A participatory Web GIS for stakeholders' engagement in the development of the electricity grid

Stefano MARAN
Sustainable Development and Energy Sources Dept., RSE SpA
Milano, Italy

Giuseppe STELLA
Sustainable Development and Energy Sources Dept., RSE SpA
Milano, Italy

ABSTRACT

The research activity presented in this paper was aimed at investigating and analyzing the Web GIS functionalities that could support people's involvement in the decision-making process, enhance their participation, and enable them to express their own opinion about the alternatives to better estimate the effects.
The tool was developed to support decisions about the development of the electricity grid but it can be used for the siting of renewable energy plants as well. Due to its specific characteristics and the geographical character of the considered data, the most appropriate stage for use of Web GIS is Spatial Planning. Web GIS are already currently used for presenting some information about grid infrastructures. In this project, we investigated how the basic functionalities of Web GIS can be improved or extended to support public participation, possibly empowering the role of the public in the decision-making process.
A prototype of participatory Web GIS has been developed and implemented, focusing on the functionalities which could improve participation of citizens, enable them to interact with the decision-makers and the proponents, and express their own opinion about possible alternative routes or solutions.

Keywords: Web GIS, Stakeholders' engagement, RES Development, Decision Support Systems, Energy Transition, Electricity Grid.

1. INTRODUCTION

Expanding the electricity grid is vital if Europe is to increase the share of renewable energy sources (RES) and to achieve a secure and sustainable supply of energy for the future, but building new power lines often faces strong opposition from the public. The project INSPIRE-GRID[1] was built on the assumption that the only viable route to increase possibly public support is a greater engagement of people in the decision making processes; consequently, the project adopted an interdisciplinary approach and tested new ways of getting stakeholders, including local residents, more involved in the planning and approval process [1].
The realization of new grid infrastructures involves disparate risks, costs, and benefits for stakeholders, affected populations, and surrounding environments. The asymmetric distribution of the related impacts has often fueled intense local opposition and compounded already complex technical and economic considerations. In order to reduce and to manage this problem, the ability to assess correctly and compare all relevant impacts and benefits of the proposed infrastructure and the possible alternatives is crucial.
Due to the existence of different impacts on different stakeholders and different objectives, the most appropriate framework for decision making is Multi-Criteria Decision Aiding [2], [3]. On the other hand, due to the local character of the negative impacts, a key dimension to take into consideration is the spatial dimension and, for this purpose, one of the most effective tools are Geographical Information Systems (GIS) that are able to represent the spatial relationships between the new infrastructure and the original landscape character. This kind of tools is becoming more and more widespread for facilitating the participation of citizens in decisions of public interest (e.g. [4]).
One of the main outcomes of the INSPIRE-GRID project was precisely the development of a GIS-based tool for promoting the engagement of the local populations and which can be linked to a Multi-Criteria analysis.

2. THE PARTICIPATORY WEB GIS

A Web GIS is an application that enables the visualization of geographically referenced data through a web interface that can be accessed online; in short, it can be defined as the presentation of the results of GIS elaborations through the internet. Unlike the GIS tools used in spatial elaborations, it does require neither any specific knowledge in geographical data analysis nor professional or specialized software; a web browser and a working internet connection are all that is needed and users are allowed to build their preferred visualization and to access relevant information very easily.
This research activity was aimed at investigating and analyzing the Web GIS functionalities that could support the people involvement in the decision-making process, enhance their participation, and enable them to express their own opinion about the alternatives or effects. Due to its specific characteristics and the geographical character of the considered data, the most appropriate stage for use of Web GIS is Spatial Planning.
Web GIS are already currently used for presenting some information about grid infrastructures. Current implementations allow the user to visualize the possible routes of the power line against a background map, to retrieve some basic data about the development project, and to localize possible sensitive areas

[1] http://inspire-grid.eu

like urban centres, cultural landmarks, and environmentally protected areas like the Nature 2000 network. In this project, we studied how these basic functionalities can be improved or extended to support public participation and possibly empower the role of the public in the decision-making process.

the decision-makers and the proponents, and express their own opinion about possible alternative routes or solutions.

Referring to Rowe and Frewer [5], participatory processes can be classified into three categories, according to the direction of the information flow between the host of the process and the public.

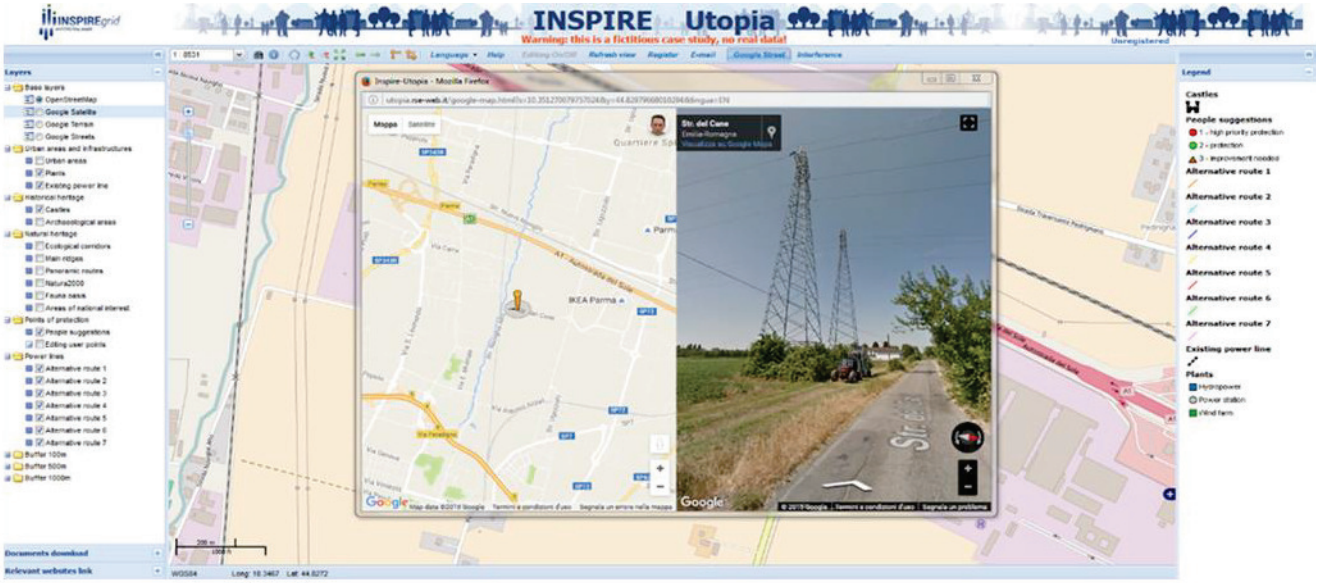

Figure 1: Direct link from the Utopia Web GIS to Google Streetview

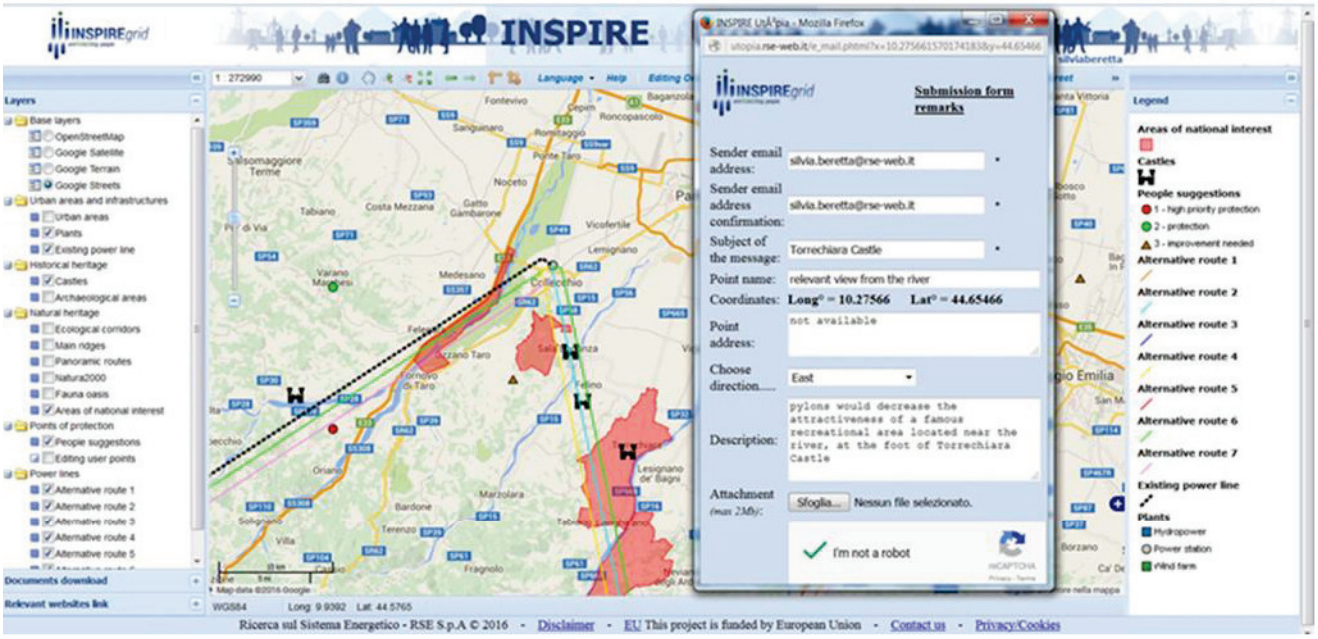

Figure 2: Sending comment through the Utopia Web GIS

For this purpose, a prototype of participatory Web GIS[2] has been developed and implemented among activities of the INSPIRE-Grid project, focusing on the functionalities which could improve their participation, enable them to interact with

They can be described as follows[6]:

- public communication: information flows from the sponsor of the process toward concerned stakeholders or the public.
- public consultation: when stakeholders or the public are consulted, information flows toward the sponsor.

[2] http://utopia.rse-web.it

In this case too, there is no direct dialogue between the sponsor and the public.
- active participation and co-decision: here, information is exchanged between the stakeholders and the sponsor in the form of a dialogue and some specific role is assigned in some form to the public in the decision-making process.

Accordingly, the functionalities added in the prototype have been classified into these three main categories.

Before all, some tools for improving standard exploration were made available in the prototype. These include the availability of different background maps, and among them: OpenStreetMap reporting the routes of the existing power lines; a tool for measuring distances and areas, which can be used, for instance, to compute the distance between the power line and the own home; a direct link to Google Streetview in order to let the user explore the real surroundings of the power line (see **Figure 1)**.

Related to public consultation, in Utopia Web GIS it has been inserted a tool enabling users to send comments and documents about some specific point. The benefit of the Web GIS is that the user can operate with a geographical interface to select the point of interest and to attach his/her comment, for instance to point out a landmark or an undetected critical situation (see **Figure 2**). The system automatically detects the geographical coordinates and, before sending an email, checks if the sender is a real person and not, for instance, an automatic program.

3. ELICITING PEOPLE PREFERENCES

Concerning active participation, a tool has been implemented to allow the user to express her/his opinion about the most relevant points in the area affected by the development project.

Specifically, the user, after having provided her/his credentials, can choose and insert (using Web GIS functionalities, like point & click) the three outstanding points for different typologies and different protection levels, such as:

- places to be fully protected or to be preserved unaltered;
- points of affection, important to preserve;
- places where mitigation measures are appropriate.

This function (collecting and storing users' preferences) is used by the program to identify the most sensible points according to residents' opinion and to compute the score of the different alternatives routes according to their possible interference with these points of interest; eventually, this functionality allows the user to give direct input to the decision-maker.

The aim is to build a piece of shared knowledge on the region that might be affected by overhead lines, in order to better assess impacts of the different options and to provide customized maps that can be used by stakeholders to represent their main concerns on a spatial basis. This is intended to make real and operating the principles stated in the European Landscape Convention[3], in which the landscape is defined as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors". The term "landscape" is thus defined as a zone or area as perceived by local people or visitors, whose visual features and character are the result of the action of natural and/or cultural factors. the Convention applies to the entire territory of the EU and covers natural, rural, urban and peri-urban areas. It concerns landscapes that might be considered outstanding as well as every day or degraded landscapes. In order to implement these principles in practice, strong feedback from the general public is needed and, as the physical support of the landscape is space, Web GIS is one of the most appropriate tools for this purpose.

To implement these principles in practice, an interference indicator is computed starting from the stated people preferences and using an additive, non-linear function of the distances from each preferred point and the route of the power line:

$$F_k = \sum_i f_D(x_{ik}) \qquad (1)$$

$$f_D(x) = e^{-(x/D)^2}$$

where F_k is the interference of the alternative route k, x_{ik} is the distance between alternative k and the point i, and D is a characteristic distance, representing the distance beyond that the interference is negligible. The next figure depicts how f_D changes with the value of D.

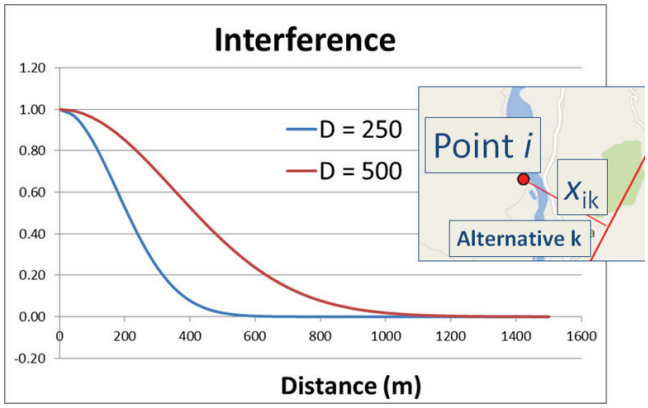

Figure 3: The interference indicator for a single point and different characteristic length *D*

It should be noted that this interference indicator has a minimum value of zero and a maximum value equal to the total number of preference points. It can be used for comparing several alternatives of the same development project but cannot be used to compare the performance of different projects in different regions.

The prototype Web GIS allows the user to obtain a real-time computation of the values of the interference indicator for the alternative routes and for the current set of preference points, and to rank them accordingly (see **Figure 4**Errore. L'origine riferimento non è stata trovata.).

[3] https://www.coe.int/en/web/landscape

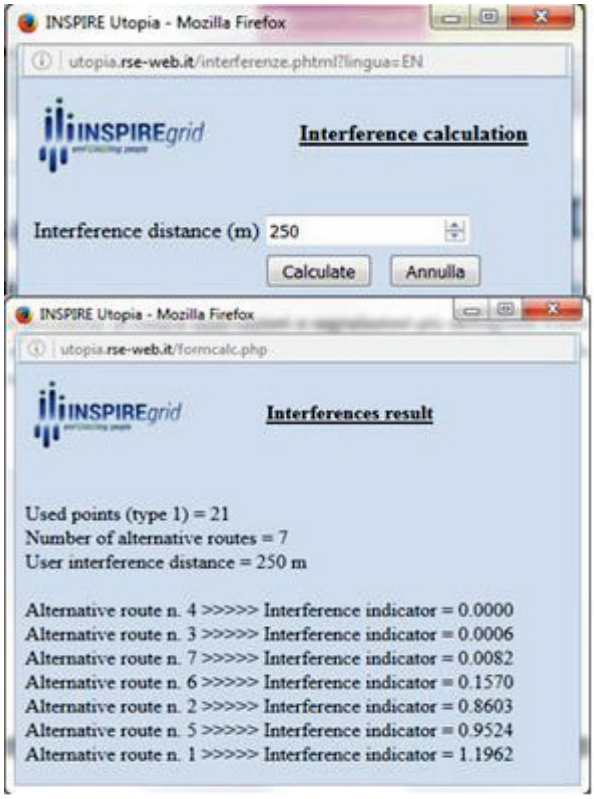

Figure 4: Interference calculation and result masks

This kind of interaction can be considered as "active participation" and not only "consultation" because in the consultation process comments are evaluated and the manager of the decision process choose if they are relevant or not. In this case, people preferences are directly used, without any external mediation or assessment, and an index is computed which is directly used in making the decision, together with the cost of line or other indicators. In this sense, people take part directly in the decision (see **Figure 5**).

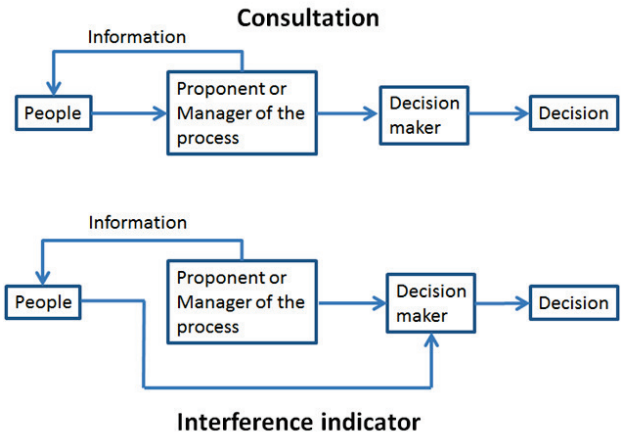

Figure 5: Schematic representation of the difference between a consultation process and the use of the interference indicator

In this respect, the interference indicator can be used and compared in a Multi-Criteria Analysis together with all other selected criteria.

4. TESTING OF THE TOOL

The tool was presented and discussed in five workshops held in four different countries, with a quite varied audience. In the following table, the place, date and main attendance of the five workshops are reported in the next Table. Here TSO stands for Transmission System Operators, i.e. the companies that manage the electricity grid.

Table 1: Workshops where the Web GIS questionnaire was distributed

Location	Origin of participants	Attendance	Number of answers
Birmingham	UK	TSO	9
San Donato	World	Master students	12
Sogndal	NO	Local Stakeholders	5
Schwäbisch Gmünd	DE	Local Stakeholders	5
Berlin	EU	TSO	12

In all occasions, the presentation method was essentially the same: the functionalities of the Web GIS were described by a PowerPoint presentation and, at the same time, they were demonstrated using the tool and attendees were encouraged to experience them directly connecting to the relevant web site.
At the end of the session, a questionnaire was distributed to the participants, asking them to express their degree of agreement to a fixed set of propositions according to a Likert scale from 1 (strongly disagree) to 5 (strongly agree).

In the following table, average scores of the five workshops are compared and the minimum and maximum scores for each question are highlighted.

To investigate the statistical significance of the previous results, an appropriate test was selected. Following directions from Siegel (1956) and Helsel & Hirsch (2002) for comparing ordered categorical responses, the non-parametric Kruskal-Wallis test was chosen.

Table 2: Comparison of the average scores for the use of Web GIS in the different workshops

1. I am satisfied with the Web GIS presentation	3.92	3.44	3.75	**3.25**	**4.25**	3.73
2. Web GIS makes it easier to access the project documentation	**4.08**	**3.56**	3.83	3.75	3.40	3.79
3. It is valuable the use of Web GIS to make simple elaborations and to extract customized dat	3.75	**3.22**	3.75	3.75	**4.20**	3.69
4. Web-GIS enable the user to submit comments and suggestions, specifying very precisely the location to which they refer	**4.25**	**3.44**	4.17	3.75	4.00	**3.98**
5. Web GIS could allow the decision makers to elicit the preferences of the general public about some aspects	3.80	**2.89**	3.83	**4.00**	3.80	**3.63**
6. Web GIS could contribute to the improvement of public engagement	4.18	**3.22**	3.83	3.50	**4.20**	3.80
Average	**4.00**	**3.30**	3.86	3.67	3.98	3.77

For each question, the highest score is showed by a blue background, the lowest by a red background; questions in bold show where answers resulted to be different among places at a confidence level of 0.05.

The possibility to send comments was appreciated most in the Berlin workshop and less in the Birmingham Workshop; it is interesting to note that in both workshops attendees were mostly

TSO representatives. As well, the use of Web GIS as a tool to elicit people preferences was appreciated most in the German workshop and less in the Birmingham workshop. Finally, the usefulness of Web GIS as an engagement tool was valued most in the Norwegian workshop and less, again, in the Birmingham workshop.

We also tested possible differences in answers between TSO and other kinds of audience. In general, the differences between the two groups are not statistically significant. The only exception is question 5 (the usefulness of Web GIS in the elicitation of people preferences) for which the average score for TSO is 3.37, for non-TSO is 3.86, the p-value is 0.06 so that the difference is significant at the confidence level of 10 %.

In general, the Web-GIS was appreciated for its functionality of capturing geographic information data in an easy and fast way. Its use as an effective tool to elicit people preferences and to implement active participation was discussed in detail and raised some doubts. The major concerns were the representativeness of the results, due to different level of familiarity with digital tools in different social groups and the resistance of the regulatory authorities to use such tools in a formal permission procedure.
For these reasons, the usefulness of this kind of tools is worth of further investigations and it would be necessary some experience in real case studies, with the collaboration not only of the proponents but of the permitting authority as well.

5. CONCLUSIONS

The tool here described was developed in the framework of research activities aimed at increasing stakeholders' engagement in grid expansion projects and better managing possible conflicts. By way of an interdisciplinary approach, methods to facilitate decision-making have been combined with engagement tools and tested with stakeholders from grid development project case studies.

Among other topics, the project dealt with the problem of developing assessment methodologies that could contribute to the improvement of stakeholders' engagement. Specifically, two main methodologies were taken into consideration and new developments and customizations were carried out to make them suitable to be used in the planning or permitting processes of overhead lines:

- Online Geographical Information Systems (Web GIS), for involving stakeholders, communicating spatial-related information on several possible routes, and gathering information from affected stakeholders;
- Multi-criteria Analysis (MCA), for supporting decision problems characterized by conflicting criteria and actors with different viewpoints.

The effectiveness of the customized tools was investigated through three case studies, representing real grid development projects, and four focus groups, where different kinds of stakeholders were involved (TSOs, Master students in Management and the Economics of Energy and the Environment, participants at the conference Grid Aesthetics, local stakeholders).

The results of the validation workshops show that the use of stakeholder engagement methods can improve the current processes.

The Web GIS, in the participatory version developed during the project, showed to be useful in communicating spatially-related information and gathering possible comments. In its use as a collaboration tool, the major problem is that the collected preferences could not be representative of the affected population due to different levels of computer literacy.

MCA showed the ability to reduce the set of alternative power line paths by using stakeholder preferences in ranking the effects and to generate acceptance for the outcome when stakeholders agree on the ranking. However, MCA did not necessarily foster systematic stakeholder acceptance of the outcomes. Our results suggest that the use of tools like MCA and Web GIS potentially increases the perceived justice by stakeholders. The choice of the methodologies and tools and their proper implementation are key factors for an effective participatory process but these tools do not warrant the positive outcome of the process.

Is it worth the effort, then?

From one side, one of the challenges should be the decrease of costs and time required for implementing participation processes: these two constraints are often the main bottlenecks that prevent the implementation of a real participatory approach in many instances. In this respect, the development of cost-effective tools like the participatory Web GIS could make more viable the adoption of such an approach.

But it is also important to acknowledge that benefits of a proper participatory process are not only monetary and go beyond the single grid project; vice versa, the impacts of a poor participatory process extend to the acceptance of all future grid development projects in the area. In fact, they undermine trust not only in the single TSO but in authorities and institutions as well, affecting the public attitude towards the following projects about infrastructures for the general public interest.

In conclusion, the drivers to implement participatory processes are not limited to costs and effectiveness, but are related also to normative (affected people have a right to be heard and involved) and substantive (participation could yield better decisions) reasons. A great deal of research (see, for instance, [7]–[9]) has shown that opposition cannot be reduced to the argument that people do not want infrastructures near to them and the NYMBY label is often used simply to disqualify the opposition. It is important to accept that, in some circumstances, a real conflict among concurrent objectives is present and, in this case, to understand the real causes and to engage stakeholders to look for a compromise. The best we can do is to adopt a transparent and traceable process and tools like the one presented in this paper can be part of it.

6. ACKNOWLEDGEMENTS

This work has been financed by the Research Fund for the Italian Electrical System in compliance with the Decree of Minister of Economic Development April 16, 2018.

7. REFERENCES

[1] S. Maran and E. Garofalo, Eds., *INSPIRE-Grid - Improved and enhanced stakeholders participation in reinforcement of electricity grid: Final Synthesis Report*. available at http://www.inspire-grid.eu: INSPIRE-Grid, 2017.

[2] J. R. Figueira, S. Greco, and M. Ehrgott, *Multiple criteria decision analysis: state of the art surveys*. Kluwer Academic Publishers, 2005.

[3] L. Späth, E. Amodeo, A. Luè, S. Muratori, A. Scolobig, and A. Patt, 'Stakeholder engagement and multi-criteria decision aiding in the electricity transmission grid reinforcement: evidence from a role-playing game', *J. Environ. Plan. Manag.*, pp. 1–18, Nov. 2017, doi: 10.1080/09640568.2017.1395317.

[4] F. Lafrance, S. Daniel, and S. Dragićević, 'Multidimensional Web GIS Approach for Citizen Participation on Urban Evolution', *ISPRS Int. J. Geo-Inf.*, vol. 8, no. 6, Art. no. 6, Jun. 2019, doi: 10.3390/ijgi8060253.

[5] G. Rowe and L. J. Frewer, 'A Typology of Public Engagement Mechanisms', *Sci. Technol. Hum. Values*, vol. 30, no. 2, pp. 251–290, Apr. 2005, doi: 10.1177/0162243904271724.

[6] L. Späth *et al.*, 'Establishing the best practices and determining a tool box', INSPIRE-Grid, Project Deliverable D3.2, Nov. 2014. Accessed: Jan. 19, 2018. [Online]. Available: http://www.inspire-grid.eu/wp-content/uploads/2015/10/INSPIRE-Grid-D3.2-Best-practices.pdf.

[7] P. Devine-Wright, 'Explaining "NIMBY" Objections to a Power Line , Explaining "NIMBY" Objections to a Power Line: The Role of Personal, Place Attachment and Project-Related Factors , The Role of Personal, Place Attachment and Project-Related Factors', *Environ. Behav.*, vol. 45, no. 6, pp. 761–781, Aug. 2013, doi: 10.1177/0013916512440435.

[8] C. Schively, 'Understanding the NIMBY and LULU Phenomena: Reassessing Our Knowledge Base and Informing Future Research', *J. Plan. Lit.*, vol. 21, no. 3, pp. 255–266, Feb. 2007, doi: 10.1177/0885412206295845.

[9] K. Burningham, J. Barnett, and D. Thrush, 'The limitations of the NIMBY concept for understanding public engagement with renewable energy technologies: A literature review', Aug. 2006, Accessed: Jul. 18, 2018. [Online]. Available: https://researchportal.bath.ac.uk/en/publications/the-limitations-of-the-nimby-concept-for-understanding-public-eng.