

1 HOW CAN CITIZENS PARTICIPATE IN RESEARCH ACTIVITIES RELATED TO SOLAR ENERGY?

Surveys should be conducted to gather research ideas and problems that people and businesses have in their day to day. These needs for problem solving should be public and any researcher should have access to them, being able to differentiate between demands of companies, the public sector, people, young people, etc.

Identifying locations where solar energy could replace other sources, telling their experiences installing solar energy systems or technology, saying who they contracted for their installation and giving them stars for creating a ranking of best installers. Installing counters of Equivalent CO2 emission reductions and adding all the counters together in a website.

It would be a good idea to teach citizens how to install and manage solar panels so they can see how the energy can be created and stored so they can install small panels at home.

Interactive visits/workshops, design sprint-like events (similar to hackathons), surveys, quizzes, serious games apps. For instance, a group of citizens could be part of a research team to define different research goals, so they can give their non scientific view on the process.

By explaining real experiences with the technology, for identifying problems or difficulties that the end user might find when using solar systems. Citizens may also share the production data of their installations, for comparison and analysis.

Monitoring the resources wherever they live; and monitoring their electricity consumption.

@Taking measurements with their mobile phones. For instance, with an app for data harvesting.

Engaging in building solar panels for personal use and discussing implementation opportunities in our everyday lives. For example, events may be organized in which citizens build solar panels able to recharge small devices (DIY) or in which they discuss applications of solar energy in urban environments.

It would be good if citizens could test the devices or solar energy equipment, assess its operation and ease of use. This experience could also make it possible to detect new needs or opportunities.

Citizens can participate in many different ways depending on which part of the broader audience is engaged. Citizens are not only and necessarily isolated individuals without any expertise and depending on research needs. Non energy interested/expert citizens can provide information on which problems they face when dealing with energy, which are their expectations and needs to better tailor research. This is important to take into account non technological barriers that need to be addressed in order to engage citizens in solar energy. A more energy engaged profile can also provide access to his/her energy data or even test/participate in pilot projects. Citizens can help with dissemination of the results of the research or be included in transforming those results into tangible innovative initiatives or projects or business models (for instance when organised into an energy cooperative/community). They can also transform the research results into political demands (for instance when participating in NGOs, local administrations or political parties among others).

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Taking action by sharing data from their solar devices and about their own energy savings and goals.

This interesting initiative occurred in Austria in which students developed a comprehensive regional concept of «green community» focused on photovoltaics : https://www.sparklingscience.at/en/projects/show.html?--typo3_neos_nodetypes-page%5Bid%5D=784

- 1- By measuring local solar irradiation using low cost sensors (irradiation monitoring);
- 2- By assessing in the long term the performance of solar energy devices (performance monitoring, which may be also useful for forecasting);
- 3- By demanding patterns for solar cells (very relevant for proper sizing) and
- 4- by 'voting' on building-integrated photovoltaic solutions (devices placed on buildings) that match aesthetic values.

Giving qualitative and/or quantitative information regarding solar energy in their day to day life to researchers. E.g. telling the feel that society has about this type of energy, counting the number of times per week when the 'solar energy' sentence comes to their mind.

Gathering data of photovoltaic systems to share with others. There are already web pages doing something similar, they should be reviewed to see how to complement them. Another thing would be to identify, with googlemaps for example, photovoltaic systems in roofs, façades or ground, to enrich an inventory of current installations.

Gathering data of available systems.

By going through games, apps, etc., partnering with some large audience institution/company.

By proposing and describing their daily needs and concerns.

They can monitor, collect and organize their electricity (or energy) consumption data - even if they do not own a solar energy system - to contribute to long range studies for the development of the new energy model.

By supplying their production data and by convincing their neighbors to install PV.

Using mobile phone sensors for data collection, PV system loggers as used by companies like SMA or Photon in former times. An important comment here is to use local language to communicate with citizens, as some of them may not be confident with English.

With public events organized by research institute and government, information workshops.

Through their observations and their knowledge of people having solar energy installation on their houses.

Providing their experience, specially those that have installed a PV system at home (self-use, water heaters, etc.)

Sharing their ideas and searching the literature online. Perhaps they could make small scale experiments and demonstrations too.

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Citizens with solar panels installed at home can contribute by sharing their generation-consumption data. Also by pointing out possible problems in their installations and suggesting how to facilitate other people install solar panels at home. Besides, all citizens, with and without PV installations, can share their ideas about what they would like to obtain from PV technology: how this technology can improve their lifestyle.

Crowdfunding could be interesting as what is made for diseases like cancer. Or, to perform experiments with devices in private houses to collect data on real use profiles.

Testing prototypes, collecting data for developing better iterations, collecting open data.

By testing the new products resulting from research.

Citizens can be integrated in solar energy to test new concepts and also they should be integrated in order to increase the awareness and acceptance of solar energy in the general public.

Provide terrace space for installation of test equipment for field testing.

Reporting their energy daily use, their expectations after the investment (if any) and some ideas 'out of the box'. Also, keeping them active in some experiments or lending them some equipment for energy production.

Citizens can collect information and data related to solar energy from newspaper articles, scientific journals and national data sheets. For instance, citizens could spend

15-30 minutes per day researching solar energy materials on the web, google, YouTube and academic research sites. GRECO could provide data to people and ask them to summarize the data, make graphical analysis and other mathematical calculations based on their provided data. Citizens can also be asked to ideate simple concepts that increase usage of solar energy in our daily lives.

Give scientists ideas on new ways to use solar pannels, for example. This would lead to innovative projects or concepts, co-created by citizens and citizens, and financed by crowdfunding.

Serve as test/experiment location. For example, we have a solar fence which requires weekly maintenance due to animals running through it. We could provide hands-on feedback about the problems we experience.

As a citizen, I am able to express questions, expectations, experiences, concerns about solar energy directly to researchers, and simply filling a form on the web! This kind of communication can take place during different phases of the research process (not at the end!) and can orient researchers' activities and lead, at least in principle, to more effective, acceptable and usable products/processes. If I would have a photovoltaic installation in use, I could send its data and my experience of use to researchers, and like me other users, thus providing a sound basis on which researchers would work.

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Citizens can participate in research activities related to solar energy by

- 1- collecting data on where solar energy use is possible;
- 2- To suggest how to keep solar energy panels all the time active & clean; and
- 3- To suggest measures to occupy less space for placing solar energy panels.

By giving citizens prototypes to test, for example.

Using particular drones for monitoring PV systems: taking daily photos of an installation in order to watch out the effect of falling leaves on the panels, bird excrements, snow and see how these unpredictable matters affects to the local production of panels. They can also use drones to know how much PV systems (not thermal systems) are installed in a local area or neighborhood.

By raising awareness: see this example https://www.seac.cc/wp-content/uploads/2016/11/7AV.6.72_paper.pdf.

By creating a community spirit. One could for instance create a worldwide free database for researchers uses and citizens awareness on PV performance. This would enable not only citizens to provide data, but also “analyze” data for comparison. They would act as real researchers. Citizens rely more on other citizens data than on companies’ data. Creating a platform where people upload photos of PV installations around the world or PV applications.

By providing equipment for children to make a contest: who can charge more electricity on their device with a photovoltaic charger? They could end up inventing concentrators. We could use the “manufactured items” for some application of research or for a social endeavor.

Identifying where are the domestic installations, type of panels, orientation are data very valuable to combine with energy prediction and ageing models.

For some research project it could be useful to engage people with small tasks such as cleaning sensors devoted to radiation measurements.

For researchers working on smart grids it could be useful to know the location of PV domestic installations and to study grid stability. This would imply to locate PV installations on a map online. This data will help to study what would happen if we replace the technology of such installations by i.e. CPV modules or perovskites modules in the future.

For developing heat pumps with PV systems, citizens would enrich the project if we know how much uncomfortable they are willing to be in order to limit their bill and/or emit less CO₂.

Citizens can contribute to the dissemination work of researchers, by organizing sessions/ events for other citizens explaining advances on our field. We could provide material and training them for carrying out such activities. They could act as a chain for providing researchers with the doubts of people and ideas coming from such events. This would contribute to our research activity because is a way to get the point of view of citizens regarding our technologies as to be incorporated later in the projects. Society could be more comfortable if sharing ideas and doubts when discussing of science with a citizen-scientist rather than with professional-researchers.

2 HOW CAN RESEARCH ACTIVITIES ON SOLAR ENERGY ENRICH CITIZENS?

Citizens can disseminate consolidated scientific knowledge in social networks, in the communication of the products and services they offer (companies) and in the areas of youth education.

Research can tell citizens where they could use solar energy and describe for them the best options in a clear way. Writing how does solar energy home installations adapt to each country.

In my humble opinion I think citizens look to this activities as a way of reducing the cost of solar energy modules. As regards the cost of the energy, it may be reduced.

By giving knowledge so they can see a practical way of the process of the creation and storage of energy and they can also use that energy to charge phones or small appliances.

Providing information about the advantages of using solar energy, the technology itself, the research goals, etc.

Increasing and improving the use of renewable energies reduces the pollution worldwide, with health benefits for people and the environment. Also, solar installations can be operated by the owner, making citizens more self-sufficient.

Promoting awareness on energy needs and use and getting to know better the potential of the solar resource

Making alternative energy sources more accessible and promoting sensibilisation around environmental issues.

They can increase the knowledge on the subject. Knowing how research is done can help citizens understand the complexity of

the process and to value more and better the research work.

By delivering responses to the questions citizens are making about energy (access, easy to use, competitive price, to go beyond just producing clean energy - making energy a more ethical choice, not just a commodity).

Besides contributing to increased knowledge about the world and how to deal with climate change, the 'reward' can be increasing the viability of solar energy technologies on their roofs; detecting early enough faults in the system and avoiding income losses if the system is malfunctioning.

Better understanding of solar energy and energy provision itself.

Reducing cost, improving reliability, providing solutions for storage and for electrification of other energy sectors.

Making electricity cheaper.

Getting kWh for free in their bills, getting solar energy at home, ...

By providing technical solutions to the citizens demands.

The benefits of solar energy are well-known... But as a citizen what I think most important is the possibility of more independence (the fuel cannot be owned by anybody) and conscious self-management; I think it contributes to democracy.

Research can provide information on daily life effects (both positive and controversial) of solar energy use to the citizens.

To help identify facts, and get away from rumors. Increase awareness for ecological topics.

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It may reduce the other energies utilisation as a complement (the sun is not shining at night and energy stocking is not yet fully efficient).

I imagine that by increasing their knowledge about the field.

Realising you can contribute to cutting edge research is the best motivation to learn.

Citizens can be benefited from the knowledge, experience and know how generated from research activities, to optimize their installations, take the maximum advantage from them and enjoy all the possibilities coming from PV technology.

Making solar energy more accessible to the general public.

Economically, the systems that use solar energy are more interesting.

Citizens should both see a personal benefit and have the possibility to learn new things.

Help bring awareness to citizens about benefits of solar energy for them and the future generations.

With science meetings organized by universities or government and well advertised.

Citizens can be more aware about the groundbreaking applications of solar energy to the availability of almost free energy that is inexhaustible in nature. They will know how solar energy will fulfill the energy needs in their daily life at a much lower cost than conventional energy.

Explain to citizens the possibilities and limitations of solar energy.

Dissemination of research activities could certainly help citizens to make choices and to set priorities (is it more important to have a pink solar cell or a more efficient one?) and to be more responsible. The most efficient places to disseminate are not so easy to find : at school, universities, NGO, professional of the energy sector...

It may make us feel like a part of the solution rather than an observer. I often lament at the challenges of the world, but I feel helpless as an individual to make a difference.

Solar energy is a clean energy that can bring us different benefits. One for all, reduction of pollution. Solar energy comes from sun, an inexhaustible energy source.

Research activities on solar energy aimed at improving the technology and optimizing the lifecycle of the installations can bring us economic benefits in a wider sense.

Research activities will clarify citizens' doubts about solar energy technology.

The benefits of renewable energy are well known and in the case of PV , I would add the democratic energy.

Citizens have data and access to their own PV installations. We could get data of the PV installations for repairing and ageing studies around the world and they would get an assessment on the performance of their installation comparing this with other's data.

- Helping to provide customized Results
- Closing the gender gap in science
- Enabling OPEN tools and results ready for use and reuse
- Adding transparency to the research process
- Expressing their needs and worries

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- By adding a new interdisciplinary way of performing projects that could open new opportunities for everybody
- Using video-tutorials on reparation that could lead them to repair PV modules themselves.

- Creating eco-awareness and therefore sustainability.
- Empowering citizens to make good decisions (participation, engagement, dialogue)
- Increasing the solar energy in the energy mix towards a more clean world better for everybody.

3 WHAT ARE THE MAIN CONSTRAINTS IN GETTING CITIZENS TO ADOPT SOLAR ENERGY INNOVATIONS ?

According to the well-known technology adoption curve the majority of the population adopts technological solutions that are tested and contrasted. The early adopters are the only ones that must incorporate new technologies that still need to be improved. The opposite would lead to a loss of prestige in technology. There are companies that offer products little developed and tested to the majority.

It is not clear to them how to do the paperwork and how much money they save. There is also an aesthetic factor in communities if each owner carries out the PV installation in their own way.

The novelty is probably the main constraint. People need to see that something is working good for a long time in order to invest. The initial investment cost is also a parameter that influences a lot. Bank solutions in order to reduce the initial investment are needed.

Lack of information and price.

Mainly the price of the installations, and depending on the country, the existing regulations that block its adoption.

They have difficult access to good financial conditions for the installation of a solar system. Also, the legislation regarding this technology is constantly changing, which makes it more difficult for the citizens to be well informed and generates uncertainty.

Lack of knowledge; stigmatization on the cost, complexity and availability of the systems.

The price: equipment and installation.

The costs, the lack of information, the interests of mainstream energy sources and the apparent technical complexity of building it yourself.

The lack of knowledge on how these innovations work and their benefits. It is also a limitation that the initial investment is usually high.

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Greenpeace has conducted a market research in Spain to address this question <http://archivo-es.greenpeace.org/espana/es/Informes-2017/Septiembre/Energia-colaborativa/>

Fuel power lobby.

Lack of reaching out. Upfront investment.

The lack of adequate and realistic advertising campaigns spread out and supported by official institutions.

Getting to know and understand well commercial and technical solutions. Difficulty in adopting an individual solution in a interrelated system dominated by few utilities and withstanding complex regulations.

Lack of clear information and lack of companies adapting solar energy innovations to particular problems.

Availability (there is an innovation, ok, but how I know and where i get it from?) Cost (In general not cheap). Compatibility (Is it compatible with my current way of work/live?) Safety/Other standars (Is it legal to introduce it in my house/office/warehouse? does it require specific permissions?).

Mainly regulation policies. Also implementation and Operation and Maintenance costs are important.

The current structure of energy consumption is so complex, so intimately linked to our way of life that I think changes of this kind are difficult.

Lack of financial support schemes

Insufficient knowledge, variable political decisions, statements from politicians and industry on renewable energy, total and individual cost of the energy transition, often related to electricity bill information (how many cents are paid for «energy transition»)

Economical aspects and lack of know-how.

The cost of installations if they have to do it on their home, the sun availability, according to the region.

A deep lack of knowledge on the field.

Uncertainty about economic costs and returns.

The complexity and price of those innovations. If this is not the case and the innovations are adapted to easy use and reasonable prices, I do not find any constraint.

Price, regulation on autoconsumption, maintenance.

Knowledge barriers.

It is necessary to replace the systems run by fossil fuels for ones run by solar energy and that results in costs.

As most of the new solar energy innovations are not in line with the every day life of the citizen, the citizens need to learn how to operate and how to use solar energy products.

Less awareness, lack of information about government initiatives and subsidies.

Costs (unfortunately many still believe that is not worthy), aesthetics.

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Ordinary citizens are not fully aware about the prospects of solar energy. They do not properly realize the extent to which, extensive use of solar energy can benefit them; both technically and financially.

Degree of difficulty (user friendly), difficulty of installation, price.

The cost? The lack of knowledge that makes people apprehensive? Legislation in some places (for instance in blocks of flats it can be quite complicated to instal solar pannels).

In Europe high efficiency technology is needed to recover the investment

Awareness of benefits personally and at a society level; access to the required technology; integrating technology with current day-of-life routines; it is often said that solar is cheaper, but depending on your family's circumstances, cost may be a constraint.

As for every innovation to be adopted, we need to clearly understand the advantages with respect to the «old» system in use. Solar energy solutions and innovative solutions will probably benefit of communication campaigns and popularization activities involving researchers, communicators, citizens. Maybe also incentives from governments would be helpful.

Not having proper knowledge about solar energy applications: citizens mostly think solar energy is not that powerful as fossil fuel energy .

Mainly the initial costs.

It's too far from the people's language.

People do not know how much money they can save, how many tons of CO2 can be avoided by implementing PV panels...And it's a pity as it is the unique democratic energy we have. This is the only way by which citizens can led a change on the energy mix of the countries without «the permission» of large electric companies.

«Leakage of knowledge, uncertainty (legislation changes) PV is "habitual" but not "close" to people, people do not trust in solar energy (intermittences)

Traditional energy sector is against (GLP, Gas seems the alternative)

People does not know alternatives to batteries

PV needs a lot of space, visual impact

High initial investment

Limited energy production

Difficulties to find a common language scientists -citizens.

It feels as something for the "future", this is not integrated when acquiring a new house (thermal panels are more frequent)

Lack of trust references and examples from other citizens

High market barriers: who should I contact with for installing PV modules? Can I install it in a building where there are more people? How does it fit with my electric company?

People think it is not easy to install PV.