZEN SCIENCE IN PHOTOVOLTAICS

Citizen Science is a process that goes beyond Public Engagement. The border is sometimes blurred, but it is accepted that citizen science refers to the active contribution of citizens to science, either with their intellectual effort, surrounding knowledge or with their tools and resources [7]. In that sense, our first described activity for Public Engagement could even be considered as Citizen Science.

We believe in the power of Citizens giving, classifying, analyzing and looking for data to help PV scientific community in our daily activity. So, GRECO is determined to launch a global Citizen Science Initiative that survives the project. This initiative will be open and free so any research group across the globe may access and benefit from it.

Currently, the initiative is on the design phase consisting of two stages. In the first part, from January to March 2019, we developed an online survey available on the GRECO website. We invited people working on Photovoltaics or interested on the topic to answer three "simple" questions: how can citizens contribute to this research? How can researchers benefit citizens? (beyond the advantages of renewable energy) and what are the main constraints in getting citizens to adopt solar energy innovations? We collected more than 60 responses from researchers, NGOs, students and people interested in renewable energies. For example, regarding the first question:

"Owners of solar energy systems [could] provide the production data of their facilities for scientific research and also convince their neighbors to install solar plants".

The answers also addressed ideas like the collaborative identification of research needs and the possibility to potentiate diffusion and communication.

During the second phase, inspired by hackathons, we performed a participatory design process. The term hackathon results from the combination of *hacker* and *marathon*, and refers to events in which several people get together to solve a challenge in very short time [8]. For GRECO, we developed a hackathon-like online event. During one week, 61 registered participants from 15 different countries worked individually or in teams to propose an initiative in citizen science for PV. To design such a useful Citizen Science Initiative, the participants had to consider the responses gathered in the first stage. The hackathon finalized in May 2019, and the assessment committee will revise 12 proposals that represent the submission of almost 30 participants by the first week of June.

GRECO compromises to devote enough resources and time to set-up and launch the best evaluated proposal, as determined by the assessment committee. Moreover, all contributions will be made public so any other research team can get inspired and launch other Citizen Science projects in Photovoltaics. By the end of 2019, GRECO expects to have launched the initiative and set a plan for sustainability.

IV. CONCLUSIONS

Nowadays fostering innovation implies sharing data, knowledge and experiences among all quadruple helix stakeholders. Three different research areas of Photovoltaics joined in a common effort to design participatory processes where civil society and citizens are a key element. GRECO is evidencing the benefits of such participatory processes despite the effort of organizing them. In one hand, researchers are being able to conduct investigations that could not be performed just with their own resources. And in the other one, researchers are better adapting their work to the needs, values and expectations of the society.

V. REFERENCES

[1] Vélot C. (2016). Scientists and civil society must move together toward a new science. Front. Public Health 4:96. 10.3389/fpubh.2016.00096

[2] E.G. Carayannis and D.F.J. Campbell, "Mode 3 Knowledge Production 1 in Quadruple Helix Innovation Systems", SpringerBriefs in Business vol. 7, 2012.

[3] Rome Declaration on Responsible Research and Innovation in Europe, 2014

[4] Bianka Kramer and Jeroen Bosman "101 Innovations in Scholarly Communication" in FORCE Conference 2015

[5] European Union, "Open Innovation, Open Science, Open to the world" 2015. ISBN 978-92-79-57346-0

[6] L. Barbosa, G. Revuelta."Guide: How to organize Mobilization and Mutual Learning Processes - Public Engagement in Science". https://doi.org/10.5281/zenodo.2652776

[7] European Commission Green Paper on Citizen Science.

[8] Briscoe, G., & Mulligan, C. (2014). Digital Innovation: The Hackathon Phenomenon (No. 6). London. Retrieved from http://www.creativeworkslondon.org.uk/wp-content/uploads/2013/11/Digital-Innovation-The-Hackathon-Phenomenon1.pdf

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