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DOCTORAL THESIS

Addressing Strategic Environmental Assessment in Mexico's transition towards renewable energy. Geospatial approach of collective intelligence as prospective support in the planning process.

PhD in System and Project Engineering
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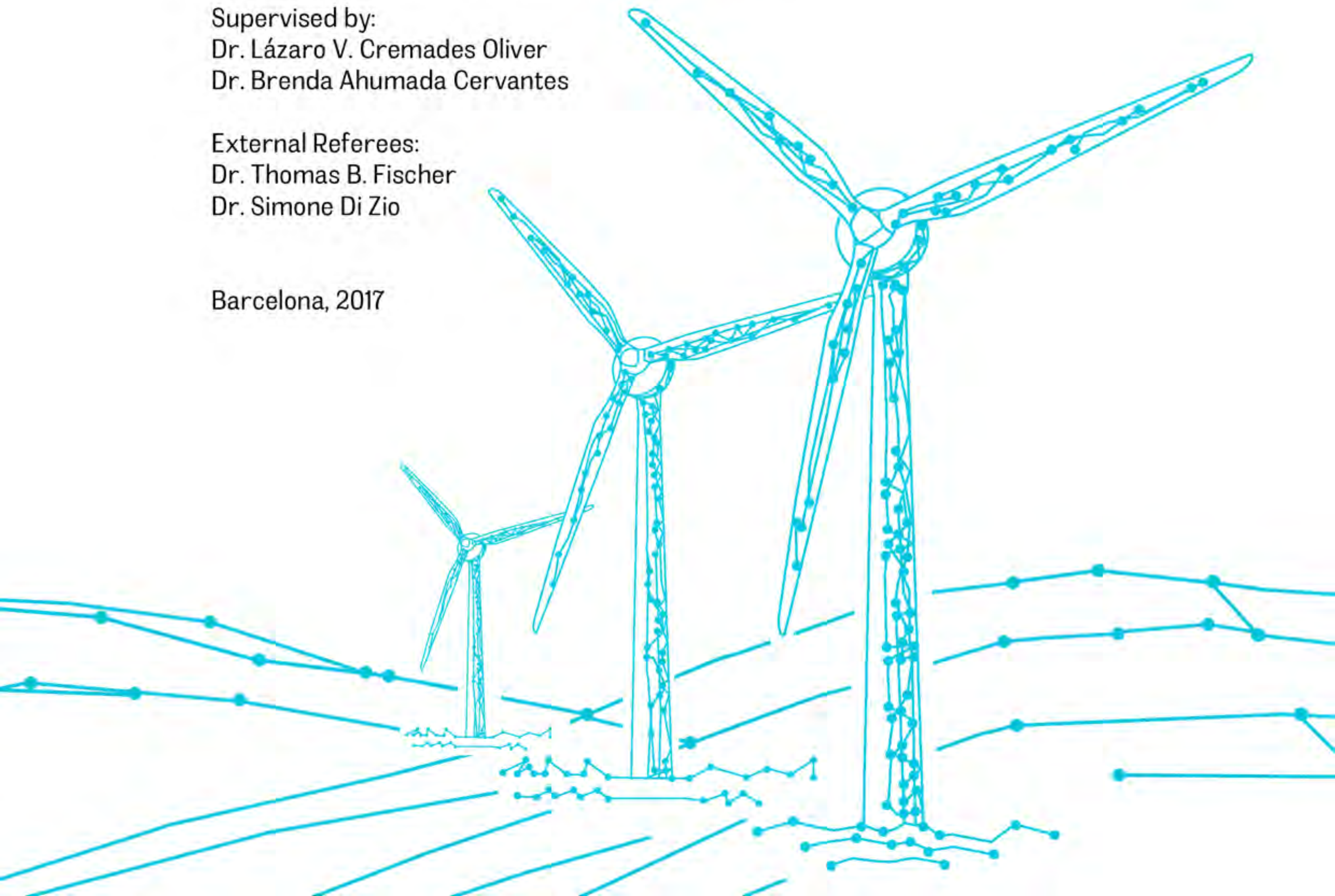

“La ventura va guiando nuestras cosas mejor de lo que acertáramos a desear; porque ves allí, amigo Sancho Panza, donde se descubren treinta, o pocos más desaforados gigantes, con quien pienso hacer batalla y quitarles a todos las vidas, con cuyos despojos comenzaremos a enriquecer; que esta es buena guerra, y es de gran servicio de Dios quitar tan mala simiente de sobre la faz de la tierra.”

Miguel de Cervantes

Table of Contents

Abstract

The transition towards an environmentally sustainable society involves a substantial transformation of the configuration of the energy system, and therefore, it entails a significant shift in planning process strategy. Strategic Environmental Assessment (SEA), an instrument which is strategic in nature, is recognised internationally as a systematic decision support process, aiming to ensure that environmental and possibly other sustainability aspects are considered effectively in Policy, Plan and Programme (PPP) making, i.e., in those planning tools that precede the project in the decision-making process and surpass it in terms of spatial and thematic scope and level of abstraction. From this perspective, and taking into consideration the current state of environmental assessment in Mexico as a basis of knowledge and understanding, this research proposes an innovative Strategic Environmental Assessment methodological framework applied to renewable energy, while looking upon the current transition process as a matter of interest, as well as the strategies and public policies proposed by governmental bodies. All this aimed at creating mechanisms that allow the effective execution of policies in the field of green energies.

It can be assumed that this doctoral dissertation supports the need for further experimentation on SEA, developing an alternative approach that integrates knowledge and tools of Collective Intelligence, Complexity Theory and Geoprospective, via the implementation of a technological Group-Spatial Decision Support System (GSDSS) usable for decision support and/or scenario building for infrastructure project planning, that operates through interdisciplinary consensus of a multidisciplinary group of experts, without strict dependency on a spatial analysis based on a single cognitive stance, not either retrospective analysis using only existing historical data. Thus, this work addresses a study case on planning of wind energy in Mexico, which has been developed through a collaborative Geoweb application, functioning in a distributed and asynchronous real-time way, so-called Geospatial System of Collective Intelligence (SIGIC).

Keywords: Strategic Environmental Assessment, Renewable Energy, Sustainable Development, Wind Energy, Mexico, SDSS, Real Time Spatial Delphi.

UNESCO codes: 590208, 332205, 540101, 330417

Resumen

La transición hacia una sociedad ambientalmente sustentable conlleva una transformación sustancial en la configuración del sistema energético, y por ende ello implica un cambio significativo en la estrategia del proceso de planificación. La Evaluación Ambiental Estratégica (EAE), un instrumento de naturaleza estratégica, es reconocida internacionalmente como un proceso sistemático de apoyo a las decisiones destinado a asegurar que los aspectos ambientales y posiblemente otros aspectos de la sostenibilidad se consideren de manera efectiva en la formulación de Políticas, Planes y Programas (PPP), es decir, en aquellos instrumentos de planificación que preceden al proyecto en el proceso de toma de decisiones y lo superan en nivel de abstracción y en amplitud de los ámbitos espacial y temático a los que afectan. Desde esta perspectiva, y tomando en consideración el estado actual de la evaluación ambiental en México como base de conocimiento y entendimiento, esta investigación propone un enfoque metodológico innovador de Evaluación Ambiental Estratégica en materia de energías renovables, considerando el actual proceso de transición energética como cuestión de interés, así como las estrategias y políticas públicas propuestas por los organismos gubernamentales. Todo ello con el objetivo de crear mecanismos que permitan la ejecución efectiva de políticas en el campo de las energías verdes.

Se puede asumir que esta tesis doctoral apoya la necesidad de una mayor experimentación en EAE, desarrollando un enfoque alternativo que integra conocimientos y herramientas de Inteligencia Colectiva, Teoría de la Complejidad y Geoprospectiva, a través de la implementación de un Sistema de Soporte de Apoyo a las Decisiones Espaciales en grupo (SADE), útil para el apoyo a la toma de decisiones y/o la construcción de escenarios para planificación de proyectos de infraestructura, que opera a través de un consenso interdisciplinar de un grupo multidisciplinario de expertos y sin una dependencia estricta de un análisis espacial basado en una única posición cognitiva , y tampoco de un análisis retrospectivo usando solo datos históricos existentes. De este modo, este trabajo aborda un caso de estudio sobre planificación de la energía eólica en México, desarrollado a través de una aplicación Geoweb colaborativa, funcionando de forma distribuida y asincrónica en tiempo real, denominada Sistema Geoespacial de Inteligencia Colectiva (SIGIC).

Palabras clave: Evaluación Ambiental Estratégica, Energías Renovables, Desarrollo Sostenible, Energía Eólica, México, SADE, Delphi Espacial en Tiempo Real.

Códigos UNESCO: 590208, 332205, 540101, 330417

Resum

La transició cap a una societat ambientalment sostenible comporta una transformació substancial en la configuració del sistema energètic, la qual cosa implica un canvi significatiu en l'estratègia del procés de planificació. L'Avaluació Ambiental Estratègica (AAE), un instrument de naturalesa estratègica, es reconeix internacionalment com a procés sistemàtic de suport a les decisions destinat a assegurar que els aspectes ambientals i possiblement altres aspectes de la sostenibilitat es considerin de manera efectiva en la formulació de Polítiques, Plans i Programes (PPP), és a dir, en els instruments de planificació que precedeixen al projecte en el procés de presa de decisions i el superen en nivell d'abstracció i en amplitud dels àmbits espacial i temàtic als quals afecten. Des d'aquesta perspectiva, i tenint en compte l'estat actual de l'avaluació ambiental a Mèxic, com a base de coneixement i enteniment, aquesta investigació proposa un enfocament metodològic innovador d'Avaluació Ambiental Estratègica en matèria d'energies renovables, considerant l'actual procés de transició energètica com a qüestió d'interès, així com les estratègies i polítiques públiques proposades pels organismes governamentals. Tot això amb l'objectiu de crear mecanismes que permetin l'execució efectiva de polítiques en el camp de les energies verdes.

Es pot assumir que aquesta tesi doctoral dóna suport a la necessitat d'una major experimentació en AAE, desenvolupant un enfocament alternatiu que integra coneixements i eines d'Intel·ligència Col·lectiva, Teoria de la Complexitat i Geoprospectiva, a través de la implementació d'un Sistema de Suport a la Decisió Espacial Col·lectiva (SSDEC), útil per al suport a la presa de decisions i/o la construcció d'escenaris per a la planificació de projectes d'infraestructura, que opera a través d'un consens interdisciplinari d'un grup multidisciplinari d'experts, sense una dependència estricta d'una anàlisi espacial basada en una única posició cognitiva, i tampoc d'una anàlisi retrospectiva emprant només les dades històriques existents. D'aquesta manera, aquest treball aborda un cas d'estudi sobre planificació de l'energia eòlica a Mèxic, desenvolupat mitjançant una aplicació Geoweb col·laborativa, que funciona de manera distribuïda i asincrònica en temps real, anomenada Sistema Geoespacial d'Intel·ligència Col·lectiva (SIGIC).

Paraules clau: Avaluació Ambiental Estratègica, Energies Renovables, Desenvolupament Sostenible, Energia Eòlica, Mèxic, Sistemes de Suport a les Decisions Espacials (SSDE), Delphi Espacial en Temps Real.

Codis UNESCO: 590208, 332205, 540101, 330417

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Panel of experts	
Dolores Barrientos Alemán	United Nations Environment Programme (UNEP - Mexico)
Gustavo A. Pérez Chirinos	Secretariat of Environment and Natural Resources (SEMARNAT)
Jessica S. Rodríguez Aguilar	Secretariat of Energy (SENER)
Alejandro Castillo Antonio	National Institute of Ecology and Climate Change (INECC)
Héctor J. Treviño	Mexican Association of Wind Energy (AMDEE)
Marco A. Borja Díaz	Mexican Centre for Innovation in Wind Energy (CEMIE-Eólico)
Luis E. Montañez Cartaxo	Centre for Services in Energy and Sustainability (ENESUS)
Gilberto Velázquez Angulo	Autonomous University of Ciudad Juarez
Miguel Puras Artajo	Environmental Consulting (Natura Medio Ambiente)

List of Tables and Boxes

List of Figures

Acronyms and Abbreviations

DSR	Design Science Research
EIA	Environmental Impact Assessment
EU	European Union
GIS	Geographic Information System
GSDSS	Group Spatial Decision Support System
INERE	National Inventory of Renewable Energies
IPCC	Intergovernmental Panel on Climate Change
IS	Information Systems
LAERFTE	Law for the Use of Renewable Energy and Financing the Energy transition
LGEEPA	General Law of Ecological Balance and Environmental Protection
MCA	Multi-criteria Analysis
NIMBY	Not In My Back Yard
RTSD	Real Time Spatial Delphi
PPP	Policies, Plans and Programmes
SEA	Strategic Environmental Assessment
SIGIC	Geospatial System of Collective Intelligence
SDSS	Spatial Decision Support Systems

Chapter 1.
Research Outline

Chapter 1. Research outline

1.1 Introduction

Ensuring a sustainable supply of energy on an increasingly populated planet with finite resources is one of the most urgent and urgent challenges currently facing humanity. In addition to being a priority, the energy issue is global and extraordinarily complex. Any attempt to tackle it rigorously requires a multidisciplinary approach that takes into account the social, environmental, economic and political aspects that comprise it. None of its facets can be ignored, since all of them are interconnected. Deepening the understanding of the energy issue is a necessary and very important task, since the future of energy will undoubtedly mark the course of our society (Torres-Casas, 2014).

Concerning the subject matter of this research, certainly the wind sector is experiencing a tremendous growth worldwide, including Mexico which is one of the countries on earth with greatest potential for such development. Despite some technical issues such as the instability of production (which might be overcome by appropriate storage systems and an efficient power network), one of the major challenges facing this millenary technique involves dealing with environmental aspects (receiving strong controversial criticism), and linked to it, the public acceptance.

However, it counts in its favour the fact that wind energy has one of the lowest CO_2 emissions and energy used throughout its life cycle as shown in the Intergovernmental Panel on Climate Change Special Report on Renewable Energies (IPCC, 2012). Meanwhile, prestigious entities like the Institute for European Environmental Policy, call on delivering synergies between renewable energy and nature conservation, showing that the impact of wind farms on most habitats and species is very low if wind farms are well planned, sited and managed intelligently (IEEP, 2015).

In line with the above, this thesis aims to inspire consideration of a wind energy project's environmental and sustainability aspects, besides meeting the need to link SEA and spatial/land-use planning through the undertaking of empirical research in which a select group of stakeholders' representatives and decision-makers joint in an exercise of public participation, thus providing a framework for addressing two main shortcomings of spatial planning observed by Nelson (2015), more precisely lacking in transparency and an absence of any genuine exploration of alternative choices of action.

Finally, it is noted that the development of this research is framed within the scopes of *Project Methodology, Design and innovation on the Internet* and *Environment and Sustainability* of the PhD in System and Project Engineering (UPC, 2010). The rationale for this is based on the following arguments:

1) The line of research seeks to respond to the challenge of technological change complexity by the advancement of theory and practice for management of multidisciplinary and multicultural projects;

2) The research with an interdisciplinary orientation combines theoretical study with empirical work in a project development environment with a high level of innovation in a collaborative context;

3) The line of research establishes concepts and working methods aim to facilitates the consideration of environmental factors as well as the impact and implications of human activities with a holistic vision, and the need for information and communication at the earliest stages of project planning/engineering and strategic appraisal;

4) The research makes an effort to identify different factors that may affect the viability of the projected solutions under broader criteria than the traditional ones of cost-benefit and time;

5) From this research, it is possible to envisage some management, communication and technological activities necessary to avoid or reduce enviro-social risks in planning and project engineering (within the context of the case study), and ultimately a contribution to sustainable development.

1.2 Problem definition

Even though Strategic Environmental Assessment has been neither formalised nor fully integrated into Mexican legislation, Mexico has been conducting Environmental Impact Assessment (EIA) practice for over twenty years. It could be argued that Mexico has been using practices and approaches which resemble the idea behind Strategic Environmental Assessment, but which are neither close enough nor sufficiently consolidated to convert SEA into a change enabler, and a valid mechanism for generating development under a doctrine of sustainability. Significant efforts have been made, including the development and introduction of government initiatives, proposals for amendments to relevant laws, and the initiation of pilot projects by governmental bodies.

Given the above, it is puzzling that there have been such delays and shortcomings in follow-ups after changes in administration, and that SEA has ultimately failed to materialise. The Federal Public Administration claims that progress has been made, but the societal and environmental benefits envisioned have not yet been realised. These benefits shall remain unrealised as long as there is no shift in focus, no promotion of structural reforms, and while the SEA formalisation process remains stagnant and constantly side-lined. Additionally, without discussion of SEA principles; a willingness to engage in constant dialogue and ongoing debate; and a consensus on the conceptualisation of SEA, its implementation mechanisms and explicit inclusion, neither a transformation in the approach to SEA project management nor the development of a true state vision towards sustainable development, and with it the sought-after change of direction in the country, will be realised (Diez Rodríguez, Cremades Oliver, & Ahumada Cervantes, 2015).

It should be pointed out, however, that there are strong foundations from which to move towards a new approach to Environmental Assessment in Mexico. The country has considerable experience in the field, consolidated institutional structures, a defined environmental legal framework to host it, as well as the acknowledgement in the country that environmental considerations must be taken into account at the same level as economic and social issues, and be part of all public policies formulated and established in Mexico (Ahumada, 2011).

1.3 Objectives

1.3.1 General

To develop an adaptable and systematic approach for the appraisal of infrastructure project planning on renewable energy in Mexico, adopting Strategical Environmental Assessment (SEA) philosophy as a tool for boosting sustainability. In addition, it is sought to provide a basis for a structured decision framework, with the goal of supporting more effective and efficient decision-making, and improving governance in terms of energy transition and the sustainable exploitation of energy resources.

1.3.2 Specific

To implement a prototype of a Geocollaborative application based on the spatial version of the Real Time Delphi method, designing and adapting its WebGIS interface for supporting decision-making regarding the spatial location of strategic sites of onshore wind energy infrastructure in Mexico, aimed at promoting that environmental and sustainability aspects are considered and integrated in national development planning and programmes.

1.4 Research questions

Is it possible that through a novel geotechnical web application, the members of a multidisciplinary panel of experts based in Mexico, with little or no technical expertise in geographic information science and the use of decision support systems, will be able to interact, from their different perspectives, experiences and interests of its members, proposing the most suitable locations for the development of wind energy facilities, under an interdisciplinary consensus approach, and taking into account environment and sustainability issues?

Following the above, is it achievable to come up with an area, which is considered to be of the highest priority and strategic relevance for wind energy development in the country?

In relation to the previous question, and taking into consideration possible cumulative effects, is it feasible to choose an area where it is deemed that a greater environmental degradation will be caused as a result of the construction of such wind-generated energy complexes?

1.5 Contributions

a. Proposal of a GSDSS-based SEA approach with practical focus to improve the understanding and future formalisation of SEA in Mexico.

b. Application of the Real-Time Spatial Delphi method in a new spatial planning context.

c. Promotion of a structured sustainability impact management framework useful for the transition process to renewable energy.

d. Implementation of an open and transparent stakeholder engagement and publication consultation exercise in line with international SEA principles.

e. Collaboration in the development of a technological application of Collective Intelligence for the geospatial analysis from an interdisciplinary perspective.

1.5.1 Published works

Diez Rodríguez, J. J., Cremades Oliver, L., & Ahumada Cervantes, B. (2015). Addressing Strategic Environmental Assessment of Mexico's transition towards renewable energy (Conference Proceeding). In *19th. International Congress on Project Managemet and Engineering*. Granada: Spanish Project Management and Engineering Association (AEIPRO). Retrieved from: http://www.aeipro.com/aplic/tree_congresos/tree_remository_aeipro.php?arbol=congresos

Diez-Rodríguez, J. J. ., Castillo Rosas, J. D., & Jiménez Vélez, A. (2015). Enfoque geoespacial de inteligencia colectiva como apoyo prospectivo a la Evaluación Ambiental Estratégica de energías renovables (Conference Proceeding). In *11as Jornadas Internacionales gvSIG*. Valencia: Asociación gvSIG. Retrieved from: http://downloads.gvsig.org/download/events/gvSIG-Conference/11th-gvSIG-Conference/Reports/11J_Evaluacion_ambiental_energias_renovables.pdf

Diez Rodríguez, J. J., Cremades Oliver, L., & Ahumada Cervantes, B. (2014). Abordando la Evaluación Ambiental Estratégica de la transición de México hacia las energías renovables (Conference Proceeding). In *IV Symposium des boursiers CONACYT en Europe 2014, Parlement europeén*. Strasbourg: Maison Universitaire Franco-Mexicaine. Retrieved from: http://www.mufm.fr/sites/mufm.univ-toulouse.fr/files/jose_j._diez_rodriguez.pdf

Castillo-Rosas, J., Diez-Rodríguez, J., Jiménez-Vélez, A., Núñez-Andrés, M., & Monguet-Fierro, J. (2017). Collection and Integration of Local Knowledge and Experience through a Collective Spatial Analysis (Journal Article). *ISPRS International Journal of Geo-Information 2017, Vol. 6, Page 33*, *6*(2), 33. http://doi.org/10.3390/IJGI6020033

Castillo Rosas, J. D., Jiménez Vélez, A. F., Diez Rodríguez, J. J., Monguet Fierro, J. M., & Núñez Andrés, M. A. (2015). Geospatial System of Collective Intelligence: a technological application for the interdisciplinary study of the geographical space complexity (Conference Proceeding). In *2015 Collective Intelligence Conference*. Santa Clara: Center for the Study of Complex Systems. University of Michigan. Retrieved from:
http://sites.lsa.umich.edu/collectiveintelligence/wp-content/uploads/sites/176/2015/06/Rosas-CI-2015-Abstract.pdf

1.6 Content of the thesis

Chapter 1. It brings forward the outline of the thesis and it is composed by the introduction, definition of the problem, objectives, research questions, and a synthesis of the main contributions of this research as well as a compilation of the works presented upon it.

Chapter 2. It exposes the research's core theory and concepts. In the same vein, it displays the *state-of-the-art* of the scientific field subject of study as well as the approaches of other related works undertaken with shared goals. All this in order to give order and structure to the existing knowledge on the matter, to sustain the problem addressed and to provide a frame of reference to the thesis.

Chapter 3. It describes the theoretical analysis of the methods applied to this research, which has been elaborated according to the principles of Design Science Research. Likewise, it comprises a constructive framework linked to the case study research in order to approach the problem environment, meet the objectives and proposed questions.

Chapter 4. It shows the experimental research performed. An exploratory and a case study approach was adopted for the purpose of this dissertation. Furthermore, it demonstrates the use of the proposed artifact, proving that it works by solving several instances of the problem, providing answers to the research questions with the empirical evidence collected.

Chapter 5. It synthesises the highlights of this work, interpreting the results obtained, discussing what they may mean to the field of study, and stating how these outcomes extend findings of previous works.

Chapter 6. It presents the conclusions of this dissertation, briefly describes the strengths and limitations of this research, and suggest future research lines that might be expanded.

Chapter 2.
Theoretical Framework

Chapter 2. Theoretical Framework

2.1 SEA: origin and international context

In their comprehensive overview *Strategic Environmental Assessment: the state of the art,* Fundingsland Tetlow and Hanusch (2012) point out that the term SEA was first conceptualised and coined by Wood and Djeddour in the late 1980s in the context of an European research project, to refer to the environmental assessments appropriate to policies, plans and programmes (PPP) of a *more strategic nature* than those applicable to individual projects, and likely to differ from them in several important respects (Wood & Djeddour, 1989). Nonetheless, the concept of evaluating environmental impacts of PPPs was formally established in the 1969 US National Environmental Policy Act (NEPA). NEPA required an environmental assessment of proposed federal agency actions, arguably constituting the first formal framework for both environmental impact assessment (EIA) and SEA in the world (Jones et al. 2005).

As Fundingsland Tetlow and Hanusch remind us:

> SEA has developed partly from the practice of EIA of proposed projects (Lee & Walsh, 1992; Wood & Dejeddour, 1992). It has been suggested that, whereas EIA is primarily concerned with how a proposed development should take place in order to minimise adverse environmental impacts, SEA can have a real influence on the choice of alternative developments during the earlier stages of decision-making (Sadler & Verheem, 1996). In other words, SEA can facilitate a proactive approach to ensuring that environmental and sustainability considerations are taken into account during early stages of strategic decision-making processes (Fundingsland Tetlow & Hanusch, 2012).

In addition, they properly highlight:

> The role and aims of SEA vary according to the planning and decision-making context in which it is applied. It has therefore been suggested that SEA should be regarded as a *family of tools* (Partidário, 2000) or *a family of approaches* (Dalal-Clayton & Sadler, 2005) and as an *overarching concept rather than a unitary technique* (Brown & Therivel, 2000).

Initially, as Fischer and Seaton (2002) claim, SEA was mainly thought of in terms of the application of project EIA principles to PPPs. Although, subsequently different interpretations emerged that were connected in particular with:

- The different geographical and time scales of SEA and EIA (Lee & Walsh, 1992);
- The different levels of detail at strategic and project tiers (Partidário & Fischer, 2004);

- The different ways in which strategic decision process are organised, when comparing with project planning (Kørnøv & Thissen, 2000; Nitz & Brown, 2001).

Therefore, according to Fischer (2002), SEA can be described as having the following meaning: "SEA is a decision-making support instrument for the formulation of sustainable spatial and sector policies, plans and programmes, aiming to ensure an appropriate consideration of the environment" (Fischer, 2003). At this point it is important to underline that for the purpose of developing this doctoral thesis, the following more elaborate and in-depth definition proposed by Thomas Fischer (2007) will be considered:

Definition of SEA

SEA aims to ensure that due consideration is given to environmental and possibly other sustainability aspects in policy, plan and programme making above the project level. It is:

- A systematic, objectives-led, evidence-based, proactive and participative decision-making support process for the formulation of sustainable policies, plans and programmes, leading to improve governance; it can function as:
    - A structured, rigorous and open project EIA-based administrative procedure in public, and, at times, private plan and programme making situations;
    - A possibly more flexible assessment process:
        - In public and at times private policy-making situations;
        - In legislative proposals and other policies, plans and programmes, submitted to cabinet decision-making.
- A policy, plan and programme making support instrument that is supposed to add scientific rigour to decision-making, applying a range of suitable methods and techniques.
- A systematic decision-making framework, establishing a substantive focus, particularly in terms of alternatives and aspects to be considered, depending on the systematic tier (policy, plan and programme), administrative level (national, regional, local) and sector of application.

Source: Fischer (2007) **Box 2.1** SEA definition

2.2 Application of SEA

As Fischer observes, to date, SEA has been applied in a wide range of different situations, including trade agreements, funding programmes, economic development plans, spatial/land use and sectoral PPPs. He also suggests that "currently, probably the best-known SEA framework that establishes a minimum procedure for certain official plans and programmes is the European Directive 2001/42/EC on the assessment of certain plans and programmes on the environment" (Fischer, 2007).

> The objective of this Directive is to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment (European Commission, 2001).

As Fischer continues, this Directive essentially advocates the application of a systematic, pro-active EIA-based and participative process. At the heart of a Directive-based SEA process is the preparation of an environmental report, which is supposed to:

- Portray the relationship with other PPPs;
- Identify the significant impacts of different alternatives on certain environmental aspects;
- Explain how the SEA was considered in decision-making;
- Provide information on the reasons for the choice of a certain alternative.

Furthermore, a non-technical summary needs to be prepared and monitoring arrangements for significant environmental impacts need to be put into place (Fischer, 2007)

On the other hand, Fundingsland Tetlow and Hanuschb report that:

> There is no recent record of the distribution of the fields of SEA application worldwide. However, they suggest that the biggest and possibly the most successful sector of SEA application is *spatial planning* (e.g. building on Wood 2002, Jones et al. 2005), due to the growth of spatial planning worldwide and the requirement for SEA for certain land use plans under the SEA Directive and the SEA Protocol. There are also other sectors with extensive SEA application, such as the transport, water management and extractive industries. In addition, there is increasing use of SEA in the energy sector, ranging from wind farm developments to energy network plans, and nuclear waste strategies (Fundingsland Tetlow & Hanusch, 2012).

In addition, Partidário (2012) notes that:

> SEA has been widely promoted by international development agencies (World Bank, 2011; UNEP, 2009; OECD, 2006). However, beyond the assessment of development proposals, SEA is an also an important tool to help face development challenges generated by:

a. Adaptation and mitigation to climate changes.
b. Poverty eradication and overcome of social and regional inequalities.
c. Enhancement and maintenance of biodiversity values, ecosystem services and human well-being.
d. Social and territorial cohesion.
e. Promotion of regional development potential.
f. Innovation and cultural diversity of the population.
g. Promotion of environmental quality, landscape and cultural heritage and sustainable use of natural resources.

2.3 Performance Criteria

International experience in combination with solid knowledge of Strategic Environmental Assessment literature has resulted in the consensus on the approval, publication and dissemination of International Association for Impact Assessment SEA performance criteria. The SEA performance criteria have been used and tested in practice by EA practitioners worldwide. It is highlighted the importance of such special publication for this research work because "this set of criteria aims to provide general guidance on how to build effective new SEA processes and evaluate the effectiveness of existing SEA processes" (International Association for Impact Assessment, 2002).

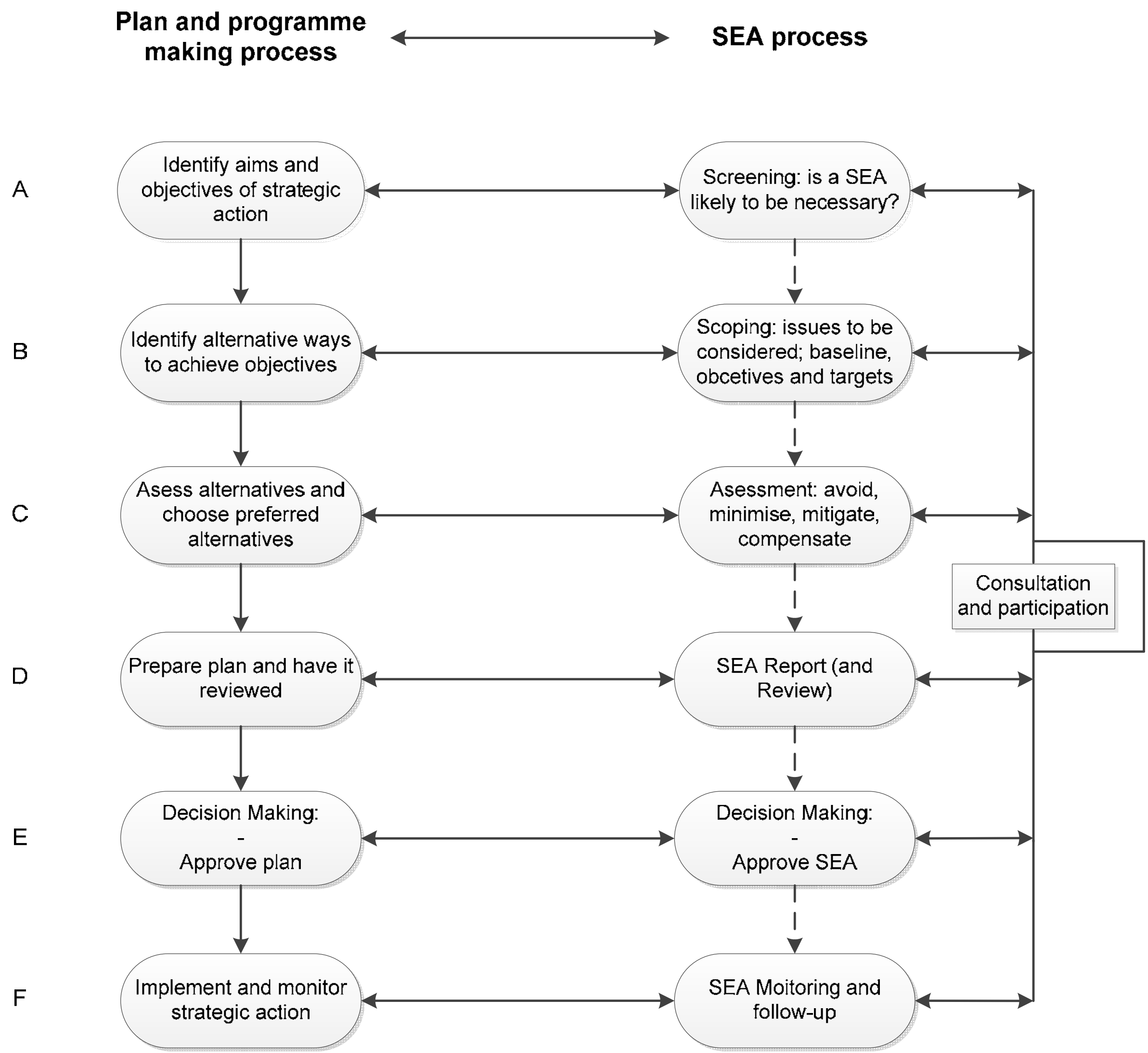
A high quality Strategic Environmental Assessment (SEA) process informs planners, decision makers and affected public on the sustainability of strategic decisions, facilitates the search for the best alternative, and ensures a democratic decision-making process. This enhances the credibility of decisions and leads to more cost-effective and time-effective EA at the project level. For this purpose, a good-quality SEA process:	
Is integrated	- Ensures an appropriate environmental assessment of all strategic decisions relevant for the achievement of sustainable development. - Addresses the interrelationships of biophysical, social and economic aspects. - Is tiered to policies in relevant sectors and (transboundary) regions and, where appropriate, to project EIA and decision making
Is sustainability-led	- Facilitates identification of development options and alternative proposals that are more sustainable[1].
Is focused	- Provides sufficient, reliable and usable information for development planning and decision making. - Concentrates on key issues of sustainable development. - Is customized to the characteristics of the decision-making process. -Is cost-effective and time-effective.
Is accountable	- Is the responsibility of the leading agencies in the strategic decision to be taken. - Is carried out with professionalism, rigor, fairness, impartiality and balance. - Is subject to independent checks and verification - Documents and justifies how sustainability issues were taken into account in decision making.
Is participative	- Informs and involves interested and affected public and government bodies throughout the decision-making process. - Explicitly addresses their inputs and concerns in documentation and decision making. - Has clear, easily-understood information requirements and ensures sufficient access to all relevant information.
Is iterative	- Ensures availability of the assessment results early enough to influence the decision-making process and inspire future planning. Provides sufficient information on the actual impacts of implementing a strategic decision, to judge whether this decision should be amended, and to provide a basis for future decisions.

Table 2.1 SEA Performance Criteria

[1] i.e., which contributes to the overall sustainable development strategy as laid down in Rio 1992, and defined in the specific policies or values of a country.

2.4 SEA Process

As Fischer proposes, Figure 1 shows an SEA Directive-based assessment process. This is EIA based and linked to plan and programme making stages in a continuous and integrated decision flow. This process is objectives-led (namely, trying to influence PPP making so that certain objectives can be reached) and baseline-led (namely, relying on baseline data to be able to make reliable projections in assessment), and reflect ideas of instrumental rationality (Falaudi, 1973; Fischer 2007).



Notes: The Review is not explicitly required by the Directive.

According to the Directive, it is mandatory to carry out consultation and participation, at least at scoping and report stages of the SEA process.

Source: Fischer (2007); see also European Commission (2006).

Figure 2.1 EC SEA Directive-based process for improving plan and programme making

Furthermore, Fischer resumes that if applied in the way shown in the figure above, the SEA process is thought to be able to influence the underlying plan and programme making process, with a view to improving it from an environmental perspective. Furthermore, a SEA that is applied in this manner may reshape the plan and programme decision flow, supporting not only the consideration of environmental issues at each stage of the process, but also leading to improved transparency and governance (Kidd & Fischer, 2007).

2.4.1 Focus of SEA and differences from EIA

SEA is applied in strategic decision-making contexts that precede project decisions. Being associated with decisions on aims and objectives for future development, SEA may deal with issues such as need and demand management, evaluating, for example, different fiscal, regulatory or organisational and spatial options. Project EIA, by contrast deals with detailed decisions that are normally concerned with the location and design of a project. In practice, project EIA has been frequently shown to resolve around measures for mitigating negative environmental impacts. Alternatively, SEA would normally aim at preventing negative impacts and proactively enhancing positive developments. Furthermore, whereas in project EIA alternatives to be assessed are often limited to minor variants, SEA may address a broad range of alternatives covering different sectors (Fischer, 2007).

	SEA	**EIA**
	Higher tiers' / Lower tiers	
Decision making level	**Policy** → **Plan** → **Programme** →	**Project**
Nature of action	Strategic, visionary, conceptual	Immediate, operational
Output	General	Detailed
Scale of impacts	Macroscopic, cummulative, unclear	Microscopic, localised
Timescale	Long to medium term	Medium to short term
Key data sources	Sustainable development strategies, state of the environment reports, vision	Field work sample analysis
Type of data	More qualitative	More quantitative
Alternatives	Area wide, political, regulative, tehcnological, fiscal, economic	Specific locations, design, construction, operation
Rigour of analysis	More uncertainty	More rigour
Assessment benchmarks	Sustainability benchmarks (criteria and objectives)	Legal restrictions and best practice
Role of practitioner	Mediator for negotiations	Advocator of values and norms, Technician, using stakeholder values
Public perception	More vague, distant	More reactive (NIMBY)

Source: Fischer (2007), following Partidário & Fischer (2004)

Table 2.2 The changing focus of SEA from lower tiers to higher tiers

Fischer argues for the application of SEA in a range of situations that may differ in terms of their *strategicness,* emphasizing that the range of different SEA applications is much wider than the range of project EIA applications. Table 2 summarises the changing focus of SEA, depending on how far away from the project level it is applied, that is, how *strategic* it is. This shows a transition in the shape that SEA is likely to take from lower tiers of decision-making to higher tiers. Whereas at lower tiers, SEA is likely to be based on a more rigorous EIA-based approach, at higher tiers it is likely to be more flexible (and possibly non-EIA based).

He also maintains that methods and techniques applied vary, depending on the specific situation of application. At lower tiers, methods and techniques typically used in EIA (for example, field surveys, overlay mapping and multicriteria analysis (MCA) for comparing different spatial alternatives) may be useful and appropriately applied. At higher tiers, methods and techniques typically applied within policy making may be more appropriate, such as forecasting, backcasting and visioning. Furthermore, there are methods and techniques that may be applied at both, higher and lower tiers, including, for example, checklists, matrices and impact trees.

The most commonly analytical and decision-making tools that may be used for SEA are mention indicated below. It should be made clear that the methods and techniques mentioned may include, but are not limited to, the following:

Indicators, Expert opinions, Checklists, Matrices, Quality of Life Assessment, Overlay maps, Land use analysis, Geographical Information Systems, Network analysis, Modelling, Scenario building, Sensitivity analysis, Cost-benefit analysis, Multi-criteria analysis (MCA), Life cycle analysis, Vulnerability analysis, Carrying capacity analysis/ecological footprints, Risk assessment, Compatibility appraisal, Participatory techniques for assessment, Stakeholder Analysis and Mapping (SAM), SWOT analysis, Sustainability Framework and Indicators, Causal Chain Analysis (CCA), Root Cause Analysis (RCA), Trend analysis, Social and economic analysis, Household Surveys, Surveys (to identify priorities), Focus groups, Consensus building processes, Statistical analysis, Forecasting, Communication/reporting (Fischer, 2007; OECD, 2006; Therivel, 2010).

2.5 Conceptualising SEA in context

2.5.1 SEA for wind energy

Throughout the last few decades we have seen that there are widely debatable issues related to energy production, and wind power generation is one of those themes that does not escape from in-depth analysis. We have also witnessed a continuous expansion of wind farms around the world. Nonetheless, even considering the “ecological label” of this alternative form of energy, there are conflicting views in society about this topic, precisely because of the various impacts of different nature, some of them crystallised in peculiar behaviours such as NIMBY (Not In My Back-Yard).

In fact, with the increase use of turbines for harnessing wind energy, the adverse environmental impacts of this renewable energy resources are increasingly coming to light (Premalatha, Abbasi, & Abbasi, 2014). What is more, the continuous growth of the wind energy industry in many parts of the world, especially in some developing countries and ecologically vulnerable regions, necessitates a comprehensive understanding of wind farm induced environmental impacts (Dai, Bergot, Liang, Xiang, & Huang, 2015).

Evidence is also emerging that the adverse impacts of wind power plants on wildlife, especially birds and bats, are likely to be much greater than is reflected in the hitherto reported figures of individuals killed per turbine. In the same way, recent findings on the impact of noise and flicker generated by the wind turbines indicate that these can have traumatic impacts on individuals who have certain predispositions (Premalatha et al., 2014).

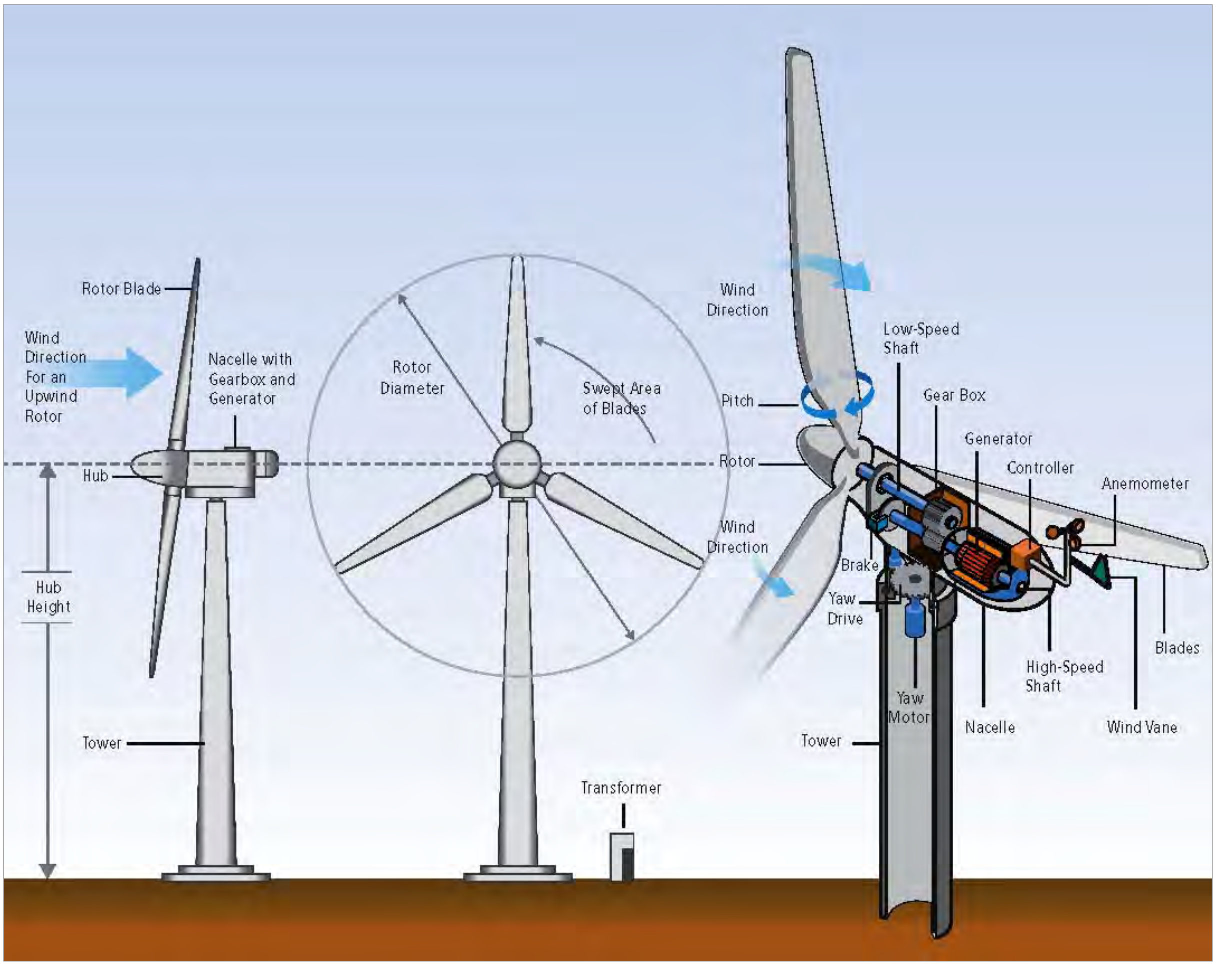
Through Strategic Environmental Assessment, attempts have been made to address those issues in a holistic and participatory manner; making wind energy subject of debate and analysis in recent years of research publications. SEA is actually considered one of the most important instruments for the implementation of the sustainable development strategy in planning. By applying SEA in wind energy planning it is also possible to realise the spatial consequences of the proposed changes in space, considering the needs of subject location (Josimović & Pucar, 2010). Likewise, the structural core of SEA lies in the extent of its influence on the related planning and decision-making process (Phylip-Jones & Fischer, 2015) as well as influencing the nature of the PPP at hand (White & Noble, 2013).

At this point, a digression is made with the aim of providing a brief overview and illustrating some basic notions about the most relevant net effects of wind energy. This following special section has been drafted essentially from a summary of the book chapter “Wind Power: Where Eagles Don’t Dare”. *Environmental Impacts of Renewable Energy* (Spellman, 2015) as well as the Special Report on Renewable Energy Sources and Climate Change Mitigation of the Intergovernmental Panel on Climate Change (2012). Other references have been added when deemed necessary.

2.5.2 Impacts of Wind Energy

Wind is a form of solar energy and is a result of the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and the rotation of the earth (USDOE, 2017). Wind energy is one of the oldest-exploited energy sources by humans and it is presumed that today is the most seasoned and efficient energy of all renewable energies. The terms wind energy or wind power describe the process which consists of converting energy produced by the movement of wind turbine blades driven by the wind into electrical energy (Acciona, 2017). In other words, a wind turbine is defined as a device that converts the wind's kinetic energy into mechanical power or electricity.

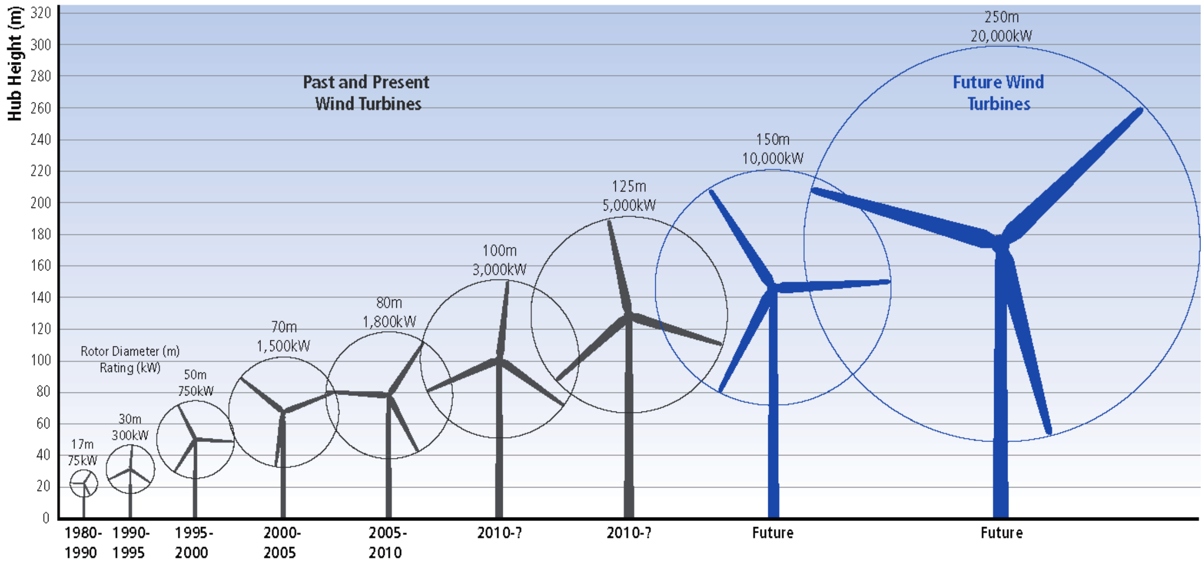
Thus, wind turbines allow us to harness the power of the wind and turn it into -renewable- energy. When the wind blows, the turbine's blades spin clockwise, capturing energy. This process triggers the main shaft connected to a gearbox within the nacelle, to spin. The gearbox sends that energy to the generator, converting it to electricity. Electricity then travels down the tower to a transformer, where it is converted again to AC or DC voltage depending on the grid (GE, 2017).



Source: IPCC (2011)

Figure 2.2 Basic components of a modern, horizontal-axis wind turbine with a gearbox (Design by the National Renewable Energy Laboratory)

Modern wind turbines fall into two basic groups: the horizontal-axis variety, and the vertical-axis design. Taking only as a standard reference, Figure 2.2 shows the components in a modern (horizontal-axis) wind turbine with a gearbox. Wind turbines are typically grouped together into wind power plants, sometimes also called wind projects or wind farms. Furthermore, it is noted that over the past thirty years, average wind turbine size has grown significantly. Figure 2.3 presents the growth in size of typical commercial wind turbines. In consequence of this and other technology developments, wind energy is already being commercially manufactured and deployed on a large scale at global level (IPCC, 2011). Finally, Figure 2.4 shows a group of wind turbines in full operation.



Source: IPCC (2011)

Figure 2.3 Growth in size of typical commercial wind turbines
(Design by the National Renewable Energy Laboratory)

Figure 2.4 Diez-Rodríguez (2016). *Wind turbines at the Whitelee Wind Farm in Scotland* [Photography]. On file with the author.

As a result of the momentum in the sector, and as noted earlier, the substantial development of wind power infrastructure also has the potential to generate some adverse impacts on the environment and on human health. Some relevant knowledge about these concerns is described below.

According to the Intergovernmental Panel on Climate Change (IPCC), there are ecological impacts that need to be taken into account when assessing wind energy. Potential ecological impacts of concern for -onshore- wind power plants include the population level consequences of bird and bat collision fatalities and more indirect habitat and ecosystem modifications.

In addition to ecological consequences, the IPCC points out that wind energy development impacts human activities and well-being in various ways. The primary impacts addressed by the Panel include: land and marine usage; visual impacts; proximal nuisance impacts that might occur in close range to the turbines such as noise, flicker, health and safety; and property value impacts.

Moreover, we are reminded that, as wind energy deployment increases and as larger wind power plants are considered, existing concerns may become more acute and new concerns may arise. In the Panel's own words, it is emphasised, that regardless of the type and degree of social and environmental concerns, however, addressing them directly is an essential part of any successful wind power-planning and plant-siting process. To that end, involving the local community in the planning and siting process has been shown to improve outcomes. Public attitudes and acceptance have been found to advance when the development process is perceived as being transparent (IPCC, 2011).

On the other hand, Spellman (2015) structures the diverse impacts according to the most relevant phases and some critical activities[2], which are summarised as follows:

2.5.2.1 Wind energy site evaluation impacts

Site evaluation phase activities, such as monitoring and testing, are temporary and are conducted at a smaller scale than those at the construction and operation phases. Potential impacts of these activities are presented beneath by type of affected resource. The impacts described are for typical site evaluation and exploration activities.

In this part, it has been used a simple matrix method for evaluating the significance of impacts that each of the most critical activities and wind energy stages may have on the environment[3]. The matrix methods and scoring mechanism are demonstrated in the successive tables below.

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[2] The energy transmission impacts regarding site evaluation, construction and operation phases are not addressed in this outline.

[3] Building on *Fischer & Phylip-Jones (2007)* and based on Spellman (2015).

First, Table 2.3 shows the list of assessment criteria. The method provided scope to indicate situations where it may not be possible to predict effects (i.e., taking into account uncertainty). Not only significant negative effects were identified, but also those that were deemed positive. Where appropriate, the duration of effects was considered with the option to value it as long-term, medium term or short term. In addition, it was indicated whether effects would be temporary or permanent.

+	Significant positive environmental effects
-	Significant negative environmental effects
--	No significant environmental effects
?	Don’t know
+/--	In the positive spectrum if any effect
-/--	In the negative spectrum if any effect
+/-/--	Range of possible scores
LT	Long Term
MT	Medium Term
ST	Short Term
P	Permanent
T	Temporary

Source: following Fischer & Phylip-Jones (2007)

Table 2.3 Symbols for assessment matrix

Type of resource	Assessment Criteria	Impact duration
Air quality	--	n/a
Cultural	-/--	T
Ecological	-/--	T
Water resources	-/--	T
Land use	-/--	T
Soils and geologic	-/--	T
Paleontological	-/--	T
Transportation	--	n/a
Visual	-/--	T
Socioeconomics	--	n/a
Environmental justice	--	n/a
Hazardous materials and waste management	-/--	T
Acoustics (noise)	-/--	T

Source: own elaboration based on Spellman (2015)

Table 2.4 Framework for assessment - Site evaluation impacts

Noise (special mention)

It should be kept in mind that the noise generated and discussed here refers to that generated during all phases of wind turbine operation. Based on the observations of experts during the operation of wind farms around the world, it may be said that turbine-generated noise can be characterised as ranging from the swooshing sound of rotating rotor blades to a deep, bass-like hum produced by a single operating wind turbine.

Using a calibrated sound pressure level (SPL) decibel (dB) measuring device, Spellman has, for instance, determined that the wind turbine-generated noise monitored and measured varied depending on the size of the turbines, their location, and the distance away from the turbine or wind farm. Nonetheless, the noise produced has the potential to escalate into a severe nuisance for small, local populations. This impact alone can have detrimental effects on a wide range of related aspects including health and property values.

Excessive amounts of noise in the wind farm environment (and outside of it) cause many problems for people, including increased stress levels, interference with communication, disrupted concentration, and, most importantly, varying degrees of hearing loss. Exposure to high noise levels also adversely affects quality of life and increases accident rates.

2.5.2.2 Wind energy construction impacts

Typical activities during the wind energy facility construction phase include ground clearing (removal of vegetative cover), grading, excavation, blasting, trenching, vehicular and pedestrian traffic, and drilling. Activities conducted in locations other than the facility site include excavation/blasting for construction materials such as sands and gravels, as well as access road construction.

Table 2.5 shows the assessment of potential impact of the construction phase.

Type of resource	Assessment Criteria	Impact duration
Air quality	-/--	T
Cultural	-	T
Ecological	-	LT
Water	-	T
Land use	-	T/LT
Soils and geologic	-	LT/P
Paleontological	-	T/P
Transportation	-	T
Visual	-	T
Socioeconomics	+/-/--	T
Environmental justice	-/--	T
Hazardous materials and waste management	-/--	T
Acoustics (noise)	-	T

Source: own elaboration based on Spellman (2015)

Table 2.5 Framework for assessment - Construction impacts

Ecological resources (special mention)

Ecological resources that could be affected include vegetation, fish, and wildlife, as well as their habitats. Adverse ecological effects during construction could be caused by the following:

- Erosion and runoff
- Fugitive dust
- Noise
- Introduction and spread of invasive vegetation
- Modification, fragmentation, and reduction of habitat.
- Mortality of biota (i.e., death of plants and animals)
- Exposure to contaminants
- Interference with behavioural activities

Site clearing and grading, along with construction of access roads, towers, and support facilities, could reduce, fragment, or dramatically alter existing habitat in the disturbed portions of the project area. Ecological resources would be most affected during construction by the disturbance of habitat in areas near turbines, support facilities and access roads. Wildlife in surrounding habitats might also be affected if the construction activity (and associated noise) disturbs normal behaviours, such as feeding and reproduction.

2.5.2.3 Wind energy operations impacts

Typical activities during the wind energy facility operations phase include turbine operation, power generation, and associated maintenance activities that would require vehicular access and heavy equipment operation when large components are being replaced. Potential impact from these activities are presented below, by the type of affected resource.

Table 2.6 shows the assessment of potential impact of the operation phase.

Type of resource	Assessment Criteria	Impact duration
Air quality	--	n/a
Cultural	-/--	P
Ecological	-	P
Water	-/--	T/LT
Land use	-	P
Soils and geologic	-/--	T/LT
Paleontological	-/--	T/LT
Transportation	-/--	T
Visual	-	P
Socioeconomics	+/-/--	P
Environmental justice	-/--	LT
Hazardous materials and waste management	-/--	T
Acoustics (noise)	-	P

Source: own elaboration based on Spellman (2015)

Table 2.6 Framework for assessment - Operations impacts

Ecological resources (special mention)

During operation, adverse ecological effects could occur from:

1) Disturbance of wildlife by turbine noise and human activity.
2) Site maintenance (e.g., mowing).
3) Exposure of biota to contaminants.
4) Mortality of birds and bats that collide with the turbines and meteorological towers.

During the operation of a wind facility, plant and animal habitats could still be affected by habitat fragmentation due to the presence of turbines, support facilities, and access roads. In addition, the presence of an energy development project and its associated access roads may increase human use of surrounding areas, which could in turn impact ecological resources in the surrounding areas through:

a. Introduction and spread of invasive vegetation.
b. Fragmentation of habitat.
c. Disturbance of biota.
d. Increased potential for fire

What is more, the presence of a wind energy project (and its associated infrastructure) could also interfere with migratory and other behaviours of some wildlife.

2.5.2.4 Wind energy impacts on wildlife

Finding from recent research clearly indicate the need to better address noise-wildlife issues. As such, noise impact on wildlife should clearly be included as a factor in wind turbine siting, construction and operation.

It should also be stressed that service roads built to perform maintenance and preventive maintenance, such as inspections of components, servicing items on a regular basis, and replacing consumable items at or before a specified age are utilised by light and heavy trucks and other vehicles on a routine basis, no matter the location. Thus, the larger the wind farm, the greater the access - consequently, the more traffic, the more noise. All access vehicles, including helicopters used to transport parts and personnel, produce noise, in some cases a considerable noise.

Given the mounting evidence regarding the negative impacts of noise on birds, bats, and other wildlife, it is important to take precautionary measures to ensure that noise impacts at wind facilities are thoroughly investigated prior to development. Noise impacts on wildlife must be considered during the landscape site evaluation and constructions processes.

Following the plan provisions established by the U.S. Fish and Wildlife Service (USFWS, 2013), Spellman claims that, as research specific to noise effects from wind energy further evolves, these findings should be added to conservation plan guidelines and utilised to develop technologies and measures to further minimise noise impacts on wildlife (Spellman, 2015).

2.5.2.5 Wind energy impacts on human health

Although the operation of a wind turbine or wind turbine farm does not directly impact human health, it is also true that factors such as stress and loss of sleep contribute to health problems for some residents living close to the installations.

It has been widely reported that wind turbines are creating sounds and vibrations that can be sensed by people up to 10 miles away. Besides, low frequency noise and infrasound (sound that is less than 20 Hz) appear to be the problem. The problem that have been reported is commonly called wind turbine syndrome, which is the disruption or abnormal stimulation of the inner ear's vestibular system caused by turbine infrasound and low-frequency noise. Symptoms of *wind turbine syndrome* include the following:

- Sleep problems;
- Headaches;
- Dizziness;
- Exhaustion, anxiety, anger, irritability, and depression;
- Problems with concentration and learning;
- Tinnitus (ringing in the ears).

Along with the turbine noise annoyance generated by mechanical and aerodynamic factors – the feeling of resentment, displeasure, discomfort, dissatisfaction, or offense that occurs when noise interferes with someone's thoughts, feeling, or daily activities (Concha-Barrientos et al., 2005) – there have been complaints about rhythmic light flicker causing intermittent shadows known as *shadow flicker* or *flickering shadows*.

Another increasing complaint being heard concerning wind turbine noise generation is related to high levels of low-frequency noise over years of exposure. This problem is called *vibroacoustic disease* (VAD). The clinical progression is insidious, and lesions are found in many systems throughout the body.

To sum up, it is considered appropriate to include the impacts compiled by Lima, Ferreira, & Vieira (2013). As a result of their overall literature survey, the most pertinent environmental and human effects of wind farms are listed as follows:

- Landscape and visual impact perception;
- Shadow flicker impact perception;
- Electromagnetic interferences impact perception;
- Noise emission impact perception;
- Wildlife impact perception;
- Land occupation and usage impact perception;
- Water resources impact perception;
- Air quality and carbon footprint impact perception;
- Socio-economic impact perception;
- Architectural or archaeological patrimony impact perception.

As a special section integrated in the previous summary, a series of issues and restrictions associated with wind energy development are presented, but not limited to the following:

Socio-ecologic			
Key issues	**Objectives**	**Criteria**	**Indicator**
Environmental degradation / Natural heritage & habitats	To reduce effects on the environment: minimise loss and disturbance of areas with high biodiversity (protected areas, natural reserves, national parks etc.).	Loss of habitat and associated biological impacts	Location of natural protected areas
		Loss of forest mass	Location of forest areas
		Interference with hydrological processes	Distance to water bodies
			Distance to water ways
		Bird collision	Bird migration route
Urbanisation	To avoid construction on built-up area.	Existing housing development	Distance to residential
Proximity to rail roads	To avoid construction on rail roads.	Railway network	Distance to railways
Recreational areas	To avoid construction on recreational areas.	Recreational areas outline	Distance to recreational areas
Air traffic safety	To avoid construction on the airport.	Province airport(s)	Distance to airport
Archaeological & architectural heritage	To avoid construction on historical places.	Location of historical places	Distance to historic sites
Distribution of industry sector	To avoid construction on industry zones.	Configuration of regional industrial sector	Distance to industries
Proximity to mining areas	To avoid construction on mining sites.	Mining sector sites	Distance to mining sites

Technical-economic			
Key issues	**Objectives**	**Criteria**	**Indicator**
Proximity to roads	To avoid construction on highways and roads.	Existing roads	Distance to roads
Proximity to power lines	To avoid construction, close to power lines.	Configuration of electric network	Distance to power lines
Wind speed/ capacity	To optimise wind speed potential.	Wind speed average in the region	Wind speed (m/s)
Monitoring	To minimise disruption to the functioning of the radar.	Radar location	Distance to radar

Table 2.7 Environmental criteria associated with wind energy projects

2.5.3 Analytical tools for strategic assessment of wind energy

With the goal of identifying how the knowledge and experience have been developed concerning analytical tools that support the processes of spatial analysis, decision-making and environmental assessment in contexts related to land use management, renewable energies, and in some cases, to wind energy; a review of relevant research works was undertaken, mainly of those found in the Scopus database. The outcomes of such review are summarised below and presented in chronological order.

Back in 1997, in their paper Jankowski et al., realised the importance of collaborative spatial decision-making, underlying that effective solutions to spatial problems require collaboration and consensus building. Thereupon, they presented a spatial decision support system for groups, called Spatial Group Choice; discussing the technical and social-oriented design guidelines adopted for the development of this tool, as well as describing the design and the implementation using a habitat restoration decision problem.

In 2007, Gamboa & Munda proposed a Social Multi-criteria Evaluation as a general framework for dealing with the problem of wind park location, using a case study. In parallel, they also underlined that management of the energy policy process involves many layers and kinds of decisions, and requires the construction of a dialogue process among many social actors, individual and collective, formal and informal, local and non-local; implying that the political and social framework must find a place in evaluation exercises.

In his paper, Geneletti (2008) aimed at improving the treatment of biodiversity assets in spatial planning by proposing an approach to map and assess biodiversity assets, and by implementing it into a planning support system (PSS) represented by a Geographic Information System (GIS) platform with a customised querying interface. The PSS was tested for a specific planning task: the screening stage of Environmental Impact Assessment (EIA). The study area was located in Trentino, an alpine region in northern Italy.

Later, Simão, Densham, & Haklay (2009), presented an interesting conceptual system framework for web-based GIS that supports public participation in collaborative planning. The framework combines an information area, a Multi-Criteria Spatial Decision Support System (MC-SDSS) and an argumentation map to support distributed and asynchronous collaboration in spatial planning. Consequently, the paper basically describes the implementation of this framework in a system for Web-based Participatory Wind Energy Planning, as a proof of concept. However, although the MC-SDSS seeks to articulate/voice views and concerns, and evaluate alternatives, functioning in a distributed and asynchronous way; this proposed platform is not capable of generating a consensus or to achieve a *convergence of opinions*[4] in real time to support spatial decision-making.

In the next contribution, Croal et al., (2010) outlined a Decision-Maker's Tool (DM Tool), designed to guide practitioners and their interdisciplinary teams through a typical SEA process. The discussion presumes that SEA is central to the PPP development process, rather than being a separate exercise; therefore, assuming that SEA should be integrated into PPP formulation and action.

Afterwards, González et al., (2011) claims in their paper that a spatial framework could especially support the specific SEA aspects of the plan-making process. Likewise, they advocate the use of Geographic Information Systems (GIS) as visual mediators of spatial knowledge, providing an effective tool for the spatial and temporal analysis of environmental impacts. They also presented a GIS-based approach to SEA applied to several development plans of differing scales in the Republic of Ireland. Finally, they confirmed that GIS have the potential to increase the objectivity and accuracy of the assessment, enhance both the understanding of environmental and planning considerations and the delivery of information, and, therefore, help to improve the effectiveness of SEA practice.

More recently, Lei & Hilton (2012) presented what they call a "spatially intelligent framework to improve the effectiveness of public participation in the EIA process". This framework proposes the integration of GIS components, data mining and mobile technology. A Web-based was also developed as a proof-of-concept information system. This study essentially aimed at designing an application prototype that can effectively present and manage EIA information to improve public participation in the EIA process. Survey questionnaires and user scenarios were designed to collect initial feedback and evaluate the effectiveness of public participation and system usability.

Finally, in their study, Gorsevski et al., (2013) presented an application of a GIS-based multi-criteria evaluation approach that uses opinions from multiple participants for assessing wind farm site suitability in Northwest Ohio, US. The multiple criteria evaluation prototype system has been intended for regional planning but also for promoting group decision making that could involve participants with different interests in the development of decision alternatives.

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[4] It is understood by convergence of opinions as "a process of *structured communication* that conveys the most competent/relevant thoughts about the subject matter, to shared conclusions as much as possible" (Pacinelli, 2008).

The proposed framework integrates environmental and economic criteria and builds a hierarchy for wind farm siting using weighted linear combination (WLC) techniques and GIS functionality. It is noted that this group-based application was developed and implemented with a group of students, who used the system in particular to assign importance and attribute weights to environmental and economic decision factors.

2.6 Setting the scene: situation of SEA in Mexico

An increasing number of countries and institutions require SEA, as it has become a useful and timely tool to reduce social and environmental impacts of PPP´s (Ahumada, Espejel, & Arámburo, 2011). Among the first countries to implement SEA were the United States in 1970, Canada in 1990, and New Zealand in 1991. As mentioned above, the European Community saw a revolution in EA with the adoption of Directive 2001/42/EC on the assessment of the environmental effects of certain plans and programmes, and with the Protocol on Strategic Environmental Assessment, formalised in 2003. The application of SEA has also been increasing in developing countries and the member countries of the Central American Commission on Environment and Development (CCAD, 2007). The World Bank has been using SEA for over twenty years, and the Canadian International Development Agency, the Asian Development Bank and the Inter-American Development Bank have been working in this field about ten years.

These agencies, as well as The Paris Declaration on Aid Effectiveness - issued within the framework of the Organisation for Economic Cooperation and Development and signed by Mexico and more than one hundred other countries in 2005 - have added further impetus to SEA design and implementation. Under the Declaration, donors and partner countries commit to strengthening the implementation of the EIA and to "develop and apply common approaches for SEA at national and sectoral level" (OCDE, 2005). These efforts to reduce global poverty focus on the Millennium Development Goals adopted in 2000, where Mexico together with 189 countries signed the Millennium Declaration (UNDP, 2000). The SEA provides a practical mechanism to move towards achieving MDG 7 on *ensuring environmental sustainability*, which seeks to integrate the principles of sustainable development into national policies and programmes.

However, despite having acceded to various international agreements, SEA has neither been formalised nor fully integrated into Mexican legislation, and it can be argued that at present Strategic Environmental Assessment *per se* does not exist in Mexico. In Mexico, the Secretary responsible for the environment sector (SEMARNAP from 1994-1999; SEMARNAT from 2000 to the present) has recognised the limitations of EIA for more than ten years, and has considered SEA a complementary instrument to the EIA, as well as a preventive mechanism of growing importance to stimulate sustainable development.

It is noteworthy that under a federal administration initiative during the 1994-2000 administration, the current Secretary (SEMARNAP, 2000) stressed the importance of taking firm steps for the development and adoption of this philosophy; acknowledged its scope and the potential areas of application; and stressed the urgent need for Mexico to create an SEA instrument of its own, taking into account international experience in the field and configuring this instrument according to Mexico's own circumstances.

Furthermore, this same authority anticipated that it might be difficult to design a unique model of SEA, because of, among other things, the complexity of the dynamic processes of decision making. However, while recognising this complexity in the design of one or more models, it was deemed essential that progress be made in this area through an approach that overcomes limitations of the current method of analysis and project-based EIA.

At the end of the six-year term from 2000-2006, SEA did qualify as a valuable tool, albeit a highly complicated one to use (SEMARNAT, 2006). It argued that in order to apply SEA it might be necessary to modify the General Law of Ecological Balance and Environmental Protection (LGEEPA) and its regulations. It was also stated that a development of methodologies and progress towards their implementation through various pilot projects was expected (neither of which materialised, however).

It also acknowledged that sufficient progress was not achieved, and it was suggested that this work be continued into the next administration, hoping for better conditions for its development. In this regard, the Environment and Natural Resources Sectoral Programme (SEMARNAT, 2007) established that SEA should be adopted, and in its objective 7.2.3 pledged to develop the methodology for its implementation, as well as running further workshops on this matter.

As part of the activities related to this challenge, the SEMARNAT, through the Environmental Impact and Risk Directorate (DGIRA), conducted in 2007 the first national course on SEA, in order to establish the conceptual and methodological bases of SEA. In 2008, as a result of the second SEA training event, a methodological proposal with the goal of implementation in a regional programme for the federal electricity sector was formulated. In 2009, in conjunction with the Federal Electricity Commission (CFE), and derived from a pilot programme, this proposal - applicable to the selection of alternatives and configuration of electrical networks (CFE, 2009) - was completed and implemented.

In addition, and in order to reinforce previous attempts, the DGIRA itself developed a political-technical document to define and present Strategic Environmental Assessment as a new tool for environmental management in Mexico[5] (DGIRA, 2010).

[5] It is noted that during the review of the study, a number of important inconsistencies and limitations were found in terms of content and structure. The beginning of the document suggested a promising work, but some approaches are diffused, and final recommendations neither promote the breaking down of existing bureaucratic barriers, nor drive important changes in the laws and related regulations.

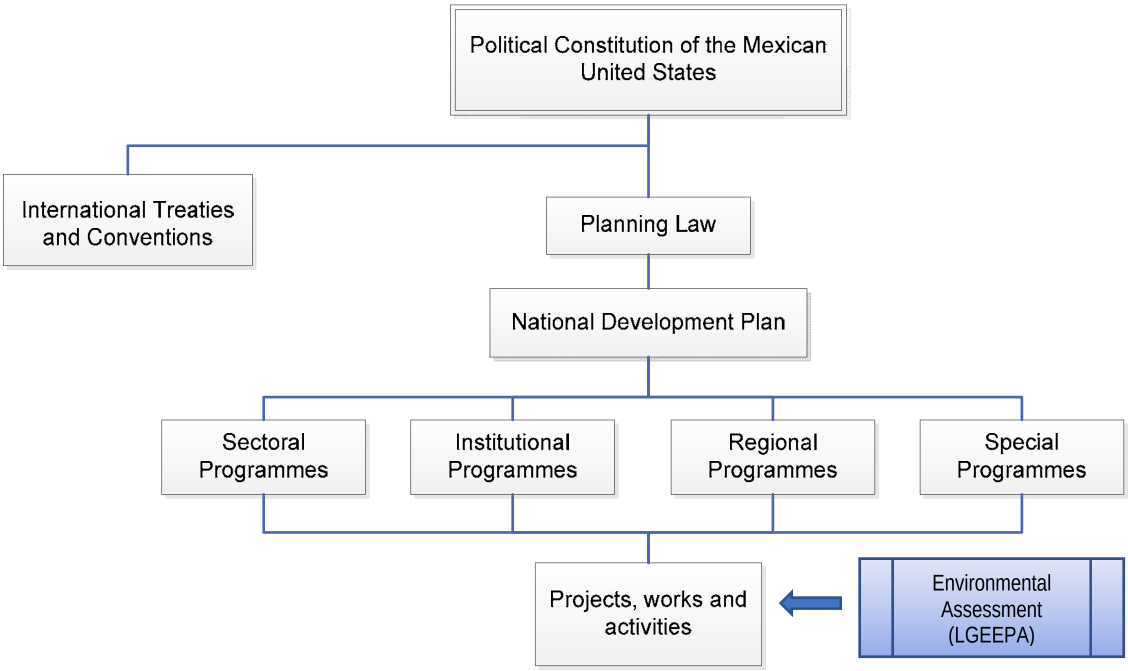
Subsequently, in this context Ahumada (2011) addressed the current state of the relationship between environmental assessment and development planning in Mexico, and proposed a methodological framework for conducting SEA of the National Infrastructure Programme 2007-2012 (SCT, 2007). This research work chose the National Infrastructure Plan as a case study due to its association with a portfolio of more than three hundred projects; and, given its political and strategic nature, its suitability for setting in context the scope and benefits of the implementation of SEA. It is worth mentioning that the development of the SEA process was hypothetical.

Ahumada et al., (2011) also suggest that formal and timely incorporation of environmental variables into development planning in Mexico requires an initial review and analysis of the process, which is supported by the Constitution of the United Mexican States (SEGOB, 2014) and the Planning Law (SEGOB, 2012). For the purposes of this law, democratic national planning can be defined as: the rational and systematic management of actions that lead to the transformation of the country's reality through the implementation and evaluation of the National Development Plan. This One Plan has to specify among other things: national objectives; strategy of and priorities for the comprehensive and sustainable development of the country; policy guidelines from which sectoral, institutional, regional and special programmes can be drawn up to meet such priorities; and the requirement to remaining in accordance with the provisions of the law.

In turn, these programs are made up of a series of projects with potential impact on the natural environment, which are subject to a procedure of Environmental Impact Assessment considered in the General Law of Ecological Balance and Environmental Protection (LGEEPA). Figure 2.5 outlines the hierarchical relationship of development planning in Mexico and the current scope of application of environmental assessment (i.e., to date, the implementation of environmental assessment is confined only at the project level). However, after almost thirty years of its implementation in the country, the practice of EIA as a tool for environmental assessment has failed to halt environmental degradation trends. For this reason Ahumada states that SEA should be incorporated as preventive instrument in environmental policy, reinforcing arguments for a reform of the LGEEPA (SEGOB, 2013), given the importance of defining the relevant competences on this matter, determining which strategic decisions to focus on, establishing a reference procedure for application, and drawing up methodological frameworks or guidelines that permit its development.

It is also worth noting other studies endorsing the formalisation of SEA in Mexican legislation. For instance, Luján Alvarez, Olivas García, & Magaña Magaña (2004) highlight that strategic evaluation should be considered as a fundamental action in sustainable development programmes, aimed at assess the changes that have to be made in order to achieve such development. In his paper Palerm (2005) discusses how SEA could have been an effective tool to implement the sustainable development and environmental integration discourse of the Mexican Government. Bravo et al., (2007) propose the use of SEA as a tool to foster cross-cutting coordination between the different competent authorities in order to formulate, apply, evaluate and follow up on ecological and territorial regulations.

In addition, Montañez-Cartaxo (2014) reports the actions carried out to include SEA into the state-owned electric utility of Mexico as known as CFE. That with the aim of promoting the incorporation of sustainability into the decision-making process of the company.



Source: adapted from Ahumada (2011)

Figure 2.5 Hierarchical display of development planning in Mexico and the current scope of application of environmental assessment

On the other hand, it is striking to observe that the Federal Government itself, having recognised the absence of SEA in the country's legal framework, hence the existing gap regarding the consideration of environmental concerns in the formulation of plans and programmes, in the most recent update of its EIA legal instrument called Environmental Impact Statement, MIA by its acronym in Spanish, (which is nowadays available to the public) argues that:

> In the conceptualisation which covers the LGEEPA, the MIA-R (MIA in Regional modality) is also a *sort of SEA* that allows the prediction of cumulative and synergistic impacts at regional level of the plans and programmes of urban development, and ecological regulations of the territory (SEMARNAT, 2016) .

In my opinion, the above statement is rather a question of interpretation that can be subject to debate, and does not exempt the country from the failure to materialise SEA and the incorporation of the dimensions of sustainability into PPP making, strategic planning, and decision-making process.

2.7 SEA for renewable energy development in Mexico

Mexico stands out globally for ambitiousness of its alternative energy generation objectives. Its Law for the Use of Renewable Energy and Financing the Energy transition requires that by 2024, 35% of energy generation must come from alternative energy source (SENER, 2008). This calls for increased and accelerated use of renewable energy sources, leading to both greater energy security and environment sustainability. This also requires a diversification in energy sources and reduced consumption of fossil fuels, resulting in reduced greenhouse gas emissions.

The country is blessed with a high renewable energy technical potential which, properly used, makes achievement of this objective entirely possible. For example, over most of its territory, Mexico has the world's highest levels of solar irradiance: double that of Germany, the country with the highest installed photovoltaic power. Most of Mexico's geothermal power comes from an area known as "Cinturón de Fuego", making Mexico the world's fourth largest producer of geothermic energy, and this while using a mere 10% of its resources. Mexico's rivers provide huge potential for hydroelectric power, and solid waste and agroforestry potential remains largely untapped. In addition, Mexico has many regions with steady prevailing winds which are appropriate for high capacity factor wind farms (SENER, 2014a).

As can be seen, technological and social evolution towards an economy based on alternatives to fossil fuels has become an issue of great importance in Mexico, since it is increasingly clear that the energy consumption model of last decades is completely unsustainable due to the exhaustion of non-renewable fossil energy resources and the effect of this consumption on climate change. Undoubtedly, we are witnessing an energy generation revolution with regards to both non-renewable and renewable sources (Koeppel & Fischer, 2013). Concerning this topic, Mexico, like several other newly industrialised nations, is steadily expanding its renewable energy capacity and building new facilities to meet its renewable energy goals. Nevertheless, as noted in Geißler's research (2013), which in turn builds on on the observations made by Bagliani, Dansero, & Puttilli (2010); Chiabrando, Fabrizio, & Garnero (2009); Johnson et al., (2004); Tsoutsos, Frantzeskaki, & Gekas (2005), decentralised energy generation such as wind farms or solar plants, although beneficial for climate protection, can however result in unavoidable impacts on other natural resources.

In the light of the foregoing, impact assessments are employed as a means of consideration of environmental effects of renewable energy expansion. As underlined by Geißler (2013), with the increase of existing and planned renewable energy generation facilities in a country, the call for strategic-level impact assessments becomes louder; in particular as cumulative effects of many individual projects need to be considered to ensure a sustainable development of renewables (Jay, 2010; Stemmer, 2011).

Hence, Geißler also encourages us to implement Strategic Environmental Assessment, which enables such cumulative impact assessment (Athanas & McCormick, 2013; Canter, 1999; Dalal-Clayton & Sadler, 2005) and furthermore allows for a broader discussion of alternative actions (Athanas & McCormick, 2013) and earlier public involvement in decision making (Eales & Sheate, 2011) than current impact assessment on the project level (Geißler, 2013).

Accordingly, it is recognised that climate change and security of energy supply are primary sustainability issues in current policy development, and an energy systems shift towards renewable energy sources is therefore urgent. However, unless environmental impacts of such a shift are carefully taken into account, imposed resource and land use changes may counteract other sustainability goals, such as preserving biodiversity and ecosystem services (Pang, Mörtberg, & Brown, 2014). In the same vein, these authors point out that, since both climate change and biodiversity are increasingly seen as being of highest priority, there is a need for an integrated approach for addressing these issues that can take both energy and environmental impacts into account.

Strategic Environmental Assessment represents the window of opportunity for that straightforward approach that the country urgently needs, providing a comprehensive framework for PPP integration, and playing a key role in helping to achieve more environmentally sustainable practices and processes related to the aforementioned transformation.

2.8 Wind energy in Mexico

As mentioned earlier, Mexico is a privilege place in terms of wind energy as its geography allows the existence of areas with high potential for the development of this form of electricity generation. In that connection, the country's energy sector is in a period of profound change, catalysed by the comprehensive Energy Reform the government has enacted since 2013 (IEA, 2016). Various regulatory frameworks have promoted the implementation of such reform and driven this recent evolution of renewable energy policy. Foremost among these is the Law for the Use of Renewable Energy and Financing the Energy transition (LAERFTE). This law has been adopted to comply with signed international agreements on GHG emissions reduction and establishes a set of non-fossil fuel generation goals of 35% for 2024, 40% for 2035, and 50% for 2050.

Likewise, the LAERFTE was meant to define and regulate the use of renewable energy mainly for power generation. It mandated the Secretary of Energy (SENER) to develop a National Renewable Energy Inventory to provide reliable information on renewable energy resources in Mexico. It also established a set of instruments like the Special Programme for the Use of Renewable Energy, an Energy Transition Strategy and a Fund for the Energy Transition and Sustainable Energy Use (IRENA, 2015).

Based on the results reported in the National Renewable Energy Inventory[6] (INERE), it can clearly be seen that the Mexican power system largely relies on conventional energy sources (SENER, 2014b). Fossil fuel power generation capacity dominates the system with some 70.18% (41,240 MW) of total installed capacity. Yet renewable power already has a capacity share of 29.82% (17, 519 MW). This included hydropower (70.95% or around 12.43 GW), wind (18.23% or 3.19 GW), geothermal (5.25% or 920 MW), biomass (4.87% or 863 MW) and solar PV (0.7% or 123 MW), (see Figures 2.6 and 2.7).

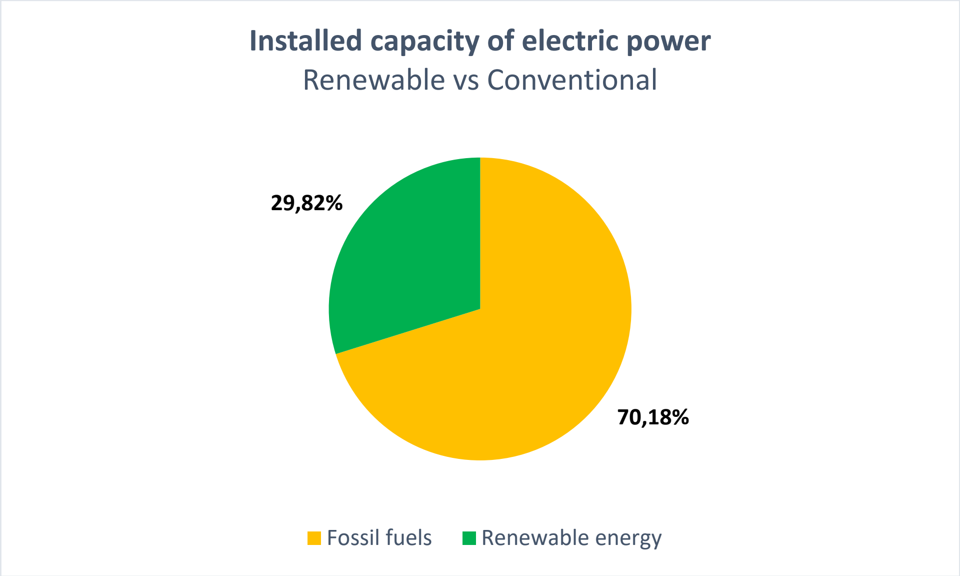


Figure 2.6 Installed capacity of electric power in Mexico

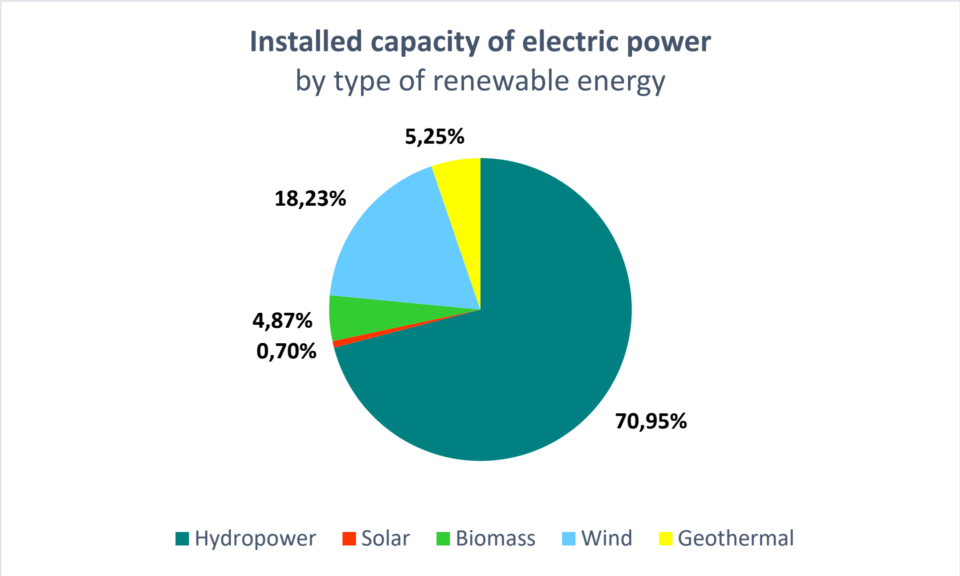
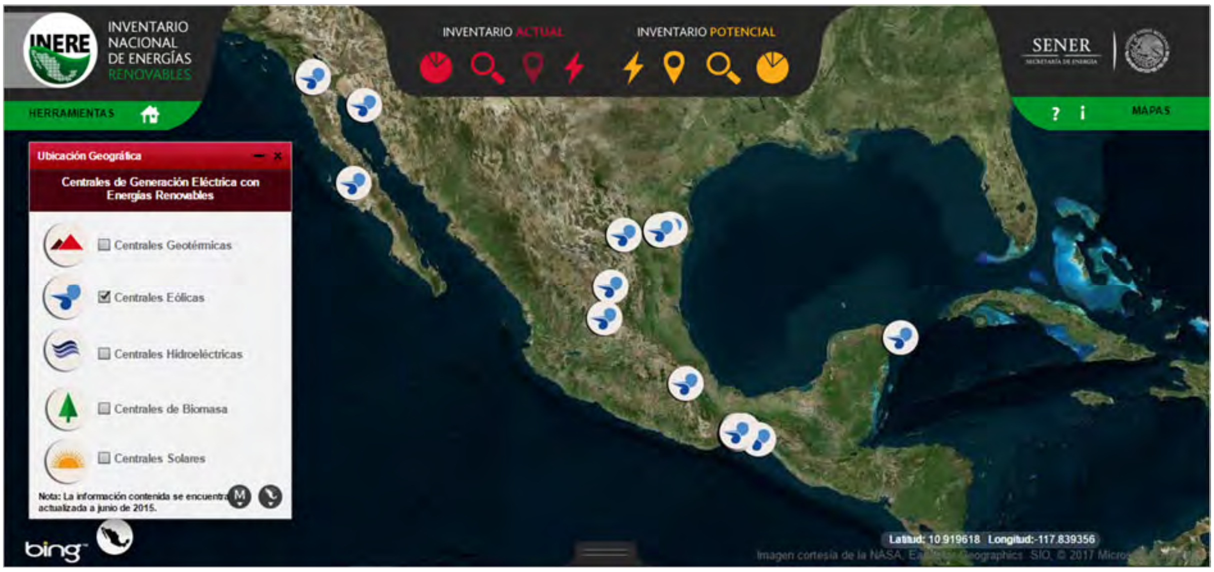


Figure 2.7 Installed capacity of renewable energy in Mexico

[6] The contained information was updated on June 2015.

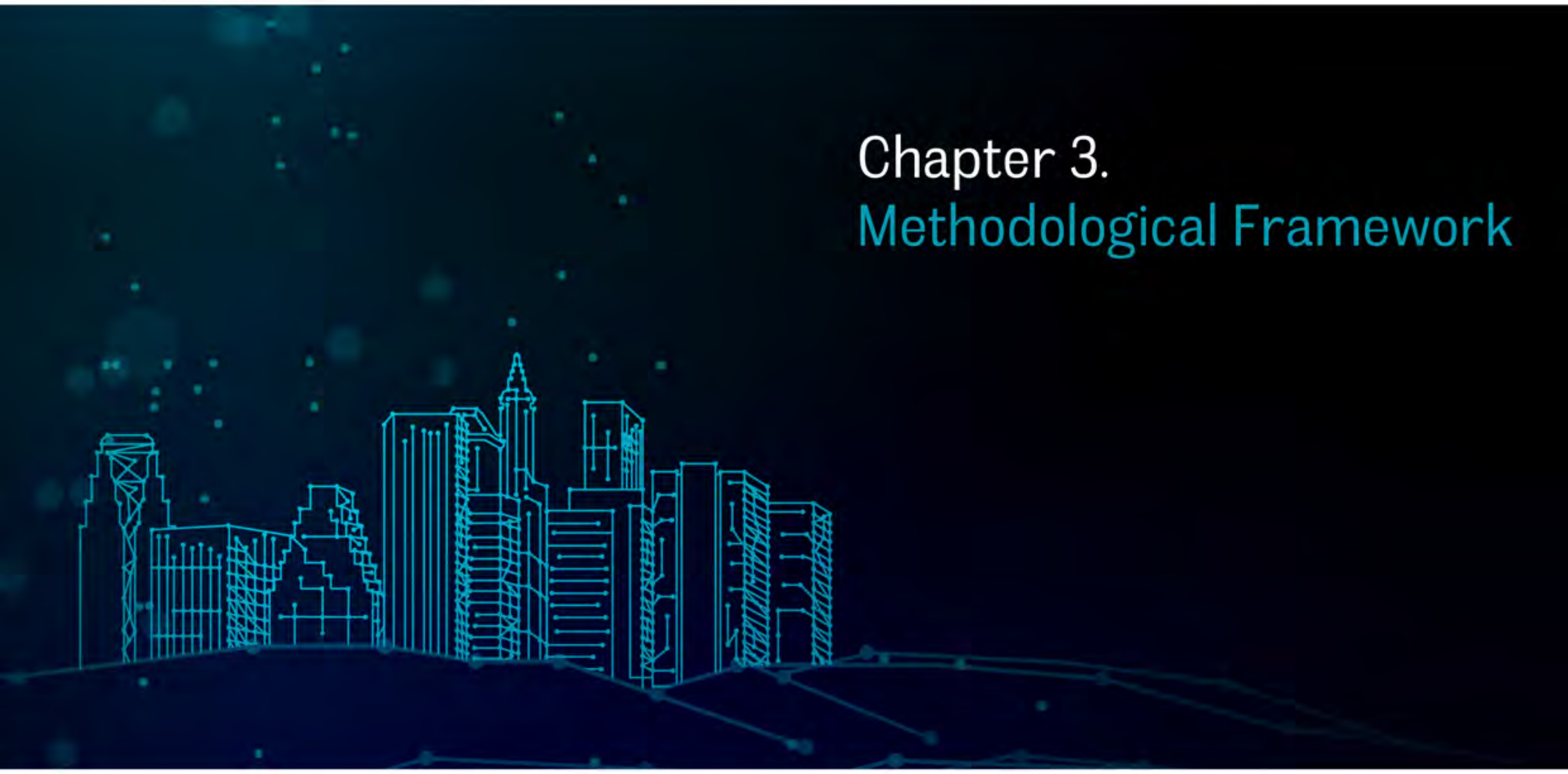
With respect to wind power infrastructure, it is worth mentioning that Mexico has 36 wind farms, which together have an installed capacity of 3,193.10 MW. These plants are located in the states of Oaxaca, Baja California, Quintana Roo, Tamaulipas, San Luis Potosí, Sonora, Chiapas, Jalisco, Nuevo León and Puebla. Figure 2.8 shows a schematic depiction of the location of wind power plants installed in the country. The information listing all the wind farms in the country, indicating the installed capacities of each one, is presented in Appendix A.

In addition, according to the study on wind potential in Mexico conducted by the multinational company PwC in collaboration with the Mexican Wind Energy Association (AMDEE), Mexico has a wind potential greater than 50 GW with plant capacity factors above 20%, whilst the Institute of Electrical Research (IIE) has also carried out studies obtaining similar results (CFE, 2014). However, these studies are based on the assumption that only 10% of the total area with potential is usable for the installation of wind farms. This is due to orographic, environmental and social factors as well as technical and economic feasibility (SENER, 2012).



Source: SENER (2014b)

Figure 2.8 Main locations of wind farms in Mexico



Chapter 3.
Methodological Framework

Chapter 3. Methodological Framework

3.1 Introduction

The research methodology applied in this thesis has been drawn up in accordance with the precepts of *Design Science Research*, whose purpose has been geared towards the development of an artifact that consists of the proposal of a context-specific Strategic Environmental Assessment (SEA) approach combined with an innovative Group Spatial Decision Support System (GSDSS) specially adapted for the selected study case. Moreover, a supplementary methodology underpinned by a documentation research was used to come up with needs, opportunities and scope of the intended artifact.

The general research process is summarised through the main following activities[1]:

a. Bibliographic review and compilation via consulting scientific databases and other sources of information such as books, search engines, technical documents, legal instruments and normative provisions.
b. Generation of empirical data, initial insights, research questions and assumptions.
c. Affiliation to prestigious international organisations specialised in the research topics.
d. Continuous PhD cross-training.
e. Access to specialised training on the research topic.
f. Fieldwork.
g. Development of thesis.

List of required means necessary for carrying out of this research:

- Laptop computer with access to the Internet.
- Desktop computer/dedicated server with access to the wired Internet and public IP address.
- Uninterruptible Power Supply (UPS).
- Open source GIS software.
- Geospatial database.
- Development frameworks.
- Reference manager software.
- Office productivity software.
- Cloud storage and file hosting service.
- UPC doctoral rooms.
- Library.

[1] Activities ‘d’, ‘e’ and ‘f’ are detailed in Appendix B “Doctoral Candidate Activity Report”.

This research took place mainly in the *Departament de Projectes d'Enginyeria* in coordination with the *Departament d'Expressió Gràfica a l'Enginyeria* which are located in the *Escola Tècnica Superior d'Enginyeria Industrial de Barcelona* (ETSEIB), Universitat Politècnica de Catalunya BarcelonaTech (©UPC). Diagonal Ave. 647, Postcode 08028, Barcelona.

An important part of this research[2] was also conducted through a doctoral stay for a period of four months at the the *Faculty of Geo-Information Science and Earth Observation (ITC)* of the *University of Twente (UT)* as well as in an additional three months at the *Environmental Assessment and Management Research Centre* of the University of Liverpool, as part of a strategic collaboration with this institution.

3.2 Design science research methodology

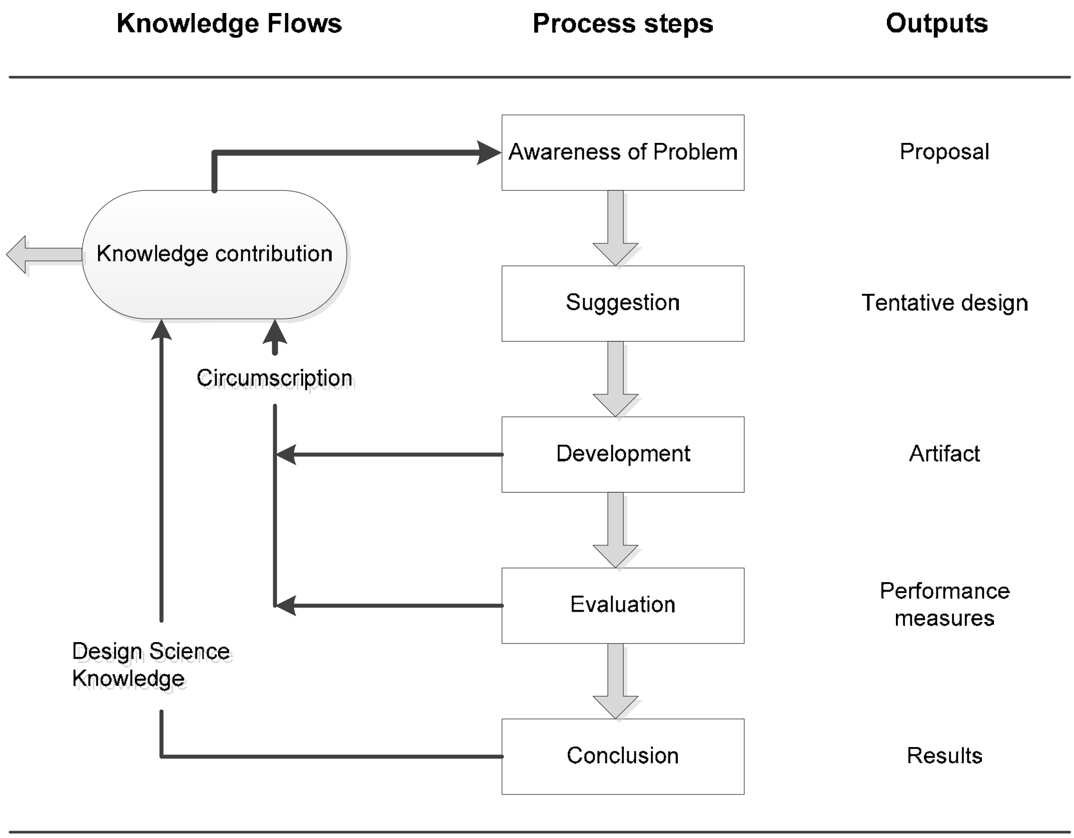
Design science research is a set of synthetic and analytical techniques and perspectives for performing research in Information Systems (IS). Design science research involves the creation of new knowledge through design of novel or innovative artifacts (things or processes) and analysis of the use and/or performance of such artifacts along with reflection and abstraction to improve and understand the behaviour of aspects of IS. Such artifacts include but certainly are not limited to constructs, models, frameworks, architectures, design principles, methods, instantiations, design theories, algorithms, human/computer interfaces, and system design methodologies or languages (Vijay K. Vaishnavi & Kuechler, 2013).

In this thesis, in order to develop the aforementioned artifact, the model suggested by Vijay K. Vaishnavi & Kuechler (2013) was adopted. Figure 3.1 shows the process that takes place during a design science research cycle.

According to these authors,

> In this model, the research begins with *Awareness of a problem*. Design science research is sometimes called "Improvement Research" and this designation emphasises the problem-solving/performance-improving nature of the activity. *Suggestions* for a problem solution are abductively drawn from the existing knowledge/theory base for the problem area (Peirce, 1931). These suggestions may, however, be inadequate for the problem or suffer from significant knowledge gaps (which make the problem a research problem). Using existing knowledge, an attempt is made at creatively solving the problem. The solution -a tentative design- is used to implement an artifact in the next phase shown as *Development* in the diagram.

[2] The activities corresponding to such stages are included in Appendix B "Doctoral Activities Summary".



Source: Vijay K. Vaishnavi; & Bill Kuechler (2013)

Figure 3.1 Design Science Research Process

Partially or fully successful implementations are then evaluated according to a functional specification (sometimes implicit) during the *Evaluation* stage. *Development*, *Evaluation*, and further *Suggestion* are frequently iteratively performed in the course of the research effort. The basis of the iteration, the flow from partial completion of the cycle back to *Awareness of the Problem*, is indicated by the *Circumscription* arrow. Conclusion indicates the end of a research cycle or the termination of a specific design science research project. Knowledge contribution resulting from new knowledge production is indicated by the arrows labelled: *Circumscription*[3], and *Design Science Knowledge*. The *Circumscription* process is especially important to understanding design science research process because it generates understanding that could only be gained from the specific act of construction (Vijay K. Vaishnavi & Kuechler, 2013).

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3 Circumscription is a formal logical method (McCarthy, 1980) that assumes that every fragment of knowledge is valid only in certain situations. Further, the applicability of knowledge can only be determined through the detection and analysis of contradictions—in common language, the design science researcher learns or discovers when things do not work "according to theory" (Vijay K. Vaishnavi & Kuechler, 2013).

All the above has led to the implementation in this work of the Design Science Research Methodology (DSRM) proposed by Peffers, Tuunanen, Rothenberger, & Chatterjee (2007). Using the table with the format and structure presented in Geerts (2011), the first column in Table 3.1 lists the six activities that make up the DSRM as a nominal sequence. Column two further describes each of the activities in detail: What to do? The third column links the knowledge base with the different activities: How the activities are executed? The arrows on the left side emphasise the importance of iteration as part of the DSRM. They show that activities such as Evaluation and Communication often result in revising the artifact's objectives and design.

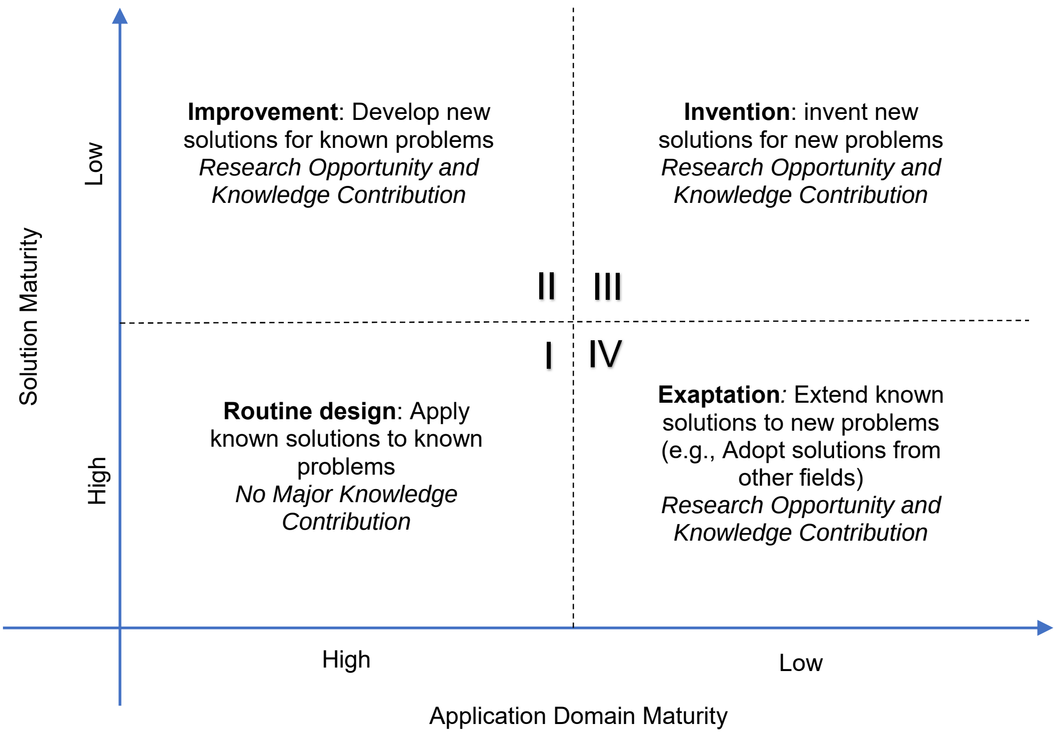
DSRM activities	Activity description	Knowledge base
Problem identification and motivation	What is the problem? Definition of the research problem and justification of the value of the proposed solution. *The execution of this activity is described in detail in Chapter 1 of this thesis.*	Understand the problem's relevance and its current solutions and their weaknesses.
Define the objectives of a solution	How should the problem be solved? In addition to general objectives such as feasibility and performance, what are the specific criteria that a solution for the problem defined in step one should meet? *The execution of this activity is described in detail in Chapters 1 and 2 of this thesis.*	Knowledge of what is possible and what is feasible. Knowledge of methods, technologies, and theories that can help with defining the objectives.
Design and development	Create an artifact that solves the problem. Creation of constructs, models, methods, or instantiations in which a research contribution is embedded. *The implementation of this activity is described in detail in Chapters 3 and 4 of this thesis.*	Application of methods, technologies, and theories to create an artifact that solves the problem.
Demonstration	Demonstrate the use of the artifact. Prove that the artifact works by solving one or more instances of the problem. *The implementation of this activity is described in detail in Chapter 4 of this thesis.*	Knowledge of how to use the artifact to solve the problem.
Evaluation	How well does the artifact work? Observation and measurement of how well the artifact supports a solution to the problem by comparing the objectives with observed results. *The implementation of this activity is described in detail in Chapters 4 and 5 of this thesis.*	Knowledge of relevant metrics and evaluation techniques.
Communication	Communication of the problem, its solution, and the utility, novelty, and effectiveness of the solution to researchers and other relevant audiences. *The present thesis is used as means of communication of this artifact.*	Knowledge of the disciplinary culture.

Source: Adapted from Geerts (2011) and Peffers et al. (2007)

Table 3.1 Design Science Research Process Methodology

Regarding the contributions of this methodology, Figure 3.2 shows a reference framework whereby Gregor & Hevner (2013) highlight the aspects in which Design Science Research gives relevance to the knowledge generation based mainly on the nature of the designed artifact as well as the solution and application domain maturity.

In this figure, it is displayed a 2 × 2 matrix of research project contexts and potential DSR research contributions. The x-axis shows the maturity of the problem context from high to low. The y-axis represents the current maturity of artifacts that exist as potential starting points for solutions to the research question, also from high to low. Basically, this framework focuses attention on the knowledge start-points (e.g., maturities) of the research project to support a clearer understanding of the project goals and the new contributions to be achieved. It is important to note that -for proper reading of the graph- when discussing in terms of knowledge, they are referring to that within the IS/IT knowledge bases, not the knowledge to reference disciplines outside IS (Gregor & Hevner, 2013).



Source: Gregor & Hevner (2013)

Figure 3.2 DSR Knowledge Contribution Framework

Taking the previous into account, the contribution of this thesis can be considered as an improvement (quadrant II), since according to the problem discussed in Chapter 1, and once in-depth understanding of the context has been acquired, a novel solution (artifact) was sought for a known problem *(in the form of an alternative methodological approach for spatial environmental evaluation of renewable energy scenarios, and a more effective strategic planning process)*. In fact, many of the artifacts obtained with DSR are found in this quadrant of improvement research, and such improvement or refinement may be in the form of positive changes in effectiveness, productivity, quality, competitiveness, inclusion, and so on and so forth.

Finally, and by way of conclusion of this section, the Design-Science Research Guidelines established by Hevner, March, Park, & Ram (2004) are presented in Table 3.2 which have been used to guide the development of this research project, and are displayed in this case as a checklist.

Guideline	Description	
1: Design as an artifact	☑	It has been produced an artifact in the form of a context-specific SEA method integrated with a prototype of a GSDSS.
2: Problem Relevance	☑	Through this tool, it has been developed a technology-based solution to an important and relevant research problem.
3: Design Evaluation	☑	The utility and quality of the artifact designed have been rigorously demonstrated via a well-executed application of a real case study based on empirical assessment.
4: Research Contributions	☑	Clear and verifiable contributions have been provided.
5: Research Rigor	☑	This research relies upon the application of a rigorous method in both the construction and implementation of the design artifact. The artifact was developed taking into consideration the problem definition, research questions, objectives and a theoretical framework on the basis of a documentary investigation as well as based on models, guidelines, criteria and recommendations issued by institutions and researchers of renowned experience and worldwide prestige. Validation was carried out through one case study with real-life application.
6: Design as a Search Process	☑	The search for an effective artifact has required utilising available means to reach the desired ends while satisfying laws in the problem environment. The proposed artifact is based on a theoretical-technological support and was developed through available resources such as Spatial Decision Support Systems, the spatial version of the Delphi method, SEA international principles, etc.
7: Communication of Research	☑	This research has been presented effectively during its development and evolution, both to technical-oriented as well as management-oriented audiences, through the participation in specialised congresses and conferences mentioned earlier. Besides, the present doctoral thesis is used as means of communication of this work and its final results.

Source: own elaboration following Hevner et al. (2004)

Table 3.2 Checklist for Design Science Research Guidelines

As discussed above and stressed by Hevner et al. (2004), design science is inherently a problem-solving process. The fundamental principle of design-science research from which these seven guidelines are derived is that knowledge and understanding of a design problem, and its solution is actually acquired in the building and application of the artifact *per se*.

In addition, it is important to underline that in this methodology, the design and evaluation of the artifact play an essential role. As for the method of evaluation, a specific case study was selected and experimental field work was conducted. For the specific part related to the use in this research of the technological tool (GSDSS), it should be emphasised that previous simulation activities were not necessary, since the functionality of this platform has already been successfully validated in Castillo-Rosas et al., (2017); Di Zio, Castillo Rosas, & Lamelza (2016); Castillo Rosas et al., (2016) and Castillo Rosas et al. (2015).

At this point I want to point out a fundamental aspect with regard to the proposed artifact:

Unlike the evaluation made by Castillo Rosas (2016), in the present research, the evaluation phase of the artifact does not seek the validation and test of the proper operation of the system used. Here, the artifact is distinct and its objectives of another nature, since the proposal covers the implementation of a WEB-GSDSS platform (with a tailored interface expressly developed for the problem environment) as well as its integration with a generic SEA method. A very different context indeed.

3.3 Documentation research

Documentary research is the use of outside sources (texts and documents), in order to support the viewpoint or argument of an academic work (Shafique & Mahmood, 2010). According to Scott (2006), examples of documents as source materials include: government publications, newspapers, certificates, census publications, novels, film and video, paintings, personal photographs, diaries and innumerable other written, visual and pictorial sources in paper, electronic, or other hard copy form.

In the light of the above, a literature searching analysis was performed using diverse resources available in the digital library of the UPC. In particular, using Metalib® system, several searches were conducted via different search engines and scientific databases such as Scopus, ScienceDirect, Web of Science, Scielo, Google Scholar, UPC Commons, TDX, and the Directory of Open Access Journals (DOAJ).

Table 3.3 shows the combination of keywords applied and the total results for each search criteria. For informational purposes, no temporary, regional or research areas filters were applied. However, it should be pointed out that search keywords in different languages (mainly English, Spanish and Catalan) were used. From the table above, a total of 327575[4] results were obtained.

[4] This analysis was performed based on the search results obtained in June 2014.

Article Title, Abstract, Keywords, Authors	***Results***
Assessment of Sustainable Projects	5795
Environmental Impact Assessment	106784
Strategic Environmental Assessment	7644
Strategic Sustainability Appraisal	186
Sustainable Development Indicators	13631
Environmental Policy	190833
SEA + EIA	562
SEA + PPP	101
SEA + Policy formulation	146
Strategic Environmental Assessment + Protocol	298
Strategic Environmental Assessment + European Union	228
Strategic Environmental Assessment + Developing countries	201
Strategic Environmental Assessment + public sector	136
Strategic Environmental Assessment + renewable energy	143
Strategic Environmental Assessment + Mexico	29
Strategic Environmental Assessment + renewable energy + Mexico	1
Environmental Impact Assessment + Mexico	761
Environmental Impact Assessment + renewable energy + Mexico	17
Evaluación Ambiental Estratégica	49
Evaluación Ambiental Estratégica + energías renovables	0
Evaluación Ambiental Estratégica + México	4
Evaluación Ambiental Estratégica + energías renovables + México	0
Evaluación de Impacto Ambiental + México	26
Evaluación de Impacto Ambiental + energías renovables + México	0

Table 3.3 Information search criteria

Figure 3.3 depicts the search criteria for some of the most significant terms and their combinations. Firstly, it can be seen that there is an important difference in Mexico between the research on Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (EIA research has been conducted more intensively). Secondly, standing in contrast with the comparable results for SEA research in the European Union vs developing countries, the graph reveals SEA research in Mexico to be virtually non-existent. With the exception of a few publications, there is essentially no scientific production of SEA in Mexico. This, combined with the extensive EIA research base presents a tremendous and unprecedented opportunity for SEA growth, and for overcoming this sustainability handicap. From this figure, it can also be seen that there is huge potential for development in environmental assessment research.

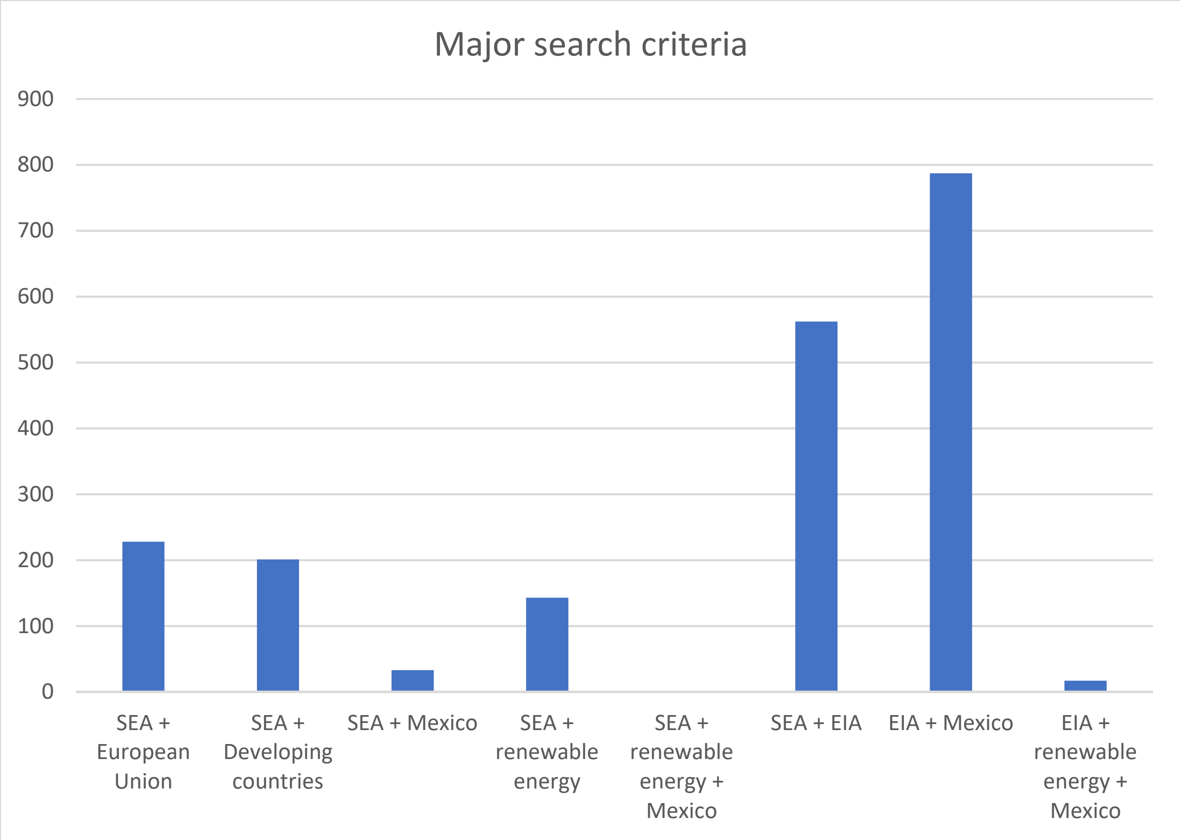


Figure 3.3 Information search criteria

Another insight is reflected in the following graph analysis. Using publicly available historical Google search query data[5] for two main concerning concepts*: Environmental Assessment & Renewable Energy* (limited to Mexico's territory), which were obtained from Google's "Google Trends" service[6], it was possible to visualize a similar evolution for both series. Figure 3.4 shows the interest over time in the two selected terms, ranging from January 2008 to January 2016. It is worth mentioning that in the second quarter of 2008 there was a significant increase in the interest of the user population on environmental assessment. It is highly likely that such interest was generated due to the great controversy around the megaproject "Escalera Náutica", in the Mexican region of *Mar de Cortés,* led by the federal government at that time. The next three years there were peaks and drops. However, at the start of 2012 began a steadier trend which has continued until early 2016, possibly due to discussion and the final implementation of the energy reform introduced at the end of 2013 (although it is clearly seen that interest in renewable energy is greater than the one over environment assessment).

[5] Google search query data has been used in a range of studies, including the monitoring of disease outbreak, economic forecasting, and the prediction of financial trading behavior (Cannarella, 2014).

[6] The Google search query data is retrieved from the "Google Trends" service and reports the relative number of Google search queries for a given search term. In other words, those numbers on the graph reflect how many searches have been performed for a particular term, relative to the total number of searches done on Google over time. They do not represent absolute search volume numbers, because the data is normalized and presented on a scale from 0-100. Each point on the graph is divided by the highest point, or 100. When Google does not have enough data, 0 is shown. Moreover, a downward trending line means that a search term's popularity is decreasing. It does not mean that the absolute, or total, number of searches for that term is decreasing (Google, 2016).

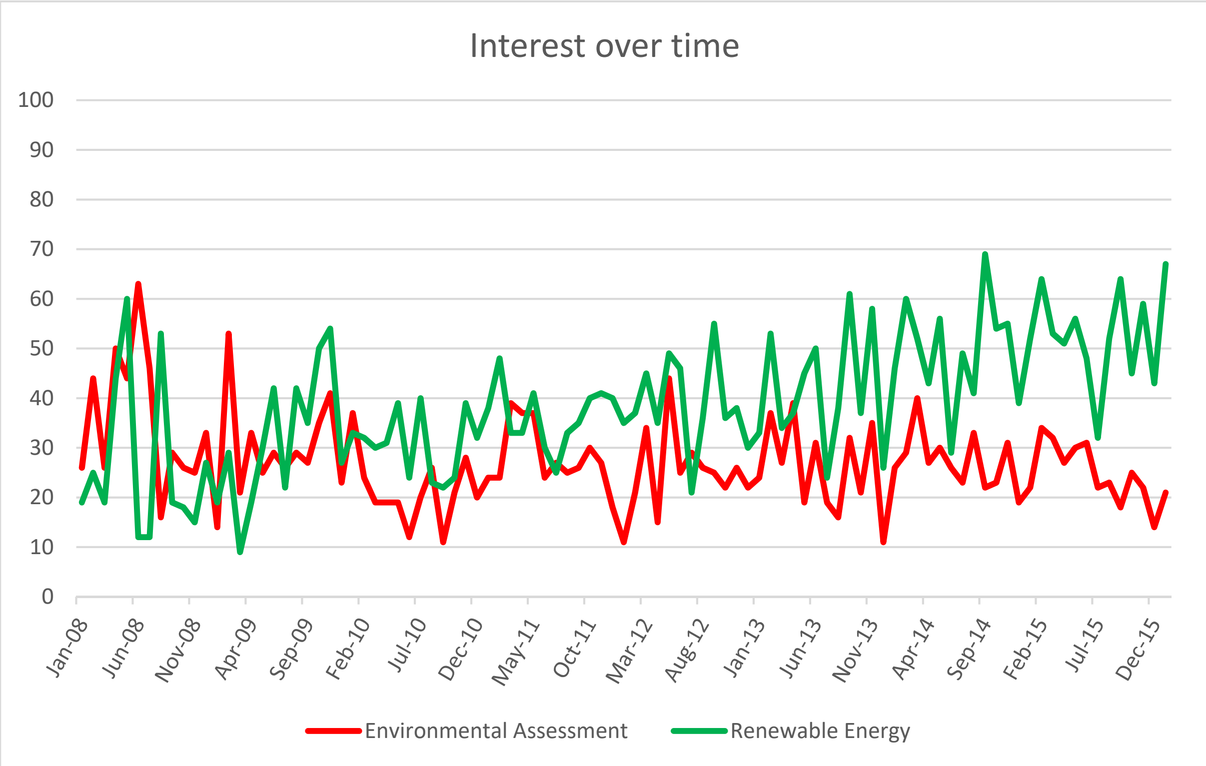


Figure 3.4 Interest over time on EA & RE

An analysis of a Scopus document search using the term *Strategic Environmental Assessment (SEA)*, from which three graphs have been selected as a representative sample, is presented below. Figure 3.5 shows the total number of documents for this query by year. Basically, this chart displays that in the last twenty-five years there has been a gradual and substantial increase in scientific production of SEA. Figure 3.6 presents the total number of documents for this query by Author. Finally, Figure 3.7 provides the total number of documents for this query by Subject Area. Essentially, this Pie Chart is interesting because also shows how the research topic fits into different fields of science.

Additionally, via the application *CiteSpace* (Chen, Ibekwe-SanJuan, & Hou, 2010) for analysing trends and patterns in scientific literature, figures 3.8, 3.9 and 3.10 depict three merged networks for the term *SEA*, each comprised of several networks corresponding to snapshots of consecutive years. In the selected demo project examples[7], the overall time spans cover from 1996 to 2003 and 1996 to 2013. Each merge network characterises the development of the field over time, showing the most important footprints of the related research activities. Each dot represents a node in the network. In this case, the nodes are cited references and lines which connect nodes are co-citation links. Each network is divided into a series of co-citation clusters. These clusters are labelled with index terms from their own citers. The merged networks provide an innovative overview of the co-citation networks.

[7] The demo project contains a dataset on publications about *Strategic Environmental Assessment* research. These bibliographic records were retrieved from *Web of Science*®.

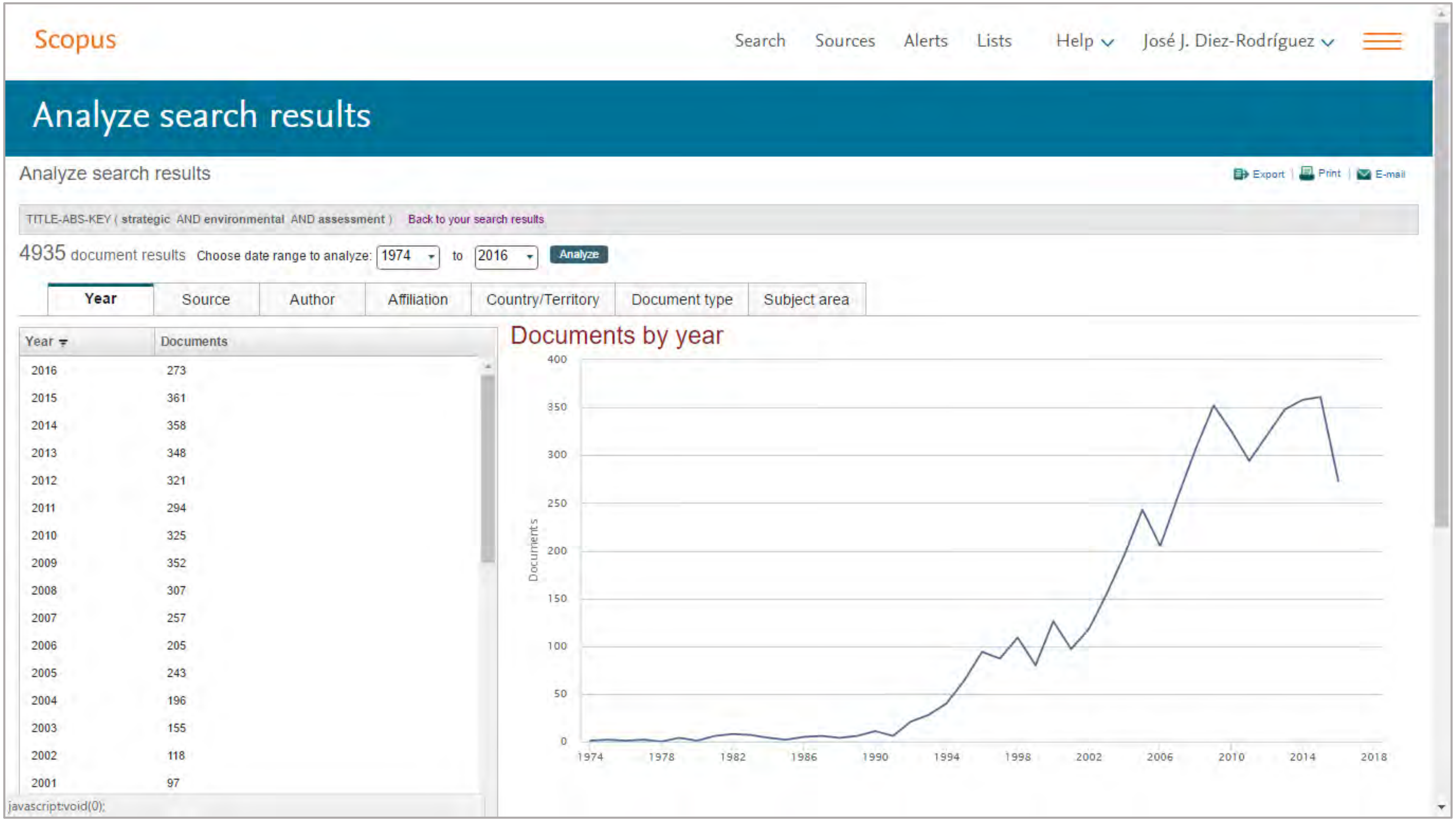


Figure 3.5 Analysis of results - scientific production by year

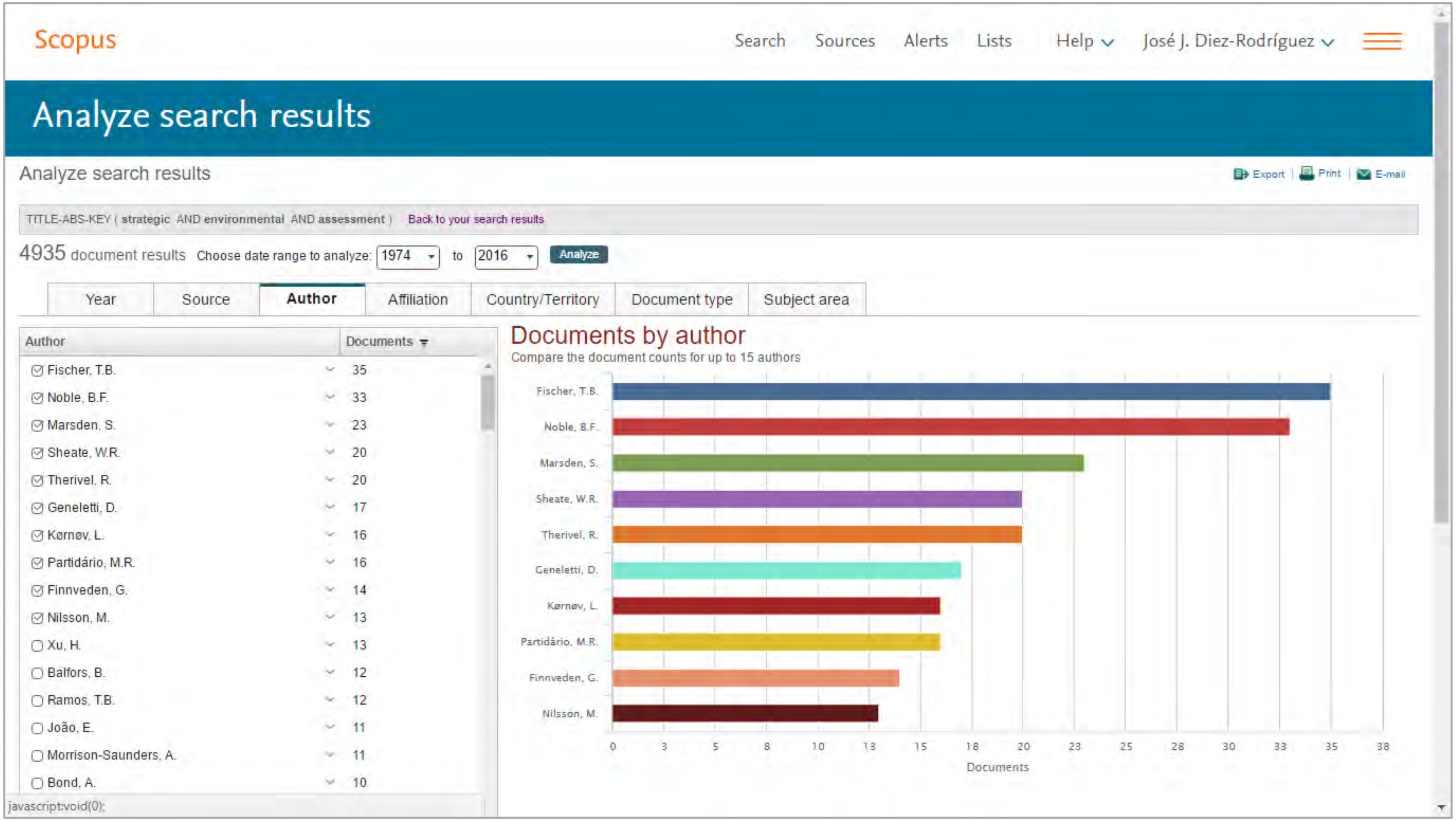


Figure 3.6 Analysis of results - scientific production by author

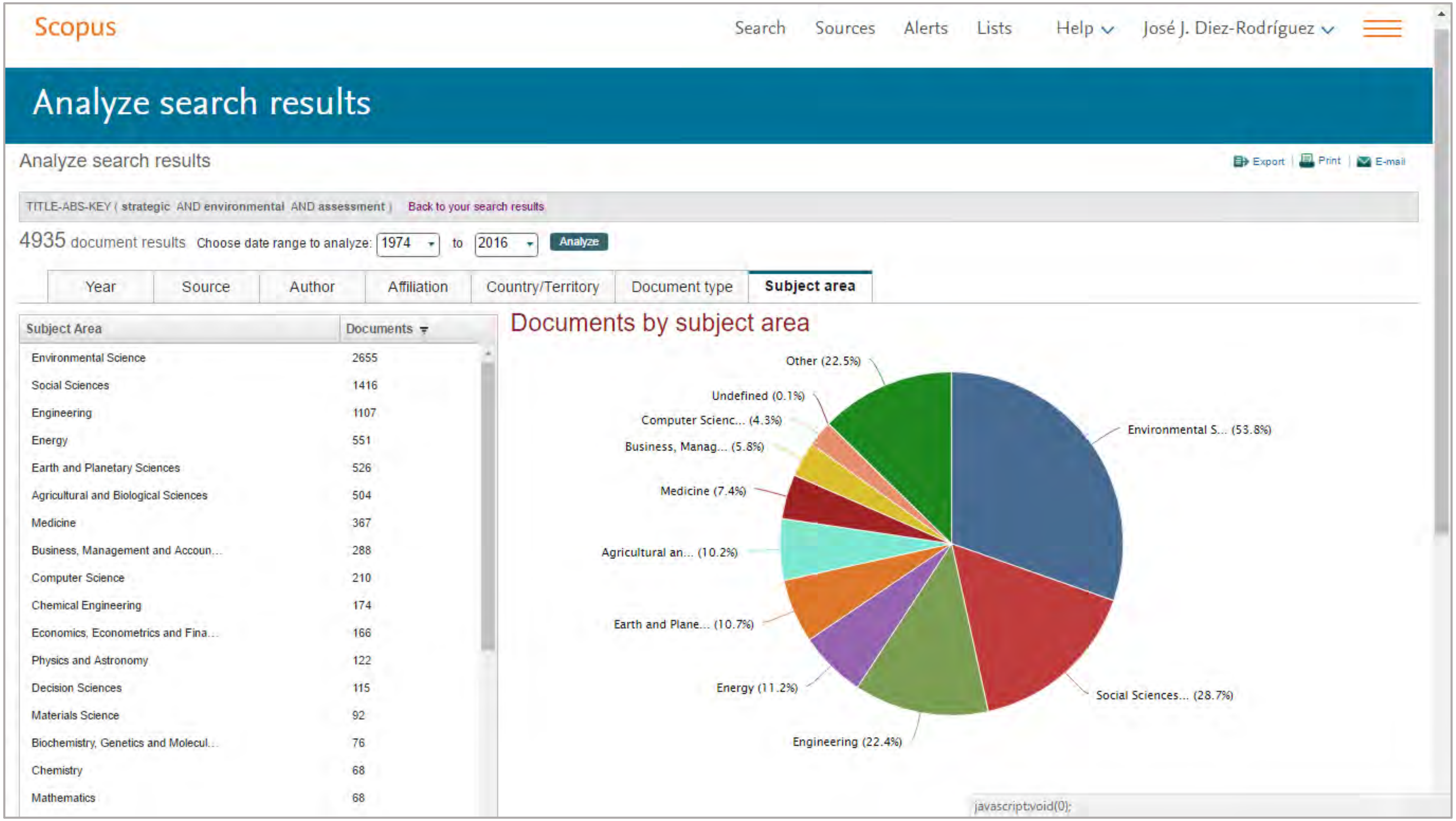


Figure 3.7 Analysis of results - scientific production by subject area

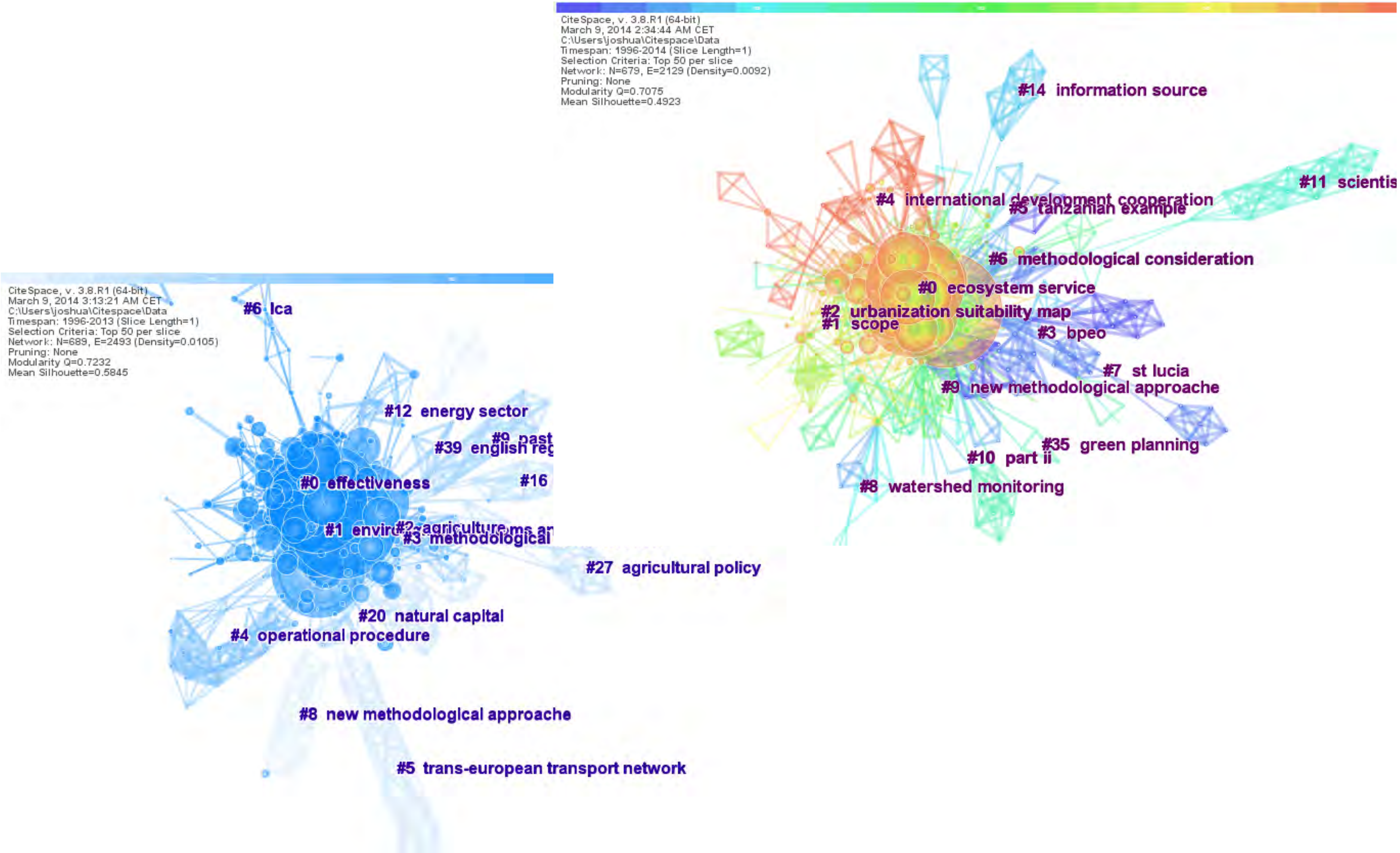


Figure 3.8 *CiteSpace* merged networks

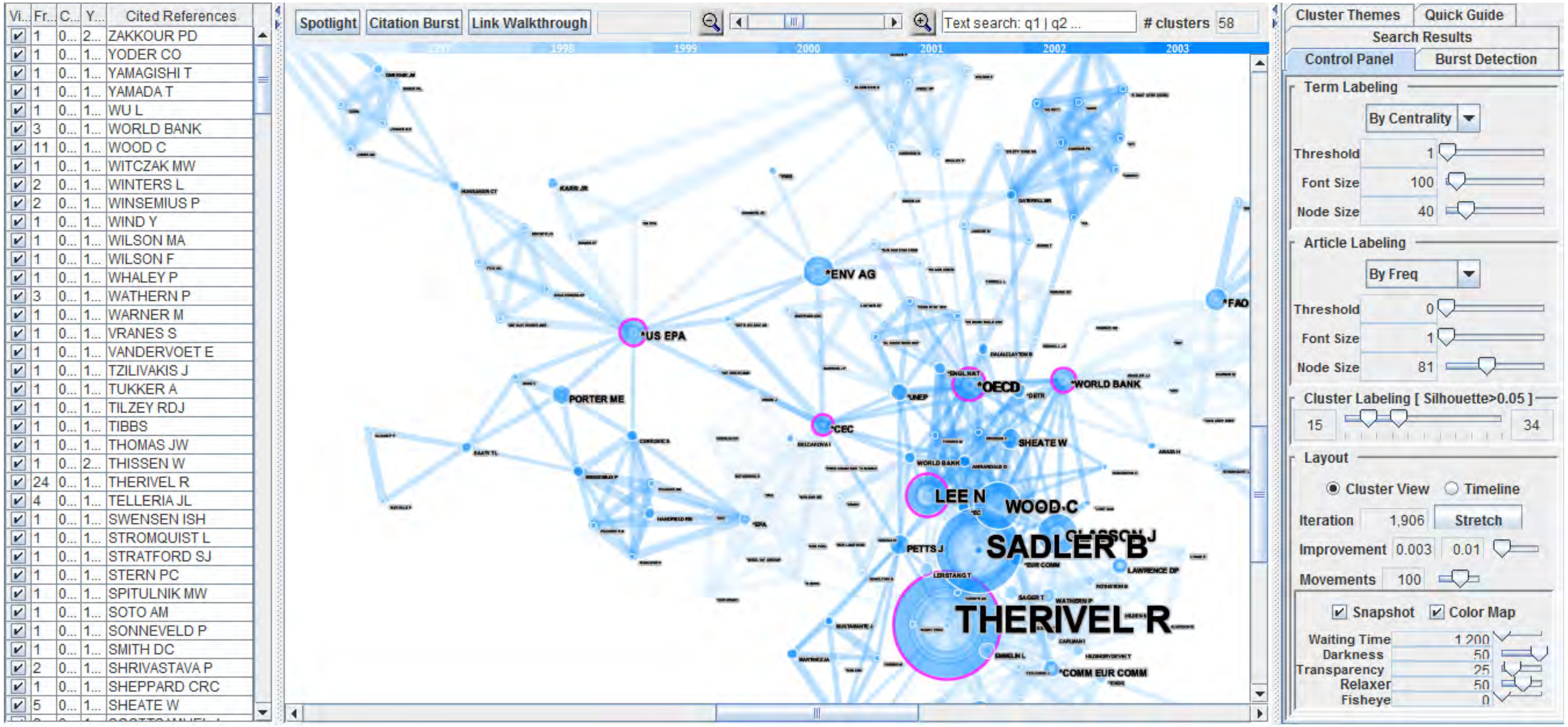


Figure 3.9 Zoom-in on the co-citation networks

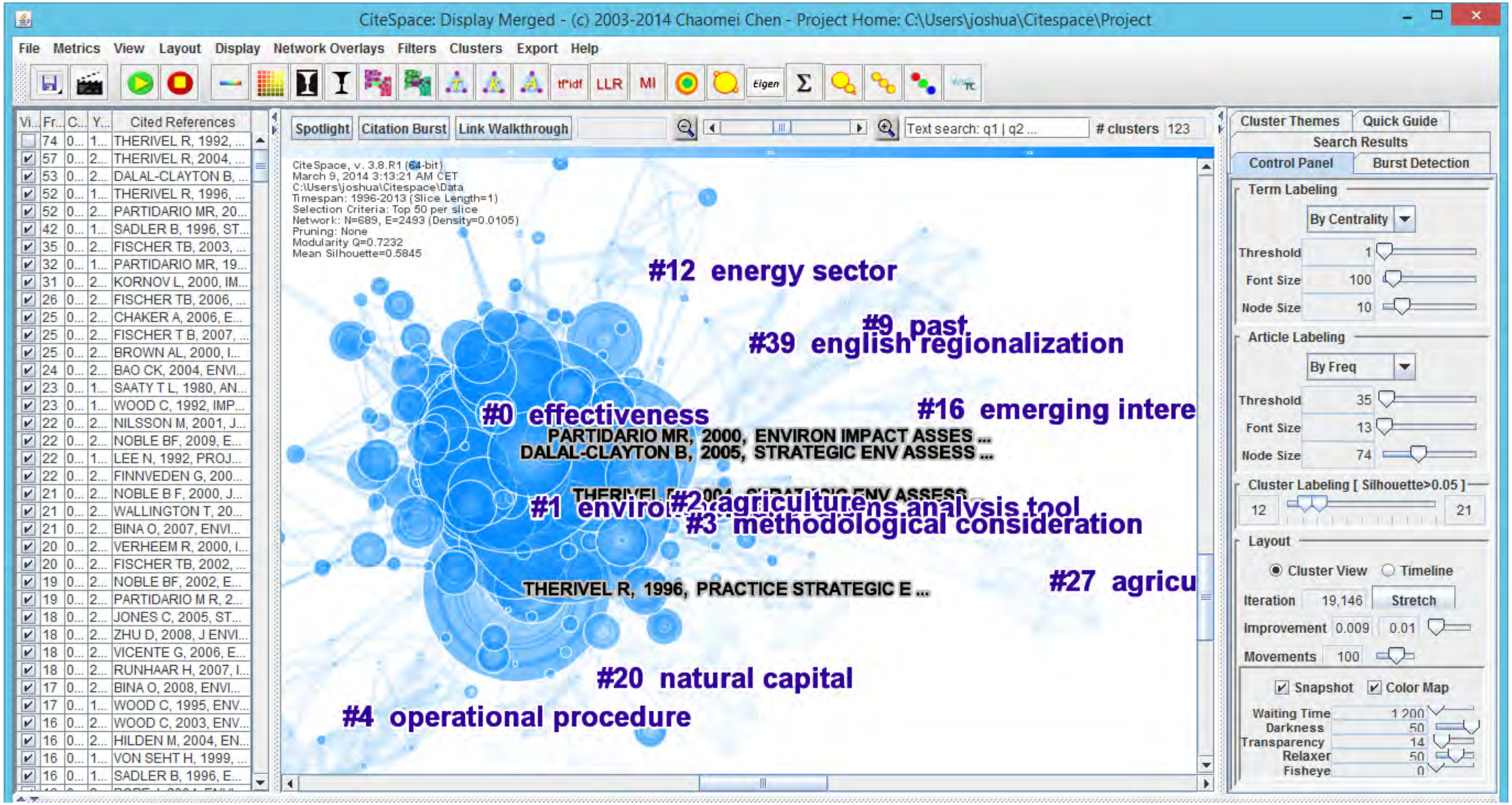


Figure 3.10 Visualisation window of the co-citation networks showing authors and labels

Chapter 4.
Empirical Assessment

Chapter 4. Empirical Assessment

4.1 Introduction

The conduction of this experimental phase has been aimed at the implementation of a GSDSS-based SEA framework, fostering a consensus process consolidated from a convergence of views within the scope of spatial planning for energy transition i.e., site location of new wind energy developments. It is well known that consensus-based decision making could result in informed decisions that are more fully supported, and more easily implemented.

In particular, concerning the technological aspect, it has been proposed the use of a prototype of a Web Group Spatial Decision Support System application named SIGIC[1]. The tool can provide outputs that could be used as inputs for generation of spatio-temporal *scenarios*[2] for infrastructure project planning on renewable energy, through *future trends*[3] obtained from an interdisciplinary geo-consensus of a multidisciplinary group of experts. This can be possible without strict dependency on a spatial analysis based on a single cognitive stance as well as the availability of geospatial data (Castillo Rosas et al., 2015; Castillo Rosas, Núñez Andrés, et al., 2015).

Nowadays, the only way to accomplish the above is through retrospective modelling, which is the most widely used in classical science. Nevertheless, it is known that scenario building is possible based on intersubjective knowledge of individuals, which is applied especially in social sciences (among which are *Prospective, Forecasting* and *Foresight* activities), recognising above all, the cognitive perspective and the incidence of subjectivity in decision-making (Jelokhani-Niaraki & Malczewski, 2012; Khatri & Ng, 2000; Leung & Andersson, 2013; Ravitch, 1989; Schoemaker, 1995; Schwenk, 1988), stressing that on those issues related also to the recent Geoprospective and Territorial Intelligence, the Geospatial System of Collective Intelligence can be a useful tool that leads to thought-provoking contributions.

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[1] This application is explained in more detail in the following section. However, a comprehensive description of the system, mainly in terms of its design, architecture, functionality and coding has been developed in Castillo-Rosas, Diez-Rodríguez, et al., (2017); Di Zio et al., (2016) and Castillo Rosas (2016)

[2] The term *scenario* is defined by the Oxford dictionary as “A postulated sequence or development of events”. Nonetheless, for the purpose of this work, a scenario is understood in the same way that was introduced into planning and decision-making by Herman Kahn in the 1950's: “A scenario is a rich and detailed portrait of a plausible future world, one sufficiently vivid that a planner can clearly see and comprehend the problem, challenges and opportunities that such an environment would present.” A scenario is not a specific forecast about the future, but a plausible description of what might occur (EU Science-Hub, 2005). Ratcliffe (2002) also points out that “scenarios are like stories built around carefully constructed plots based on trends and events”, and just as Barbanente and Khakee explain (2003), “they assist in selection of strategies, identification of possible futures, making people aware of uncertainties and opening up their imagination and initiating learning processes” (Ratcliffe, Krawczyk, & Kelly, 2006).

[3] As it can be deduced, the concept of future trends is quite complex and certainly subjective. However, the clear idea is to project whatever is intended to build or do not, based on what presumably may or may not occur in the future. That is, a structured discussion is fostered, in which is attempted to evaluate where is intended to develop a specific infrastructure, considering what may occur in a particular place or given area of study.

In other words, the objective focuses on supporting the construction of prospective alternative energy scenarios using the SIGIC application (in terms of prospective, referring to a desirable future, immediately possible). Practically speaking, here we are reasoning in general terms, and not technically of scenario building, as we are aware that scenario building is a complex process including different methods, techniques and procedures. In this case (as in any Delphi-like approach), the result of the application cannot be considered a *scenario* but it is for sure a good “starting point” for the development of a scenario.

Accordingly, this task can be perfectly embedded into the SEA stage intended to appraise, in this specific context of study, reasonable alternatives either strategic options (Partidário, 2007) for the location of renewable energy facilities, all of this so as to support spatial decision-making. Here, the assessment of alternatives could arise when a panel of experts is questioned about suitable locations for the development of structures and complex networks of renewable energies. it also occurs when each member of the panel is free to revise and modify his or her own opinion, as long as this is performed over the given period of time for analysis.

It should be taken into account that optional strategies mean those pathways which will have different environmental and sustainability implications (Partidário, 2012). Such forethought is certainly relevant and represents a key input in the decision-making process for the simple reason that these pathways will enable us to make the move towards proposed strategic objectives. It is worth recalling that the original purpose of this process stage is also to compare proposed and alternative planning options by assessment of impacts, including risks and benefits, as a basis for decision-making, highlighting a particular attention given to cumulative and synergistic effects.

In addition, it is important to acknowledge and to stress that one of the central ideas behind the selection of this platform is the need for an application of a tool in which not only collective participation in real time is possible, but equally assists in the development of future spatio-temporal scenarios, keeping in mind Partidário’s (2007) view in this regard:

> The modelling of desirable futures, through scenarios development, has a core role in this phase (Analysis and Assessment) in the identification and assessment of strategic options and, subsequently, of the proposals that shape the development strategy. The involvement of all relevant stakeholders in the discussion of the strategic risks and opportunities of the plan or programme in preparation is also a fundamental moment in this phase. […]

It is worth noting that the application responds positively to situations where there are insufficient data to perform geoprocessing, or in circumstances which are characterised by uncertainty as in the case of nonlinearity, emergency and surprise; being even useful as support to narrow, guide, verify and/or correct the results of other Spatial Analysis alternatives (Castillo Rosas et al., 2015).

Consequently, it is here where SEA and EIA principles are putting into action, since the involvement of relevant stakeholders, a transparent and adaptive planning process, and the consideration of alternative choices is promoted. Thus, attempting to use the best possible knowledge for decision and policy making, therefore improving both the (spatial) planning process and the information used in this process (ITC, 2015)

Finally, it is considered necessary to emphasise that, what this tool can do, is to help find the locations which in turn lead the development of such spatio-temporal scenarios. The outcomes shall not be considered as definitive results but as a valuable and richer information that will provide a basis for a structured decision framework, aimed at supporting more effective and efficient decision-making. Therefore, contributing to develop a better understanding of a sustainable energy transition, and improving governance in terms of energy management, and inherently a more intelligent use of it.

4.2 The Geospatial System of Collective Intelligence

The work of Jelokhani-Niaraki & Malczewski, 2015; Chang & Li, 2013; Sugumaran & Degroote, 2011; Jankowski et al., 1997 (as cited in Castillo Rosas et al., 2015) points out that Spatial Decision Support Systems (SDSS) are designed to help decision-makers to solve complex problems related to geographical space, and are mainly based on the technology of Geographic Information Systems (GIS), which together with other components can create robust systems for group collaboration. However, as emphasised by Di Zio (2016), “SDSS imply the use of tools and methods of spatial analysis that are executed by a single individual user”. He also notes that a different approach is that of Group Spatial Decision Support Systems (GSDSS), which, instead, are based on the collaboration of a group of people, often experts (Armstrong, 1994). In this family of systems fits the Geospatial System of Collective Intelligence, called SIGIC based on its Spanish acronym *SIstema Geoespacial de Inteligencia Colectiva* (Castillo Rosas et al., 2015). It is a set of hardware, software, procedures, data, and people whose purpose is to support the decision-making process in geographic complex scenarios, mainly regarding the planning, organisation and/or use of resources in a territory and is based on the consultation of groups of experts (Di Zio et al., 2016).

As Di Zio et al. describe:

> The Geospatial System of Collective Intelligence system is based on the methodology of the Spatial Delphi (Di Zio and Pacinelli, 2011), as well as the Vector Consensus model (Monguet et al., 2012). The system can store and display documents, pictures, videos, reports, maps and any other material useful for understanding the research problem and objectives to be achieved. It was designed to accommodate for different group consultation methods and different GIS data formats (points, lines, polygons). Moreover, it can also be programmed to handle simple questions, as in a classic online questionnaire.

> The SIGIC platform (v. 1.0) is based on the GETSDI Geoportal Open-Source Software (v. 3.0), a platform developed in JavaScript and PHP, which incorporates tools and functions based on OpenLayers, ExtJS, GeoExt and Proj4js. The Real-Time functions are developed with the Socket.IO Server and Node.JS. All the other methods and functionalities implemented on the SIGIC platform, are programmed and customised by the authors with JavaScript, PHP, ExtJS, Postgresql and PostGis, as well as other API services like Google Maps, OpenWeatherMap, OpenStreetMap, Twitter, Wikipedia and WebGL Earth (Di Zio et al., 2016).

In the words of Di Zio et al.:

> The first method implemented on this platform is the Real Time Spatial Delphi, which is based on *opinion-points*, as for the Spatial Delphi. However, unlike the Spatial Delphi method, there are no rounds and the Delphi procedure develops in real time, just as in the Real-Time Delphi (Gordon, 2009; Gordon and Pease, 2006). Once the research problem is defined, the experts receive the credentials to access the system and can immediately start providing *opinion-points* through a WebGIS interface. According to the study, a number of questions - *n* - appear next to the map, each with a different colour; appropriate buttons allow each expert to locate the *opinion-points* on the map, one for each question. These *n* points represent, according to the assessment of the expert, the places more suitable for the problem under study. After the positioning of each point, a dialog box opens, in which it is possible to write reasons for that choice. The first expert of the group, who starts the survey, sees on the map one circle for each question, which we call the initial circles, covering the entire area related to the question. If, for example, the study area includes two towns (*n=2*), there are two initial circles, each covering the corresponding town. After at least two opinion points for each town are given, the initial circles automatically reduce (or expand) and move, according to the algorithm of the Spatial Delphi method (Di Zio and Pacinelli, 2011).

In the same line of reasoning, Di Zio et al. (2016) continue:

> There is a window that opens when the expert gives an argument, displaying a series of information regarding the history of the points given until that moment. More precisely, for each point, there is: the argument, the date, the time, the diameter and area of the circle, and a marker. The marker (a rectangle) is a consensus indicator; it is green if the point was positioned inside the circle of convergence (indicating consensus) or red if the point was located outside (indicating dissent). Thus, the experts can see a list of useful data, in chronological order, regarding the whole process of consultation and convergence, providing tangible support in making his/her choice. This system is perfectly in line with the Real-Time Delphi because each expert can see (anonymously) the statistical synthesis and arguments of the other experts and can answer as many times as desired, changing his/her opinions as often as necessary.

> In addition to the circle of convergence and the feedback, experts can use a number of WebGIS tools to move the map, zoom in and out, measure distance and areas or visualise different types of maps, such as street maps, satellite images, land use, and so on. Presently, the system is programmed with three different languages (Spanish, English and Italian), and other languages will be loaded eventually.

Finally, they remark:

> At the end of the consultation, the system produces two types of results: *geographical* results and *non-geographical* results. For each question, the main geographical result is a *final circle*, which, if the experts converge, is small enough to represent a solution to the research problem. The *n* final circles depicted on the map are understandable by anyone and thus are immediately usable for decision support or for spatial scenario building, without any further processing. Other geographical data are all the sequences of the *opinion-points* and the sequences of the circles. Also, very important are the arguments given by the experts, which, together with a number of statistical data, constitute the non-geographical product of a survey. Once the survey ends, having the size of the initial circle and that of the final circle, we can construct, for each question, some measures of the convergence of the “spatial” opinions, namely, some quantitative indices of the consensus among the experts, which we can now call *geo-consensus*. The simplest measure is the area of the final circle (or the diameter) because the smaller the circle, the greater the geo-consensus.

An application of the Real Time Spatial Delphi through the Geospatial System of Collective Intelligence from a SEA perspective, is properly displayed and thoroughly discussed in the next section.

4.3 SEA Methodological Framework

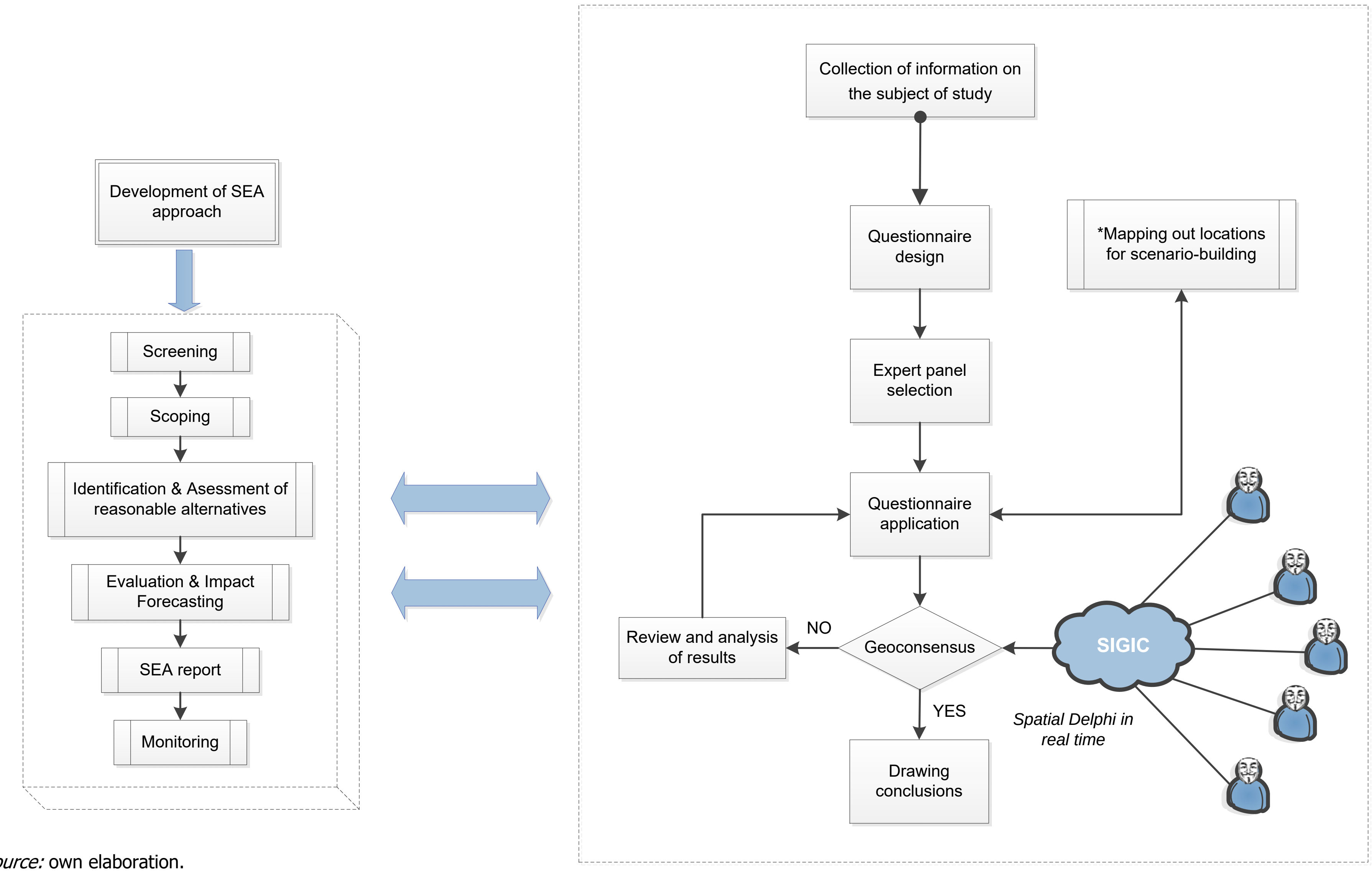
"No one SEA methodology will apply to all strategic actions and in all socio-political contexts: we must begin to think in terms of an array of SEA tools from which the appropriate one(s) can be selected to meet the needs of the particular circumstances".
(Brown & Therivel, 2000)

The following methodological framework is presented at the beginning of this section intended to organise, assemble and contextualise the main concepts and components that conform the proposed artifact in terms of SEA. The tag cloud below (Figure 4.1), which depicts some keyword metadata obtained from different scientific sources, attempts to represent that significant challenge.

Figure 4.1 SEA as an evolving question.

In order to have a deeper understanding of the scheme proposed, the principal process elements are described as follows. In this regard, a methodological framework is structured in interrelated phases in a cyclical process. This is not a recipe that applies to all cases, but a number of key driving elements for conducting a SEA. Hence that it should be considered as an interactive, flexible and adaptive process (Ahumada et al., 2011). This methodological structure is outlined in Figure 4.2 indicating the main strategic steps to undertake the collective spatial analysis proposed (right-hand side of the diagram) and its integration into the core of the SEA process (left-hand side) through the stages of *Identification & Assessment of Reasonable Alternatives* and *Evaluation & Impact Forecasting*.

It is highlighted that the methodological framework suggested follows the United Nations guidelines on mainstreaming sustainability into policymaking (UNEP, 2009), as well as considers the Impact Assessment Guidelines of the European Commission (2009), while responding the call regarding a need for more effective reasoning in decision-making (Fischer, 2007) by proactively developing possible *spatial* development options and enabling the assessment of impacts of these options.



Source: own elaboration.

Figure 4.2 SEA methodological framework

With respect to the analytical technique used for the SEA stages considered, it is pointed the choice of a public consultation route, through the application of a survey that is an integral aspect of the GSDSS platform. It should be noted that surveys allow for the collection of information on opinions, attitudes and knowledge and are widely used in SEA (Fischer, 2007). Surveys with experts, stakeholders and the public can take the form of interviews, questionnaires and emails.

In the same vein, Fischer also manifests that expert opinions on possible effects are frequently generated in SEA through surveys, particularly in situations that are complex and where the assessment is supposed to be done and at low cost. Furthermore, expert surveys may be helpful for achieving a better understanding of possible future development, particularly in situations that are marked by a high degree of uncertainty. Surveys with stakeholders allow the identification of different interests in PPP making processes.

Thus, the usefulness of the GSDSS-based SEA framework, covering a cluster of features and technology components, was empirically tested via the practical Mexican case study for site location and strategic sustainability planning of new onshore wind energy developments. This approach has been developed to meet the research objectives and address the research questions rather than to provide a conventional SEA methodology. Further details on the specific process is provided in the next section.

4.4 Step-by-step description of the process

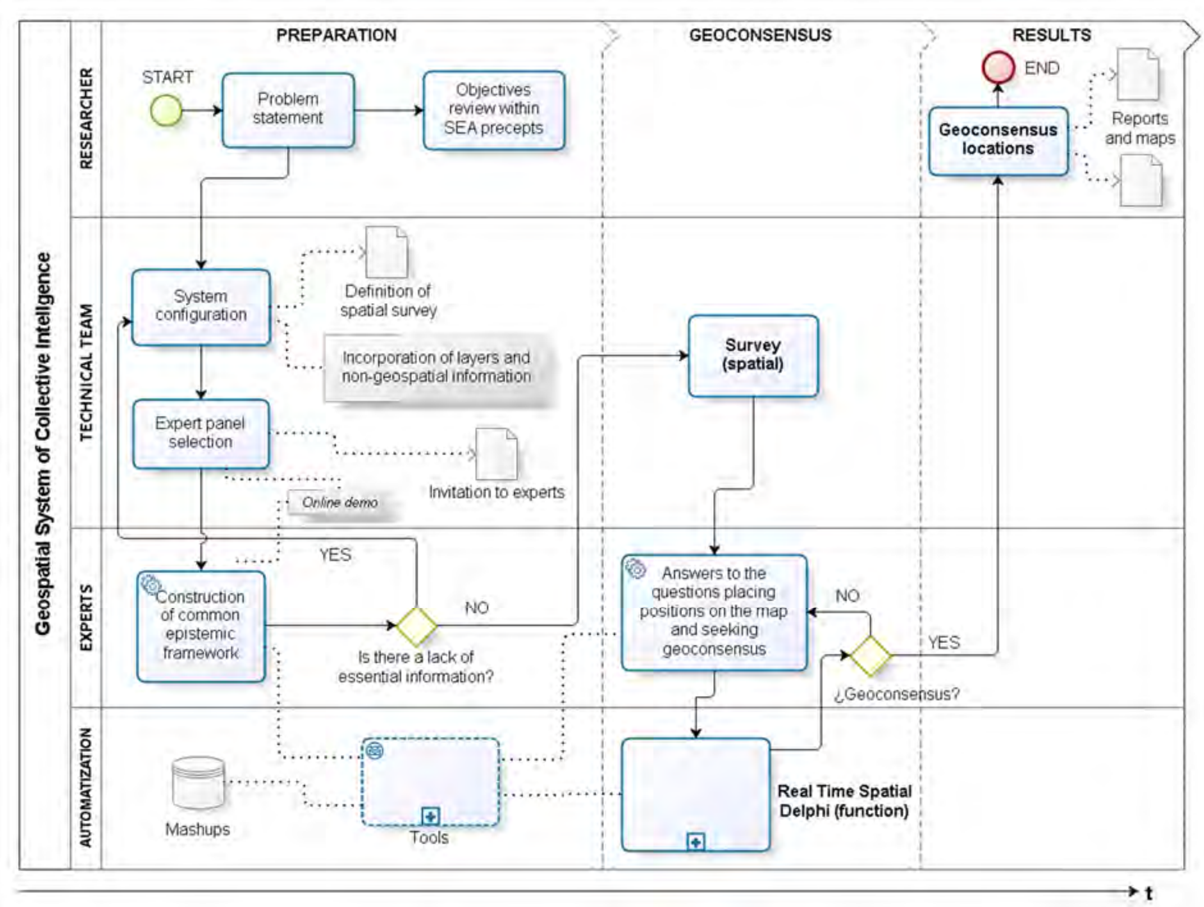
With the goal to provide a broad overview of the general workflow, and a proper description of the system implemented, in Figure 4.3 the context diagram[4] that illustrates the overall method of the collective spatial analysis for its mainstreaming with the SEA process is presented. The three main phases that compose it can be observed (preparation, geo-consensus, and results), along with the four cardinal participation elements (researcher, technical team, experts, and automations), the basic tasks and processes, as well as the logical sequence flow and main interconnections between all of them.

Preparation

a. The process began with the definition of the decision problem and the case study approach (site location of wind energy in Mexico).
b. The objectives of the analysis were reviewed in accordance with the precepts of SEA and Collective Spatial Analysis.

[4] For purposes of replication of experimentation and other related concerns, it is noted that the sequential order shown here does not necessarily have to be strictly followed. Some activities can be performed in parallel according to how the needs and opportunities are presented.

c. A spatial survey was defined and information layers (base maps and special maps) were proposed.



Source: Adapted from Castillo-Rosas et al. (2017).
Elaborated with Bizagi Modeler.

Figure 4.3 Scheme of the methodological process

d. The first stage of the system configuration and adaptation of the interface was undertaken that consisted of the registration of the questionnaire in the database as well as the integration of geospatial information, and other information of a general nature[5].

e. A selection of the group of people that would be part of the panel of experts was made following the *IAIA Public Participation Best Practice Principles* (Enserink, Connor, & Croal, 2006), adopting the participation by consultation typology proposed by Hughes (1998), and considering the stakeholder categories and types observed in Vivek et al. (2007). Note that in real terms, the case study addresses *technical participation*, since the consultation is held with experts and not with the layman.

[5] It is noted that the integrated information layers, the questionnaire, and the SEA geospatial approach itself were subjected to the judgment of experienced academics during the doctoral stays held at the Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente, and the Environmental Assessment and Management Research Centre of the University of Liverpool respectively. By doing so, a valuable feedback was obtained, that in turn resulted in an interface better adapted for an adequate analysis.

As a result, a group of candidates (all of them based in Mexico) from different target groups were formally invited, including representatives from government institutions, private industry, intergovernmental organisations, consulting sector, NGO, and academia.

In this line, people from different disciplines and diverse backgrounds, familiar with the case study and knowledgeable about the geographical area of study were included. That for the purpose of assembling *a multidisciplinary team that put forward an interdisciplinary solution*[6] (García, 2011). At the end of this process it was possible to conform an expert panel composed of representatives of various institutions as well as independent consultants (Table 4.1). Among the institutions and organisations to be mentioned are:

Confirmed participants	
United Nations Environment Programme (UNEP - Mexico)	Mexico's Representative Officer
Secretariat of Environment and Natural Resources (SEMARNAT)	Sub-directorate of Spatial Analysis and Support to Decision Making
Secretariat of Energy (SENER)	Directorate of Renewable Energy
National Institute of Ecology and Climate Change (INECC)	General Coordination of Climate Change and Low Carbon Development
Mexican Association of Wind Energy (AMDEE)	Executive Management
Mexican Centre for Innovation in Wind Energy (CEMIE-Eólico)	Technical Specialist
Centre for Services in Energy and Sustainability (ENESUS)	Directorate General
Autonomous University of Ciudad Juarez	Department of Civil and Environmental Engineering
Environmental Consulting (Natura Medio Ambiente)	Technical Specialist
*Greenpeace Mexico *(declined its participation)*	Executive Office

Table 4.1 Final list of confirmed participants

[6] A common epistemic framework was sought to create with the information made available to the panel of experts; a process reinforced on the basis of the recommendations made by them, according to the given cases, and which continued during the development of the exercise. According to García (2006), what integrates an interdisciplinary team for the study of a complex system (like the one concerning the present research) is a common conceptual and methodological framework, derived from a shared conception [...] that will allow to define the problem area under the same approach, which is a result from the specialisation of each member of the research team. In other words, in the interdisciplinary study of complex systems, the articulation between disciplines begins at the very starting point of the research through a common epistemic framework (and a collaborative approach as here discussed). Without this, it is not possible to achieve a systemic study leading to an integrated diagnosis and a shared formulation of alternative policies.

f. Subsequently, the users/experts who accepted to participate in the exercise (second stage of the system configuration) were registered. In addition, they were informed about the implementation period and the mechanics of the exercise, providing with all the necessary information in the form of instructions and tutorials[7] as well as their system login credentials.

Geoconsensus

g. This step essentially represents the beginning of the exercise, and basically, having reached this point the survey was conducted employing the *Real Time Spatial Delphi*[8] technique, collecting answers to the questions and placing positions on the map looking for geo-consensuses, i.e. a convergence of opinions in a geospatial context. By the expression “convergence of opinions” is understood as a structured process in which individual thoughts on issues under discussion lead to relatively shared conclusions (Di Zio & Pacinelli, 2011).

h. It is worth highlighting that likewise the members of a multidisciplinary team of interdisciplinary research ought to share an epistemic framework and agree on the analysis of a common problem, which does not mean to have an omni-comprehensive common theory on the problem (García, 2006), the geo-consensus building does not represent in any way a mandatory requirement or a dominating factor within the proposed analysis.

   That is, the members of the panel have been informed about the objective of the exercise and encouraged to seek a possible convergence of opinions, nonetheless, this has not been imposed as a preconception or condition to perform the exercise. The consensus is an element of particular concern in this research, but it is not the ultimate goal of the implementation of the experimental phase.

   The survey is completed according to the procedure described in the following section.

Results

Thanks to the system features and its real-time mode, basically, the results were obtained during the course of the experimentation. However, this process was synthesized and complemented with the production of reports including maps and statistics regarding the evolution of the exercise, pointing out the identified areas, as appropriate.

[7] It is worth mentioning that, one-to-one online demonstrations of the archetype were optionally offered to the panel members. Through this interaction with those who accepted, they were asked about the consideration of additional information for its incorporation.

[8] The Spatial Delphi is based, like the classical Delphi, on the judgments of experts, and it is useful in the consultations for decision and/or forecast purposes, provided that they concern matters of spatial location. The basis for the questionnaire is a map, on which each expert provides, as answer(s), one or more opinion-points, i.e., locations that, according to their opinion, are best for a specific purpose (Di Zio & Pacinelli, 2011).

4.4.1 Conducting the exercise

Initial considerations

1) The access to the platform was possible through the web address http://www.sigic.net (Fig. 4.4) using the login credentials sent via e-mail. Participants were advised to change their password the first time they enter the system using the 'Password' option from the toolbar.

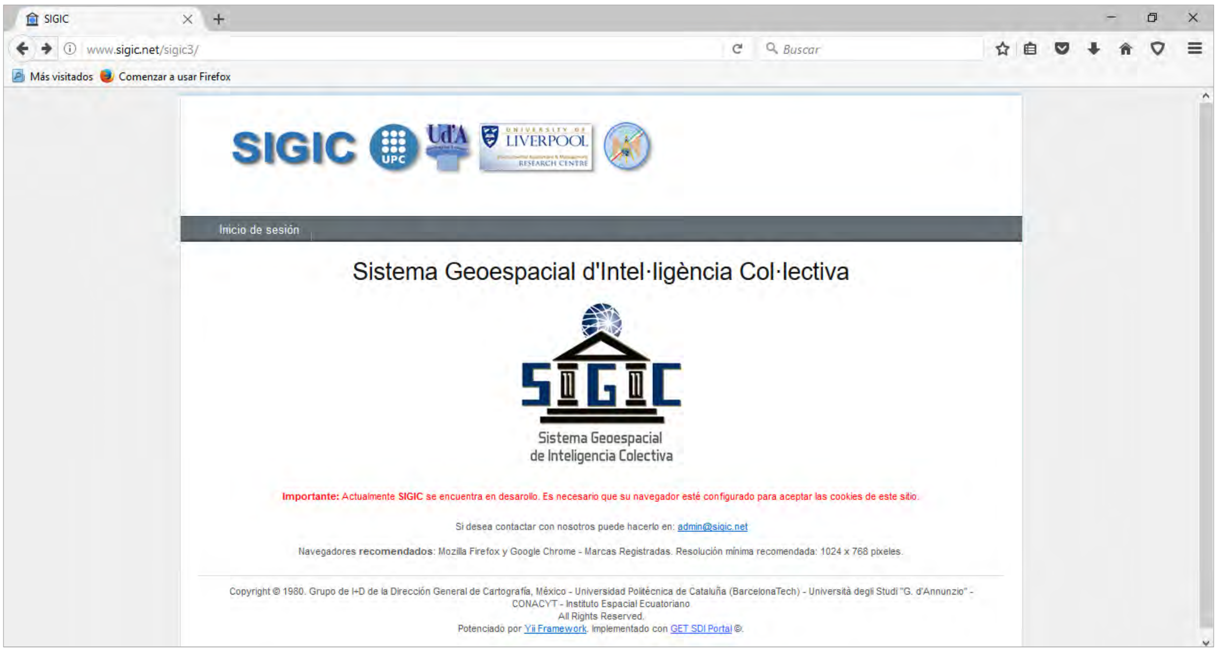


Figure 4.4 SIGIC access interface

2) Once having accessed, participants were encouraged to explore all available tools, even if only out of curiosity, with the confidence that they could not cause system crashes.

3) In the *Options* panel on the left side of the main interface (Fig.4.5/A), the base map could be changed and the visualisation of the special maps available turned on and off.

   The selection of map layers for spatial support was composed as follows: inventory of wind energy (existing and potential), wind speed, wind power density, protected natural areas, regions with high concentrations of indigenous people. Ramsar sites, archaeological sites, national power grid, and zoning of the country.

4) By right clicking on these special maps the participants could find some options, among which are the symbology and the adjustment of transparency (Fig. 4.5/B). Different *cartographic information* (i.e., map layers) was added that was considered to help the experts to visualise and to understand the geographic space that is object of study, and this way to ensure that the opinions and proposals of site locations had a solid scientific basis.

The layers of information for analysis have been integrated from diverse sources of information; among those considered are: National Inventory of Renewable Energies (INERE), National Institute of Statistic and Geography (INEGI), National Institute of Anthropology and History (INAH), International Renewable Energy Agency (IRENA), Google Maps, Google Earth and OpenStreetMap Foundation.

5) In addition, a *File section*[9] (non-georeferenced information) was made available, where the members of the panel could find documentation intended to support when thinking about their opinions (Fig. 4.5/C).

6) In the *Notifications section* (Fig. 4.5/D), the experts could see the messages issued by the SIGIC administrator, as well as the document history that each user uploaded as contribution to the analysis. They were also recommended to regularly review this tab.

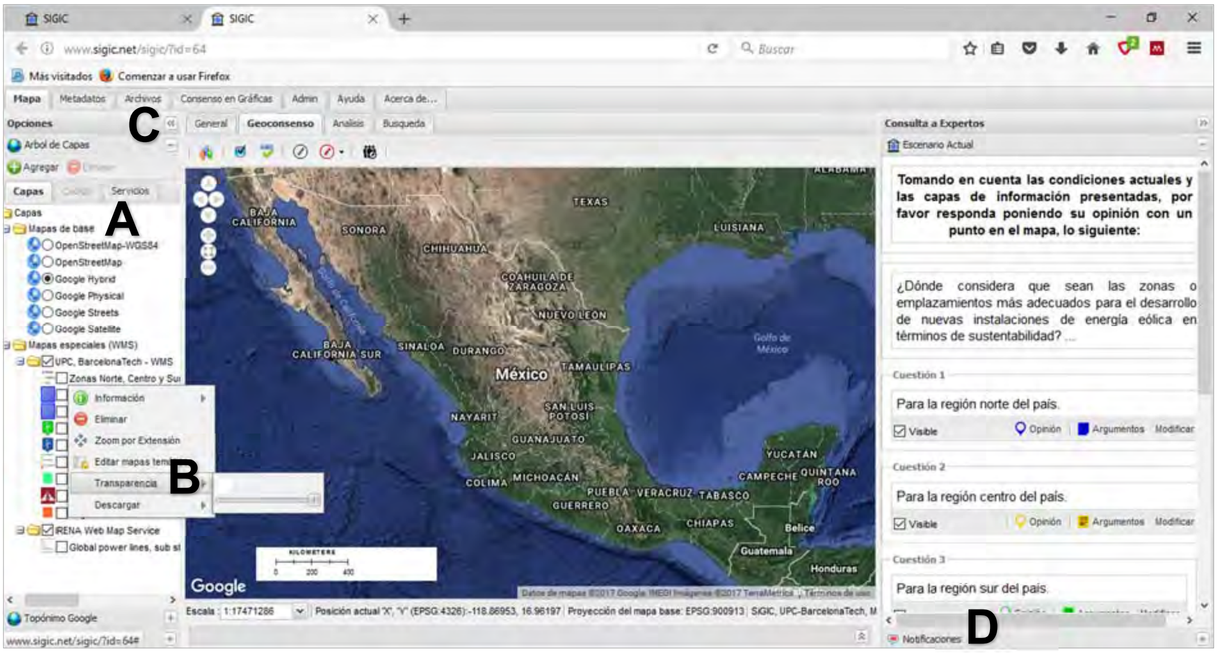


Figure 4.5 Dashboard view

[9] By the same token, in this section (during the completion of the survey) they were also able to upload digital documents such as pictures, provisions, applicable laws, papers, etc., which they would consider relevant to support their arguments besides being useful to other participants, thus stimulating the discussion and providing a positive feedback.

Responding to the survey

7) Unlike a common survey, here the answers to the questions are considered as *spatial opinions/answers*. That is, the participant would have to answer each question by placing a location on the representation of the territory under study, which he or she thinks is most appropriate[10]. To do so, each member had to select the *Opinion* button (Fig. 4.6/A) of the question to be answered; then, adding a brief comment that would guide others regarding his or her choice.

   It was important for the participants to consider that they were part of a multidisciplinary group, so not all members have the same professional and academic backgrounds. In addition, it was pointed out that neither too extensive nor too complex answers were sought, but concrete reflections that could be expressed and understood in a relatively small number of statements.

8) The questions of the survey were displayed on the *Expert consultation* panel (Fig. 4.6/B). The buttons for answering such questions were presented with different coloured icons for each of them. The same colour corresponded to the mark of everybody's opinion on the map (Fig. 4.7/A).

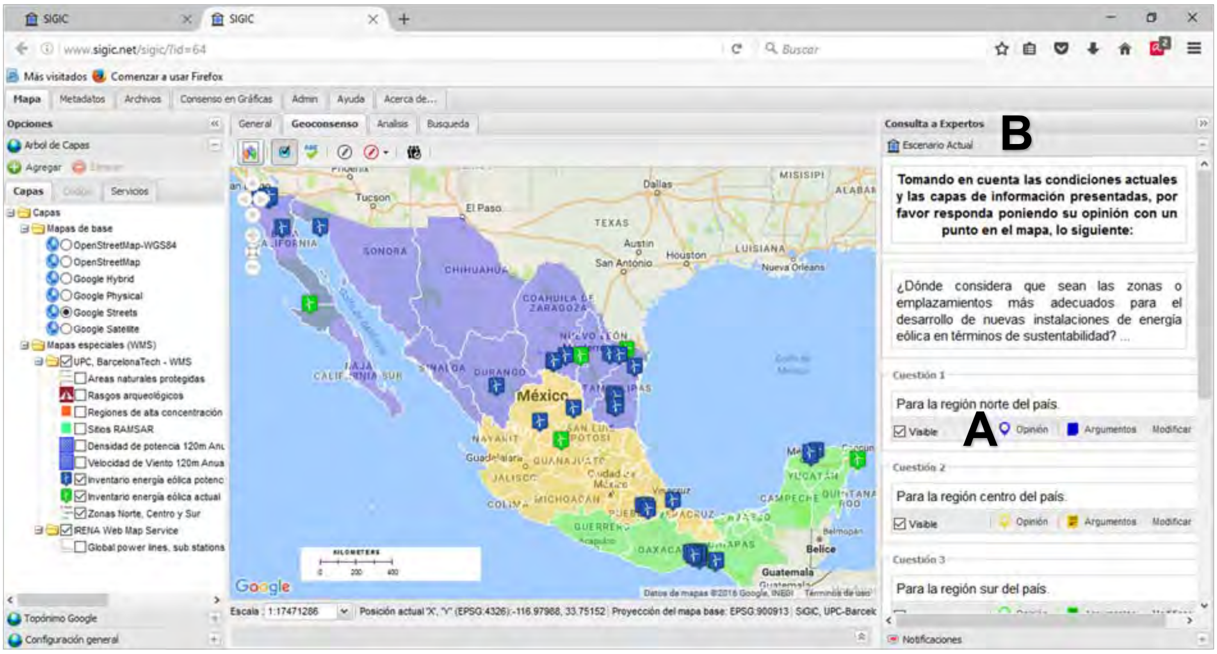


Figure 4.6 SIGIC user interface

[10] In other words, following the principles of the spatial version of the Delphi Method, through the survey, I asked the experts to indicate points that represent the most suitable locations for either goods or places where a future event will likely take place directly on a digital map. The experts could also provide the documents justifying their choices. The result of these iterations is a map with a set of geo-referenced opinion-points (Di Zio & Pacinelli, 2011), each with geographic coordinates (e.g., latitude and longitude).

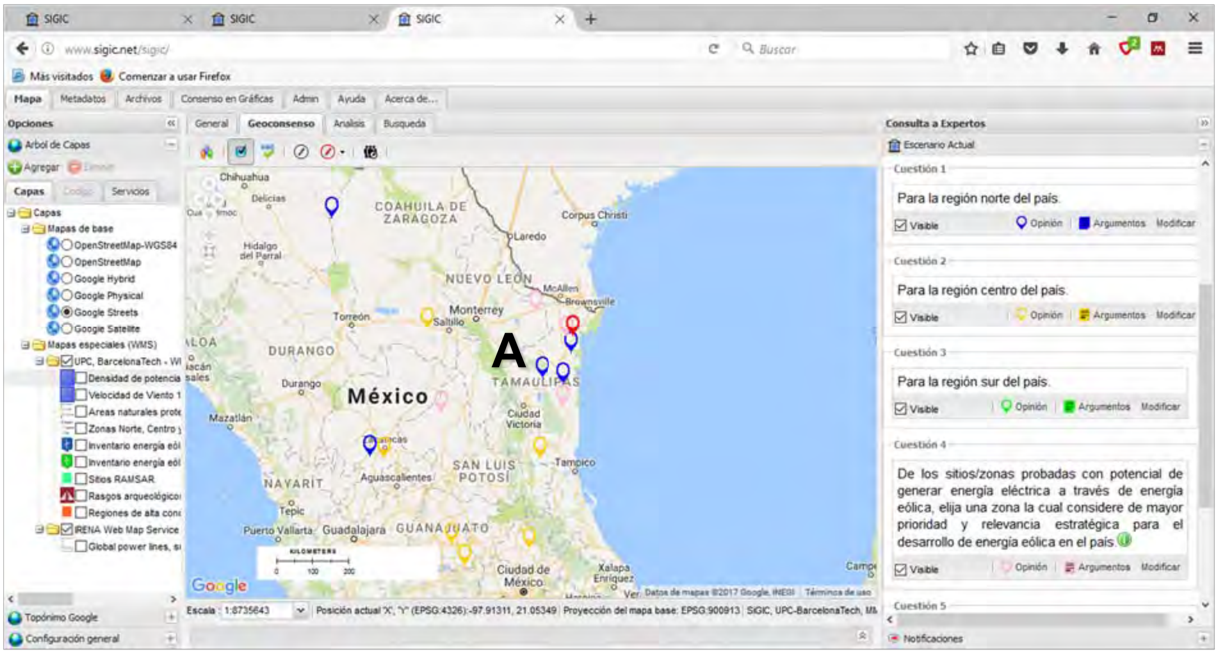


Figure 4.7 Interactive map

9) The interactive map also showed a circle for each question in the colour corresponding to the icons of the buttons (Fig.4.8/A/B). This circle indicated the area of *convergence of opinions*[11] (agreement, consensus or rather geoconsensus) among the experts. The larger the circle, the smaller the agreement and vice versa.

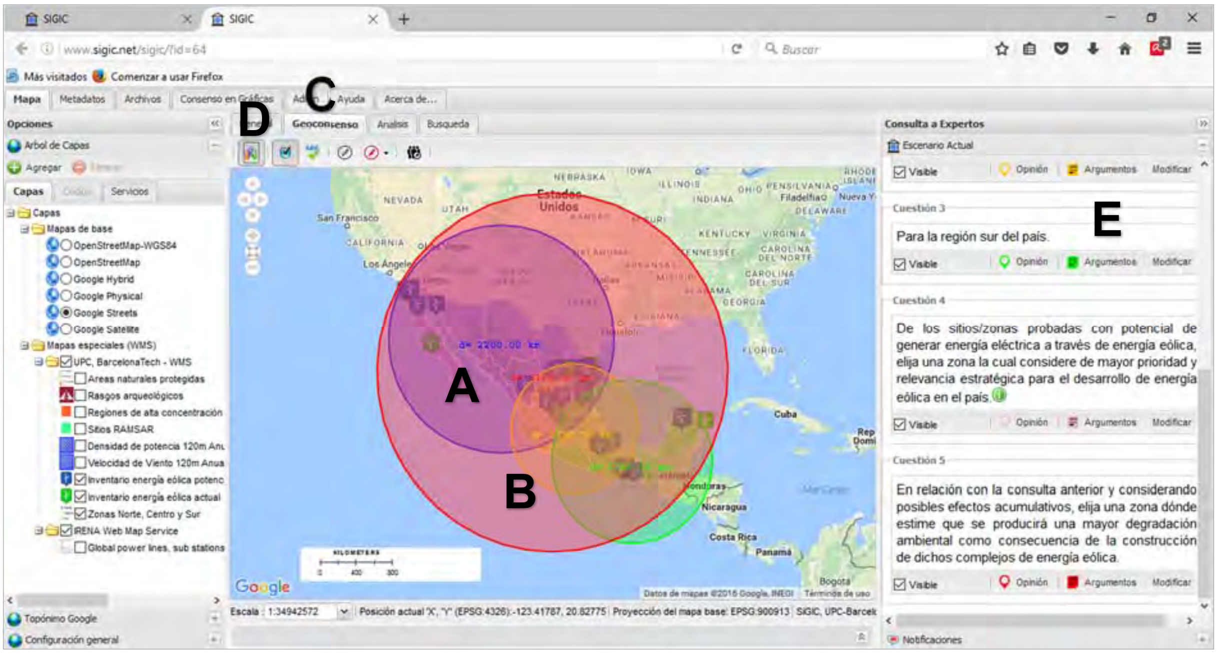


Figure 4.8 Example of geoconsensus circles

[11] As noted by Di Zio & Pacinelli (2011) "in the classical Delphi, the convergence is governed by the interquartile range, which contains 50% of the respondents. In the Spatial Delphi, these guidelines are kept, but rather than an interval containing 50% of opinions, an area is used".

10) The experts were not allowed to see the spatial opinions of the other members of the panel (due to the element of anonymity, distinctive feature of the Delphi Method), but they were able to observe the *circles*[12] mentioned in the previous paragraph (Fig.4.8/A/B), which indicate the area containing at least fifty percent of the opinions of the whole group.

    It is also worth recalling that on the *Geoconsensus* toolbar (Fig. 4.8/C), the users could activate and deactivate the visualisation of the geoconsensus circles (Fig. 4.8/D). They were recommended that, at first, and before starting to answer the survey by placing their marks on the map, they could deactivate such a display. Then, once they have started, they could re-activate the visualisation of these circles; so, they would be able to observe in real time the system performance and the evolution of the geo-consensus. Additionally, they would be able to read the rationales of all the members of the panel through the *Arguments* button of each question (Fig.4.8/E).

11) In the *Arguments*[13] window (Fig. 4.9) the experts could find the updated justifications of each expert who answered the survey. They could also see in a green rectangle, those comments that are within the areas of convergence of opinions (Fig. 4.9/A). On the other hand, the comments that support the opinions outside this area were represented by means of the red rectangles (Fig. 4.9/B). The user icon corresponds to the response of the active users (Fig. 4.9/C). Finally, they were able to show or hide the corresponding text messages by clicking in the icon located to the left, flagged with the symbol '+' (Fig. 4.9/D).

Figure 4.9 Arguments window

[12] "Assuming isotropy and thus excluding non-random directions, the first possible geometric shape in a two-dimensional space is the circle, i.e., we are interested in finding a circle that contains 50% of all opinion-points" (Di Zio & Pacinelli, 2011).

[13] Please note that the respondents could change their answers as many times as they wanted, nevertheless, they should be aware that every change would invalidate the previous answer. Consequently, only the latest changes in each question have been considered because each participant can only provide one answer per question (Castillo-Rosas et al., 2017).

4.5 Results

4.5.1 Exercise of site location of onshore wind energy in Mexico

Currently, we are witnessing a steady deployment of wind energy on a wide-scale around the world. Nevertheless, and despite its significant potential to reduce greenhouse gas emissions (GHG) by displacing fossil fuel-based electricity generation, wind energy (as with other industrial activities) has the potential to produce some detrimental impacts on the environment and on human activities and well-being. Therefore, these potential concerns need to be taken into account to ensure a balanced view of the advantages and disadvantages of wind energy, especially if wind energy is to expand on a large scale (IPCC, 2011).

Concerning the present case study research, it is noteworthy to mention yet again that Mexico has a large and diverse renewable energy resource base. With regard to wind, the high volume of usable resources (12,000 MW by 2020) indicates that Mexico is a country with great potential for the use of wind energy (PwC, 2012). Hence, given the right mix of policies, Mexico has the potential to support large-scale investment in renewables that can also help diversify its energy supply. Increased renewable energy use would also set the country on a pathway toward significantly reducing its GHG emissions (IRENA, 2015). Furthermore, accelerating Mexico’s uptake of renewable energy could substantially benefits its population as well as its environment, resulting from lower harm to health and reduced carbon dioxide (CO_2) emissions.

However, to gain such benefits, policy changes in the environmental protection approach and spatial planning are needed, since planning is essential for transmission, expansion and grid integration to accommodate the full range of renewable power technologies. That is why, in order to give a different perspective to the new architecture of the wind sector under a holistic vision of the planning process, the present exercise of site location of wind energy with a specialised technique has been put forward, expecting in a broader sense that, while considering and reducing the varying impacts, this analysis can contribute to the sustainability and diversification of the energy generation matrix. All this, based also on the premise that wind energy is a necessary option for the articulation of a sustainable and diversified energy policy, that allows to achieve the objectives and targets of energy transition established in the national legislation as well as to comply with the international commitments made in terms of climate change.

The brief survey that integrated the exercise was composed of the following questions:

Questionnaire

Taking into account the current conditions and the layers displayed on the platform, please place your opinion with a point on the map, the following:

What do you consider to be the most suitable sites/areas for the development of new -onshore- wind power facilities in terms of sustainability?

1. For the Northern region of the country.
2. For the Central region of the country.
3. For the Southern region of the country.
4. From the tested areas -shown on the screen- with the potential for electricity generation through wind power, please choose an area which you consider of highest priority and strategic relevance for wind energy development in the country.
5. In relation to the previous question, and taking into consideration possible cumulative effects, please choose an area where you deem that there will be a greater environmental degradation as a result of the construction of such wind-generated energy complexes.

Box 4.1 Exercise questionnaire

The experimental exercise was carried out during two phases over 55 calendar days; allowing access to the SIGIC platform from November 14th to December 9th, 2016, and from January 9th to February 7th, 2017 (excluding the Christmas holiday period).

From the definite list of 11 experts who formally confirmed their participation, at the end 9 of them intervened in the collective spatial analysis answering the survey fully or partially (see Table 4.2).

Participation Report					
user id	**Question 1**	**Question 2**	**Question 3**	**Question 4**	**Question 5**
126					
127	✓	✓	✓	✓	✓
128			✓	✓	✓
129	✓	✓	✓	✓	✓
130	✓	✓	✓	✓	
131	✓	✓	✓	✓	✓
132					
133			✓	✓	
134	✓	✓	✓	✓	✓
135	✓	✓	✓	✓	✓
136	✓	✓	✓	✓	✓

Table 4.2 Final participation of panel members

Table 4.3 provides the participations of experts in the spatial survey, in which the *percentage in relation to the total*, refers to the proportion of participants who answered each question with respect to the total number of experts who agreed to participate in the survey (11), just as the *percentage of real participation* is given by the number of experts who answered each question in relation to the nine experts who actually participated in the survey.

As a result, it was possible to obtain a final participation average of 71% and an average level of -real-participation of 86.7%.

Question number	Experts	% in relation to the total	% of real participation
1	7	63.6	77.8
2	7	63.6	77.8
3	9	81.8	100
4	9	81.8	100
5	7	63.6	77.8

Table 4.3 Participation of experts regarding each question

Below, several images generated during the experimental exercise are presented:

The focus of Figure 4.10 is to put emphasis mainly on the opinion-points placed on the map, and it also presents an overview of the information layers integrated into the platform.

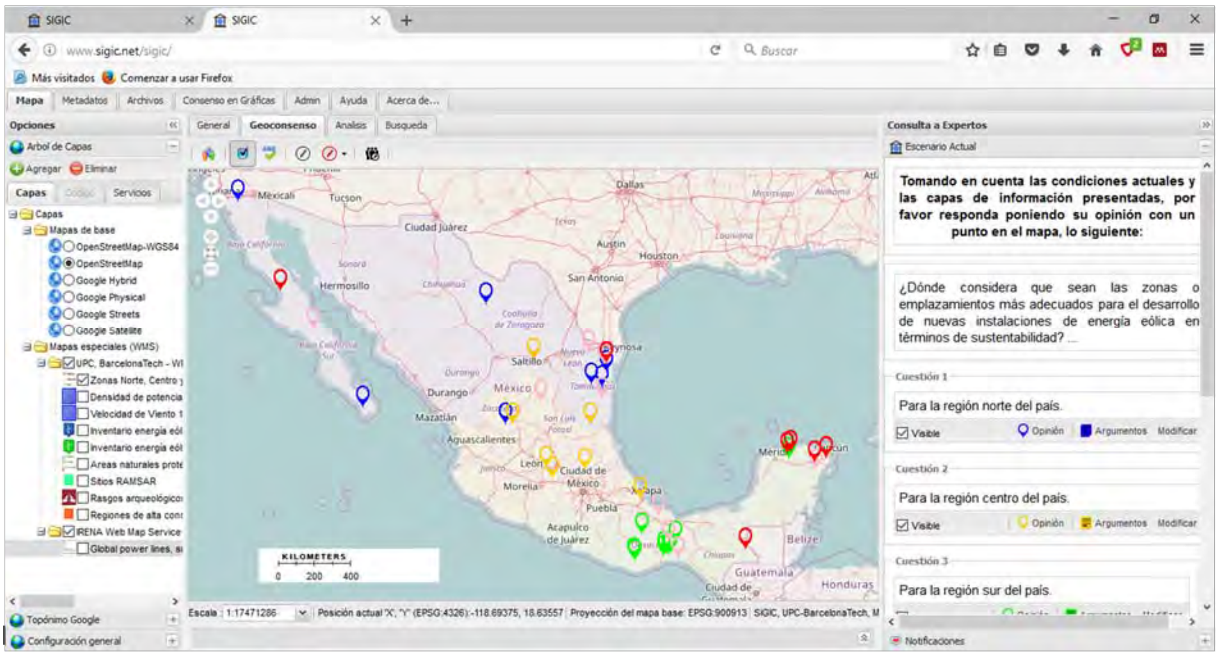


Figure 4.10 Expert opinion marks and layers of information on display

Figures 4.11 and 4.12 show the display of the arguments windows as well as the geoconsensus indicator. As previously mentioned, it is green if the point was positioned inside the circle of convergence (indicating consensus) or red if the point was located outside (indicating dissent).

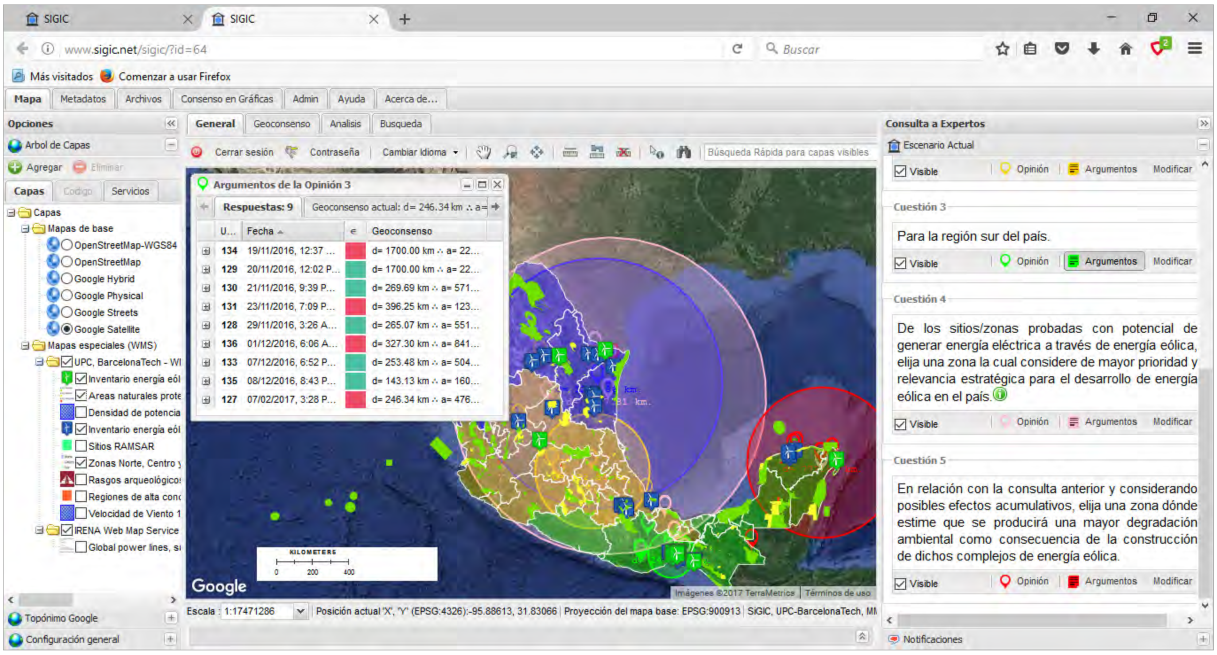


Figure 4.11 Convergence circles and consensus indicator rectangles

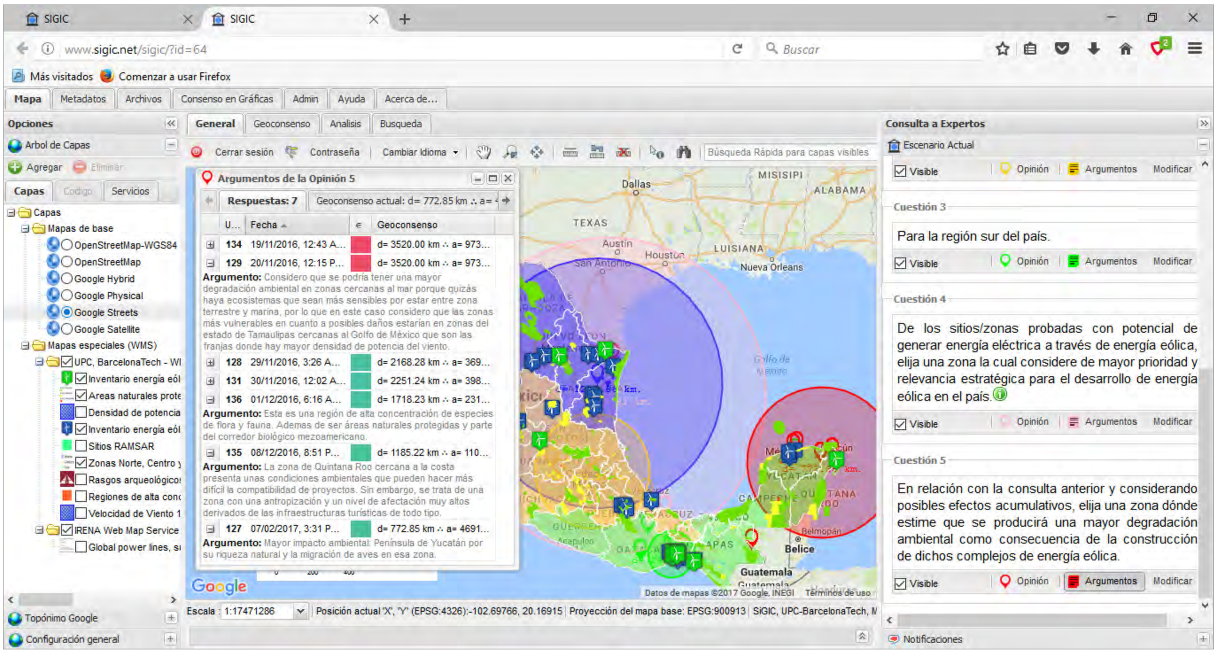


Figure 4.12 Display of the arguments given by the experts

In the following maps (Fig. 4.13 and Fig. 4.14), through the activation of different layers of information and using the zoom function, it is possible to observe the complexity that characterises the Mexican territory: large areas with significant potential for the use of wind energy, but also large expanses of land with high concentrations of indigenous people and important geographic spaces where it is important to preserve biodiversity as well as cultural or historical values. As an example, is the south of Mexico, which, while considered one of the areas with the highest wind energy potential in the country, is also one of the most complex to address regarding the social and ecological dimensions of sustainability.

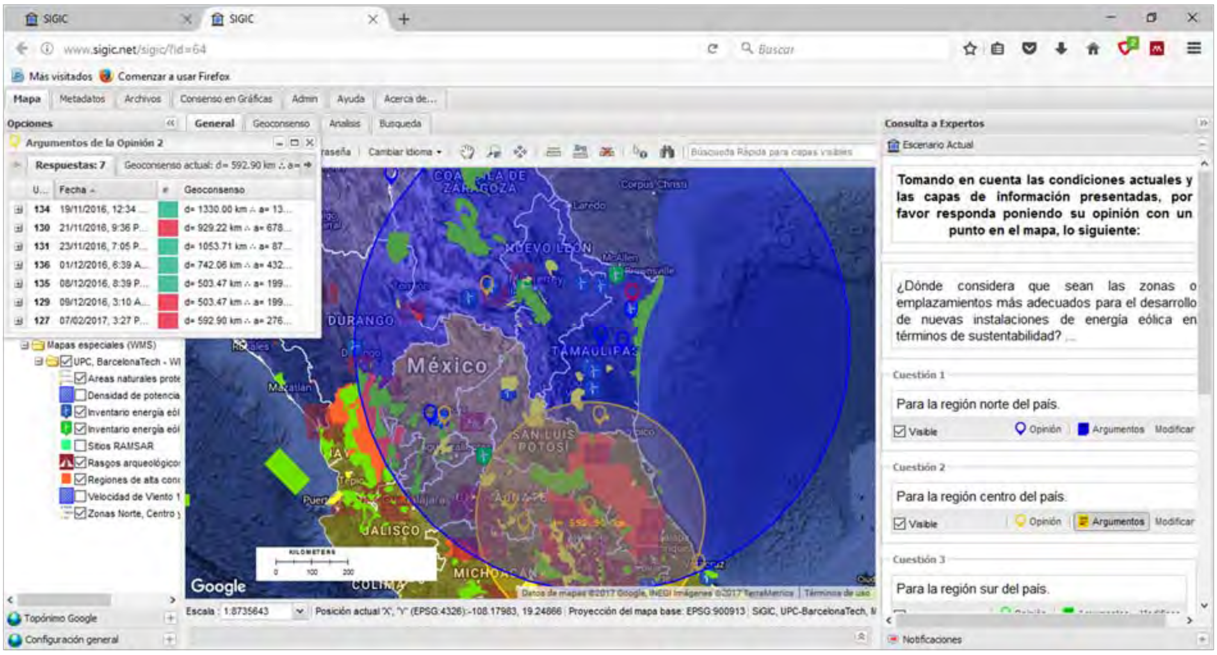


Figure 4.13 Zoom of the study area

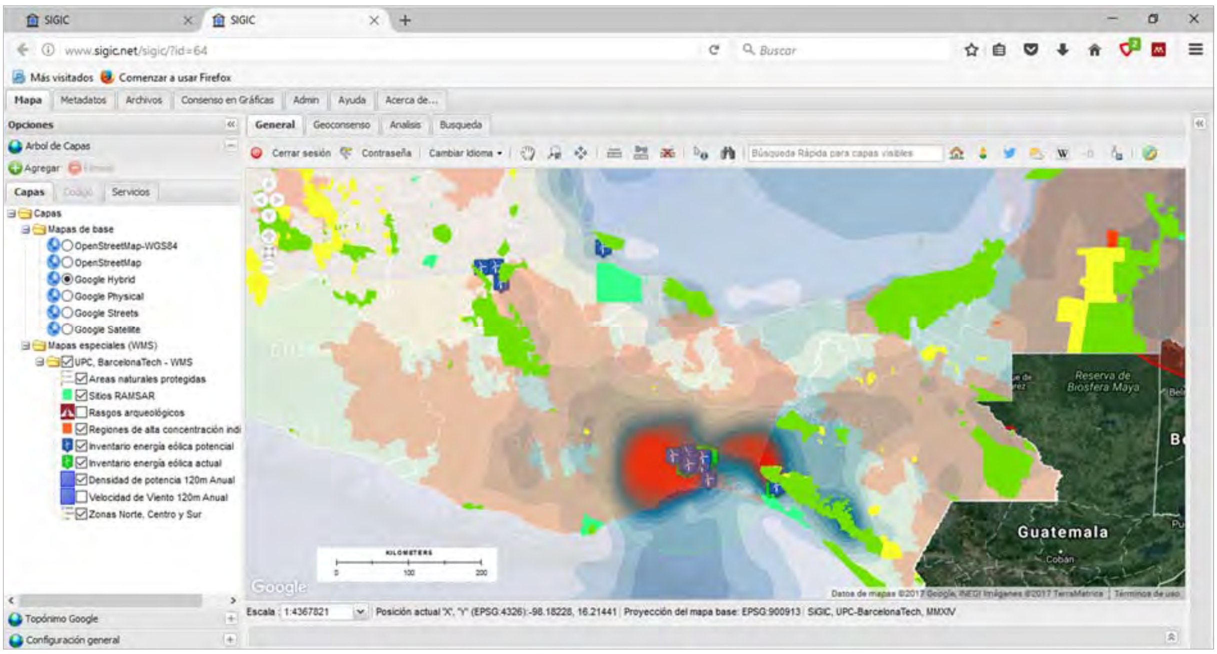


Figure 4.14 Deployment of existing and potential wind energy development within a complex territory

As can be seen from Figures 4.15 and 4.16, the areas of convergence and consensus markers were calculated based on the opinion-points from the panel of participants. On the other hand, however, it was also possible to realise that, although wind speed is a critical feature to consider in project planning of new wind parks (a stronger wind means a lot more power), this -and other technical factors- should not be decisive when proper land-use management is conducted, and particularly when the country presumes to be strongly committed to sustainable development.

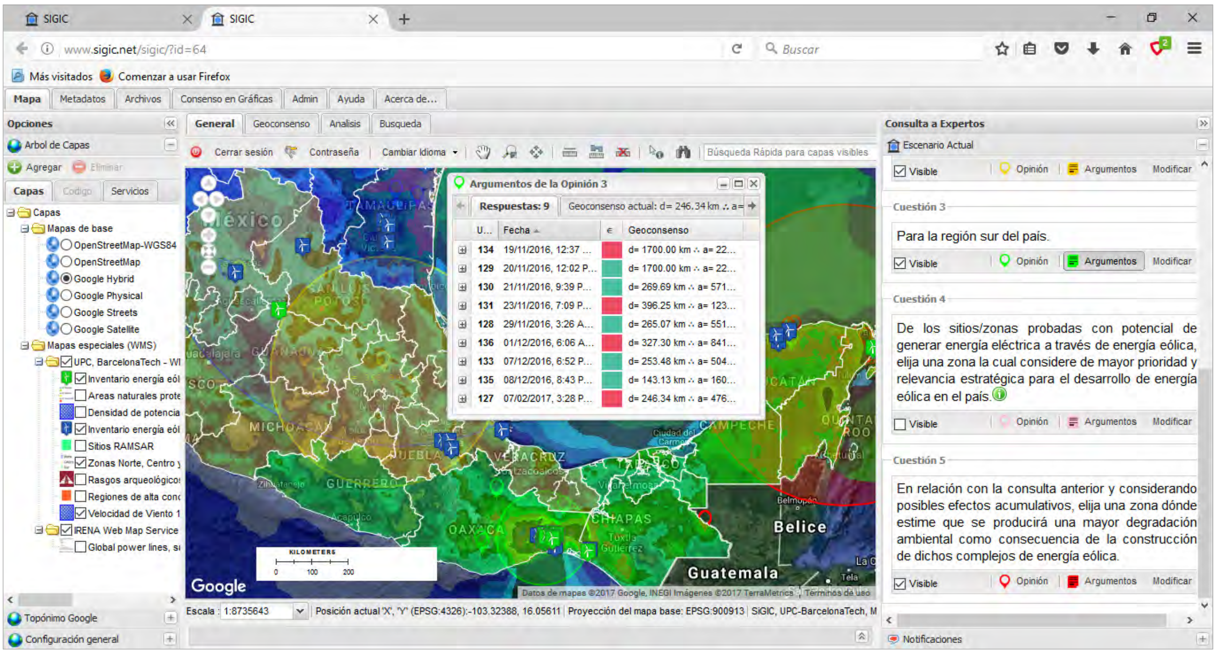


Figure 4.15 Areas of convergence of opinions and consensus markers

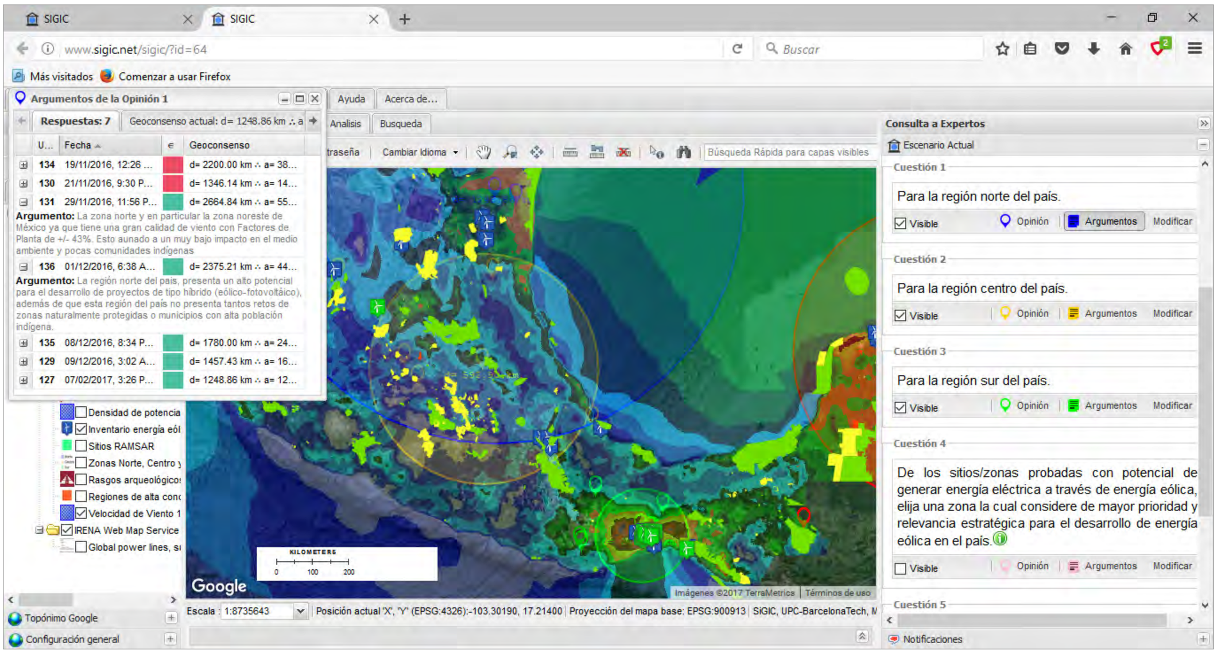


Figure 4.16 Areas of convergence of opinions, consensus markers and display of arguments

The two figures below show a geographical representation of the history of geo-consensuses which has evolved over time when the opinions have been modified or added new ones. From Figure 4.17 the spatio-temporal evolution of the geo-consensus for each of the survey questions can be seen, and from Figure 4.18 the view for a specific question. This information can only be viewed by the system administrator.

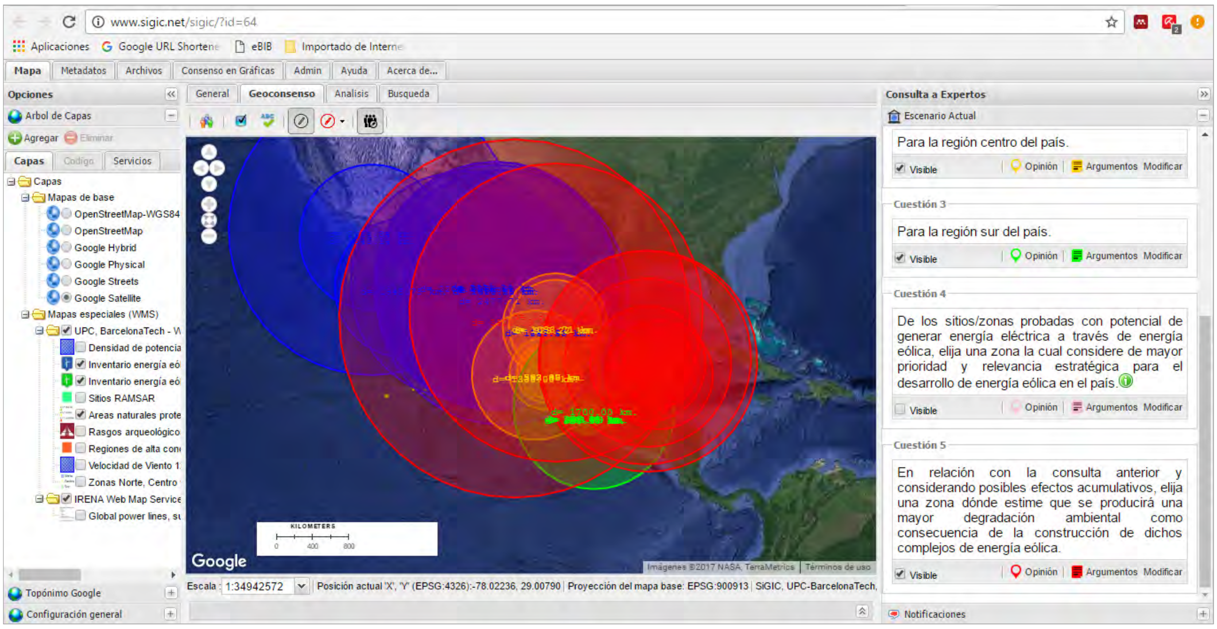


Figure 4.17 Evolution of geoconsensus regarding each question

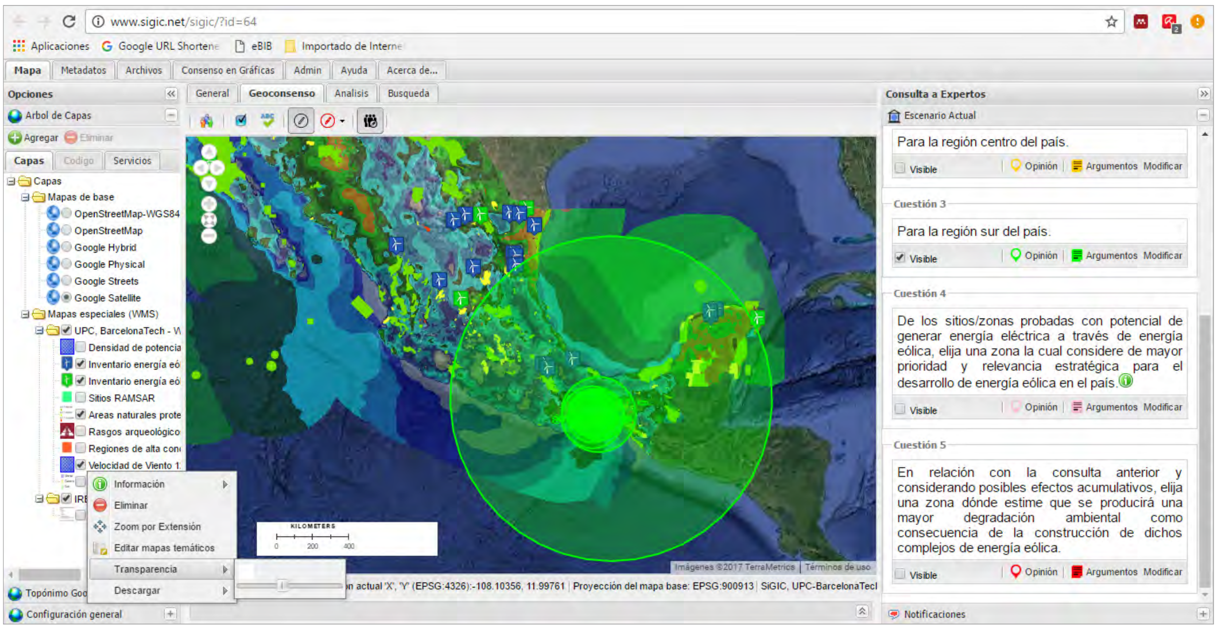


Figure 4.18 Geoconsensus history for a specific question

On the other hand, during the exercise several participants were sharing and making available to the panel some related documentation which provided useful feedback for the analysis. Figure 4.19 presents the SIGIC user interface that includes the *Files section* with documents (non-georeferenced information), some uploaded to the system by the participants themselves.

Figure 4.19 Display of non-georeferenced information

Figure 4.20 and Figure 4.21 provide different perspectives of the geographical results of the appraisal of wind energy site location. It is assumed that through the opinion-points and the interaction that has taken place, it was possible to identify certain areas that might be useful for sustainable spatial planning and environmental assessment of wind energy at the strategic level.

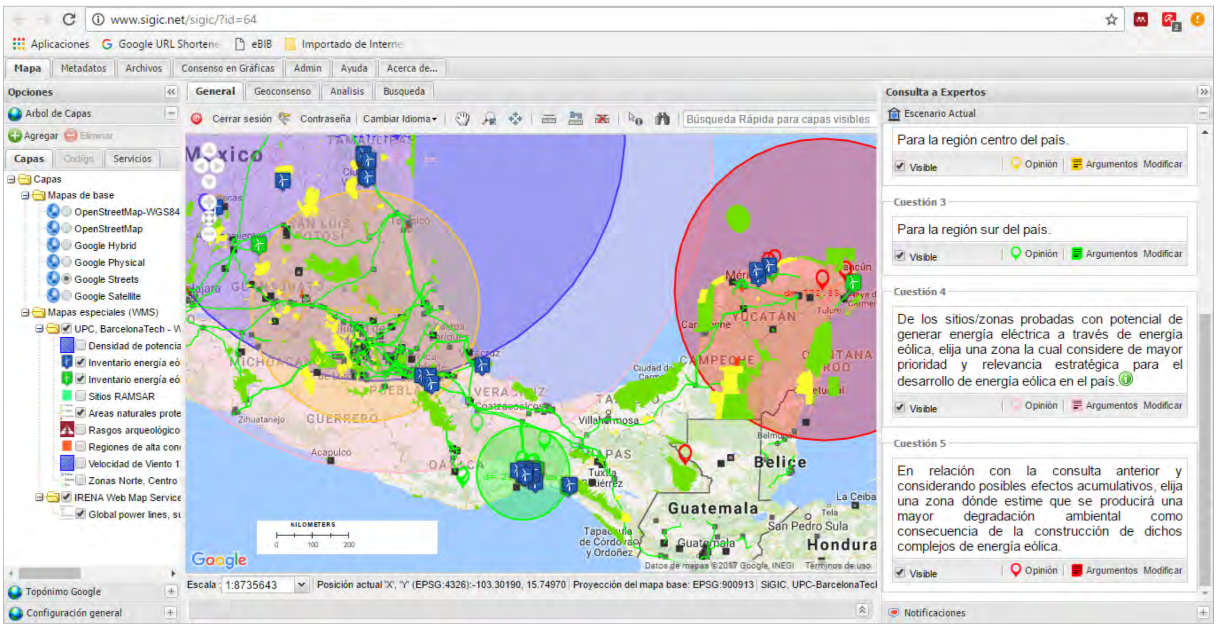


Figure 4.20 Circles of convergence and opinion marks

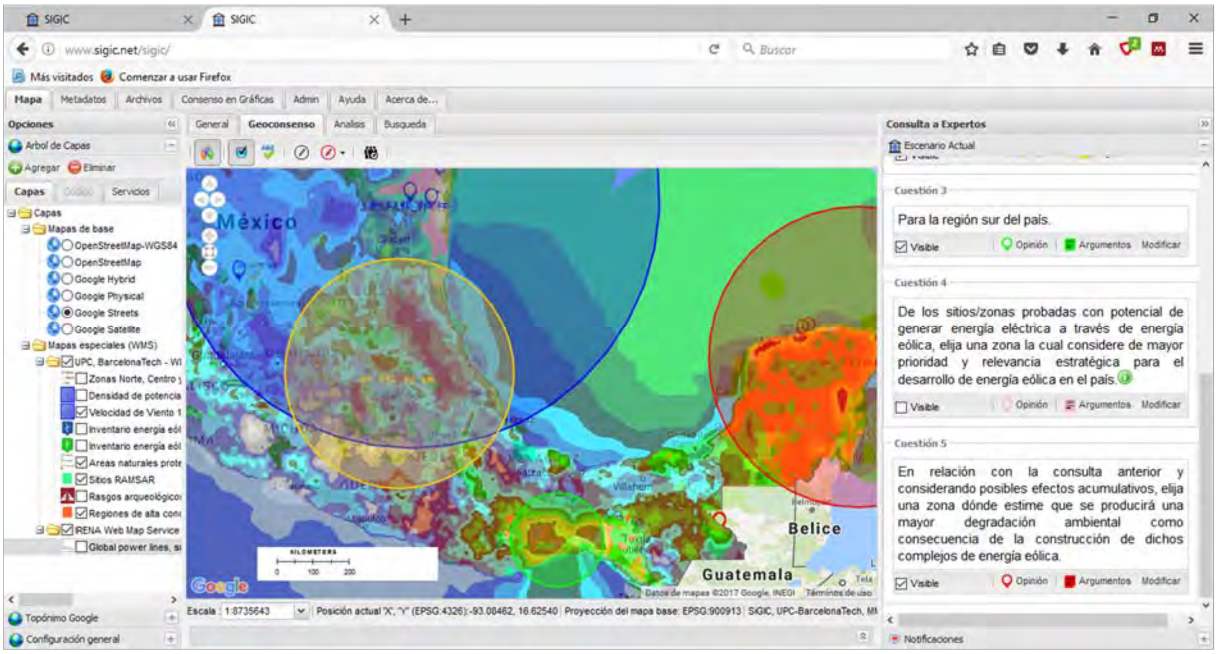


Figure 4.21 Geographical results of the appraisal of wind energy site location

To summarise the above, in Figure 4.22 it is possible to observe the result of data processing performed by the system, where the areas shown correspond to the circles (one per question) that contain 50% of all the opinions points provided by the panel, which represent the convergence achieved.

Note that, in terms of the size of the country and the zoning considered, the dimensions of the geo-consensuses in questions 2, 3 and 5 show well defined areas, but not the extension of the geo-consensuses corresponding to questions 1 and 4. This might be due to the complexity that is attempted to address, either the relative to the territory in question, or perhaps the one regarding the proposed problem itself (or both).

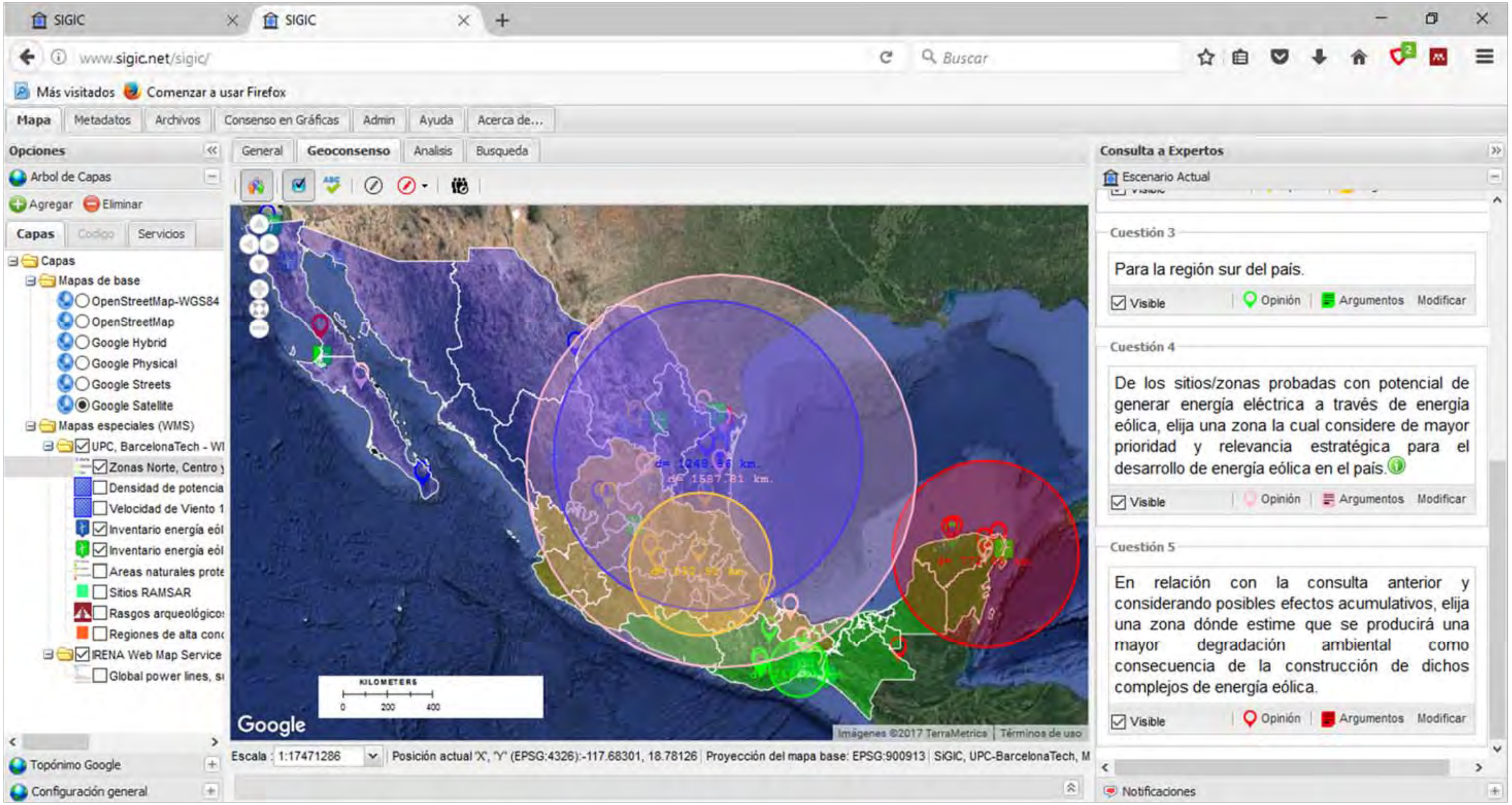


Figure 4.22 Final status of circles of convergence and opinion-points

As a complement of the aforementioned, Figures 4.23 to 4.27 show the evolution in the geo-consensus for each of the questions, calculated based on the panel's opinions. The X-axis shows the spatial evolution of the geo-consensus, determined by the circumference diameter that indicates the portion of the territory containing at least 50% of the spatial-opinions of the experts in relation to the chosen sites. A smaller diameter means a greater consensus and vice versa. In the Y-axis, the temporal aspect is represented, from the beginning of the exercise until the conclusion of the same.

Finally, the raw data generated are presented in Appendices C *(Response history)* and D *(History of geoconsensuses)*, respectively.

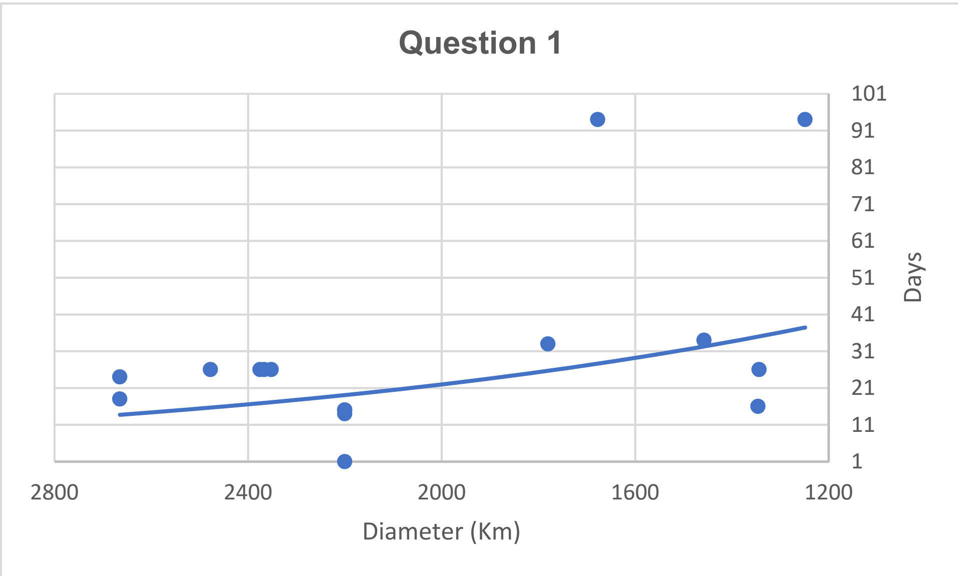


Figure 4.23 Spatio-temporal evolution of the geo-consensus regarding question 1

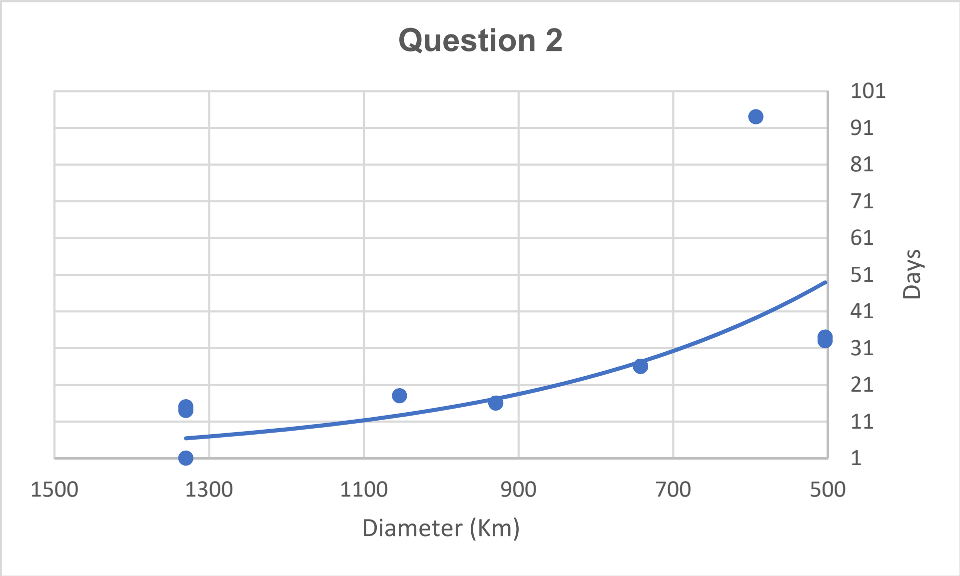


Figure 4.24 Spatio-temporal evolution of the geo-consensus regarding question 2

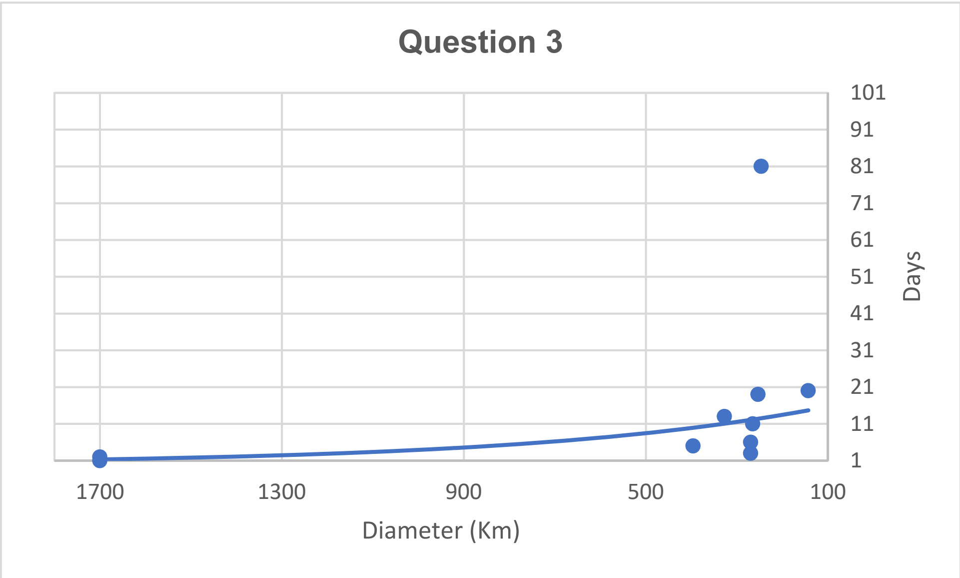


Figure 4.25 Spatio-temporal evolution of the geo-consensus regarding question 3

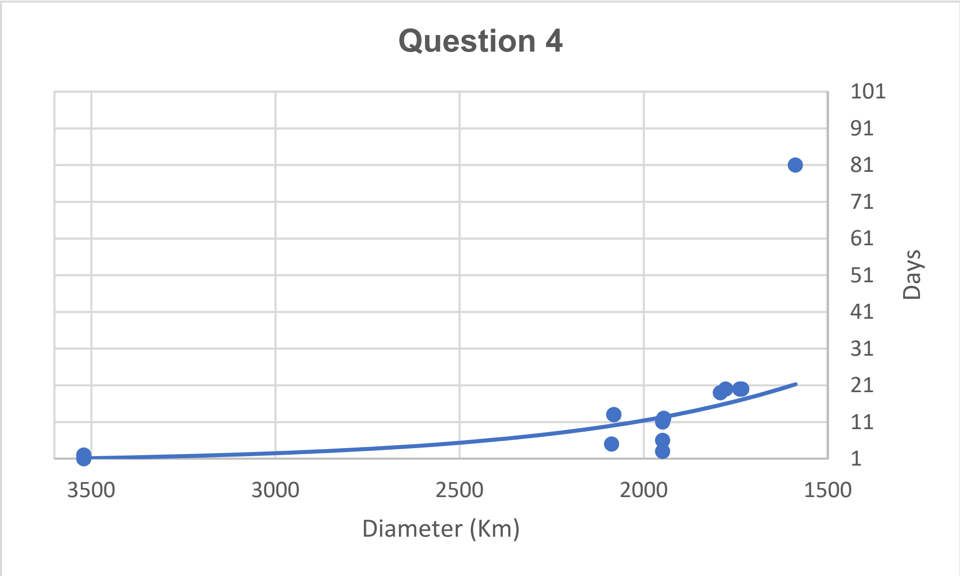


Figure 4.26 Spatio-temporal evolution of the geo-consensus regarding question 4

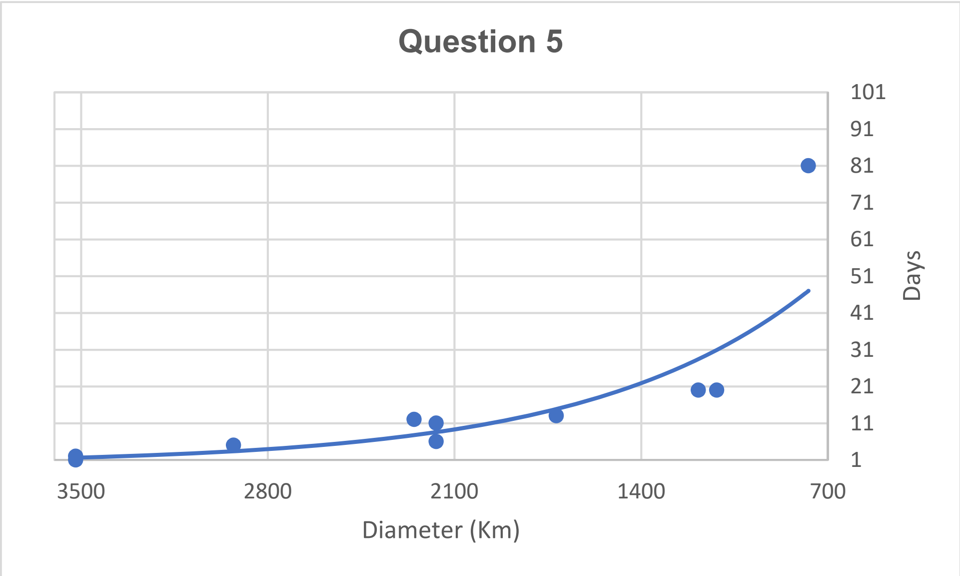


Figure 4.27 Spatio-temporal evolution of the geo-consensus regarding question 5

Chapter 5. Discussion

Chapter 5. Discussion

In this thesis, a methodological approach that integrates the essential principles of the SEA has been developed, combining it with the implementation of a technological tool of collective intelligence as support for decision-making in the context of spatial planning of renewable energies in Mexico. In other words, this tailor-made approach aims to provide valuable strategic information to enable environmental interests to be properly taken into account in decision-making of wind energy, playing a fundamental role in the refinement of the national spatial planning, but also offers a holistic perspective that can help to make renewable energy development more sustainable, participative, open and transparent.

In light of this, it is important to keep in mind that SEA is a relatively recent innovation, so to speak, that attempts to foster effective guidance in policy and project planning. It extends the project-specific EIA to the level of policy, plan, and programme. In this capacity, the SEA is distinguished from the EIA and can be applied at a far earlier stage. This allows for environmental considerations and project objectives to be viewed early on and handled as inherent elements of planning for prevention rather than backseat opportunities for mitigation and reaction (Sayre, 2009 following Eccleston). That is to say, instead of the established practice of designing for mitigation over avoidance, with an SEA the impetus becomes prevention before mitigation (Sayre, 2009 building on Fischer, 2007). Nevertheless, it is essential to remember that the SEA *per se* represents a special instrument that precedes and does not replace the practice of Environmental Impact Assessment (Orea, 2007) that, in any case, shall be undertaken for each of the projects and actions considered within the plans and/or programmes.

Additionally, it is worth noting that this work copes with the need to better address analytical methods in SEA research in order to foresees and assess environmental effects at the strategic level. In this sense, the present research was directed at innovating a SEA method, by promoting the use of appropriate spatially-explicit and (semi)quantitative approach, which has been based on advances in relevant disciplines (e.g., Complexity Theory, Technology Forecasting, Geographic Information Science, Geoprospective, in this case), and the increasing availability of data and technology (Geneletti, 2015).

This assumption was made based on the information presented in chapters 3 and 4 of this dissertation, but also during the development of the state-of-the-art (Chapter 2) through which it could be seen that the spatial decision-making process in an energy transition full of green projects, and good environmental intentions reveals a wicked problem with a considerable level of complexity. Moreover, concretely related to current models used for spatial analysis and environmental assessment in contexts related to wind energy, it was noted that, although these involve GIS applications, concepts and criterion of collaborative planning, evaluation of alternatives, public participation and spatial analysis; they do not, however, underpin the spatial decision-making process on the basis of consensus or convergence of views.

From here, it can be stated that this is therefore a pioneering methodological and empirical work in its field, since it is the first time that it is performed an application of the Real-Time Spatial Delphi (RTSD) through the Geospatial System of Collective Intelligence from a SEA perspective in an energy context.

Speaking of convergence of views, which is one of the main elements of the empirical assessment conducted, it is recognised that this was not achieved in all que questions of the survey. As was indicated in the previous chapter, there were three questions where it was possible to observe certain level of consensus among the participants, and two where this condition could not be met (or it is not very clear). That is, at the end of the experimental exercise it was feasible to identify -a convergence of views about- the most suitable areas for the development of new onshore wind power facilities for the Central and Southern regions of the country, as well as an area where it is deemed to occur a greater environmental degradation as a result of the construction of such wind-generated energy complexes. On the other hand, the most suitable area for the development of wind energy in the Northern region could not be easily distinguished. Likewise, a consensus was not reached when proposing an area considered of highest priority and strategic relevance for wind energy development in the country.

In the case of the questions where consensus could not be reached, the reasons might be due to factors of different nature. It is believed that the first of them is related to the territorial extension under analysis. It can be possible that concerning the size of the country, and even though the territory was zoned into three main regions, the geographical space still to be significantly wide (Mexico is a massive country). Secondly, and correlated with the previous consideration; the great wealth of wind resources observed throughout much of the national territory (north, centre and south of the country) turn the various regions into zones with numerous candidate states than can compete for the development of wind power infrastructure.

Nonetheless, in an exchange of emails with Dr. Di Zio (2016), looking for insight and clarification, he points out that “in any Delphi the lack of consensus must not be interpreted as a failure of the exercise. It means that the problem must be deepened”. Moreover, he also reminds us that in Delphi studies, as is expressed by various authors (Scheibe, Skutsch, & Schofer, 1975; von der Gracht, 2012), the absence of consensus is, from the viewpoint of data interpretation, as important as the presence of it. In the same way in which it is emphasised the importance of the opinions collected throughout the exercise, as well as of the useful remarks that can be deduced from the arguments of the experts, and from the observation of the spatial distribution of the points. (Di Zio et al., 2016).

With regard to the results obtained in other studies with related objectives, it is noteworthy the recent materialisation of a project led by the Mexican Secretary of Energy (SENER) in collaboration with the Federal Electricity Commission (CFE). From this work, it is underlined the elaboration of the National Atlas of Zones with High Potential of Clean Energies (AZEL by its Spanish acronym).

This atlas provides geographical information needed to locate generation projects and resource potential and that should facilitate the decision-making processes for developing and authorizing renewable energy generation projects (IRENA, 2015)

Essentially, this is a navigation application that shows the results of the evaluation of the potential for power generation from biomass, geothermal, solar and wind energy of Mexico (SENER, 2016). AZEL is a platform developed through a Geographic Information System, whose information is displayed through tables, graphs, information sheets, interactive maps and geographically located sites. It is important to mention that the application operates via a sophisticated quantitative evaluation model composed of a set of algorithms, databases and satellite measurements. The methodology used has been adapted from an analysis of various assessments carried out around the world, but mainly by the National Renewable Energy Laboratory (NREL), the Chilean Ministry of Energy and the German Corporation for International Cooperation (GIZ), respectively.

Concerning wind energy, the platform is capable of showing areas with *high wind potential* and areas with *high wind quality*[1] (see Figure 5.1). The base information used has been integrated with wind speed and wind power density maps from NASA's MODIS database (Moderate Resolution Imaging Spectroradiometer). The maps are the result of mesoscale simulations of the atmosphere using a model developed by the Danish company Vestas, based on the WRF (Weather Research and Forecasting) model).

Source: SENER (2016)

Figure 5.1 Interface of Mexico's atlas of zones with high potential of wind energy

[1] For the purposes of such work, the zones considered with high potential are those areas away from the National Transmission Network (RNT) in which there is a great potential of wind *(and solar energy)*, with the aim of serving as a guidance in the planning for the construction of the new RNT infrastructure. Complementary to this, the areas identified with high wind quality are those with the greatest potential of the resource (it is not considered minimum values of the resource). That is to say, these are only the zones or sites in which the resource is good for its use in the production of electricity (SENER, 2016).

Moreover, the application presumes of having a special tool to simulate the location and distribution of a power plant and its components. However, this function was designed to performed a spatial analysis by a single individual user and one cognitive stance. Thus, the whole system functionality (just as the analytical tools discussed in Chapter 2) has been configurated to operate under this approach and preserves the same spirit[2]; unlike the context-based Web-GSDSS application presented in this thesis, which, instead, is based on the collaboration of a group of people, allowing to address the complexity of the geographical space subject of study from multiple (human) cognitive perspectives, experiences, and criteria.

Regarding common ground between the two applications, it can be highlighted the outputs derived from the collective spatial analysis, and compare them with results of the evaluations displayed by AZEL. Thus, although the focus of both platforms is rather different, from there, it is noted that the distribution of the spatial opinions provided by the experts throughout the proposed regions, and the resulting areas, relatively coincide with the high potential zones in the north, centre and south of the country.

In line with the above, it was stated that the goal of the research was to develop the proposed artifact outlined throughout this thesis. But precisely in practical terms, one of the key challenges was to form a committed group of participants with different visions that could interact in an environment of anonymity, with an interdisciplinary disposition and a shared goal. It is worth mentioning that there was a selection process extended over several months (which in turn became a scheduling problem). There were some invitations to potential candidates from which no response was ever obtained. With regard to the experts who finally agreed to participate, it should be noted that not all of them provided a rapid confirmation. Thus, a stage of regular contacts, persuasion, and motivational work was carried out, where not only the initial presentation of the project was considered, but also an ongoing process of emailing and phone calls. Furthermore, one-to-one online demonstrations of the platform had to be provided for those members who accepted this type of support.

With respect to the development of the collective spatial analysis, and as was stressed in the research conducted by Castillo (2016), the major problem detected is related to a basic component of the system: the human factor; since this is one of the main distinctive features for our data processing. This is due to the fact that (as some authors have manifested regarding the use of participatory technologies or the completion of surveys) not all people are willing to collaborate without receiving a direct benefit in return (apart from the proper citation and public acknowledgement). This was later noticed during the development of the exercise. There were days of complete inactivity and experts who accessed the platform only once. Or even some of them that, despite having formally accepted to collaborate in the analysis, never provided their answers (in fact, one of them openly gave up his participation). Certainly, the reasons can be countless, and in most cases, are uncontrollable (Castillo Rosas, 2016).

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[2] It should be clarified that, it is not intended to imply, nor intended to disregard the current techniques used for spatial analysis. Here, the present research (following Castillo Rosas et al., 2015) only attempts to raise awareness, and supports the argument about the necessity to consider new research lines in spatial analysis that take into account the participation of multidisciplinary groups to develop knowledge of geographic space under an interdisciplinary approach .

Finally, returning to the subject of the first paragraphs of this section. It must be clear that this research seeks to stimulate discussion, whereby the application of environmental assessment should not come after the drawing up of a business proposition or the proposal of a particular policy, plan or programme. Hence, it should be part of the process from the beginning, and be carried out in a way which is interdisciplinary, transparent and free of all economic or political pressure (Pope Francis, 2015). That is a complex matter that calls for a comprehensive approach (like the one put forward herein) which would require, at the very least, greater efforts to continue working in lines of independent and interdisciplinary research capable of shedding new light on the problem.

Chapter 6.
Conclusions and future research

Chapter 6. Conclusions and future research

6.1 After thoughts on the evaluation exercise

The current research was conducted to develop an artifact in accordance with the precepts of Design Science Research, which consists of the proposal of a context-specific SEA approach integrated with a geo-collaborative platform for supporting spatial decision-making regarding the site location of onshore wind energy in Mexico.

To that end, the main tasks covered the implementation of a WEB-GDSS application based on the Real Time Spatial Delphi (RTSD) method, whose GIS interface was designed and specially adapted for the study case. It should also be considered that the tool presented here is an archetype that is based on a Spatial Decision Support System, and, like any other decision support system, this does not generate an ultimate solution, but only contributes, together with other elements, to the choice of most suitable locations/options.

The central function of the RTSD enables and promotes the study and reflection among the participants in order to reach a geoconsensus -or spatial consensus- regarding locations of the infrastructure under consideration in the defined territory, thus achieving a better understanding of possible future development. This represents an important advantage over the standard Spatial Analysis, especially in those situations where there is little data to perform geo-processing, and/or in circumstances that are marked by uncertainty and nonlinearity.

Among the strengths of the delivered archetype, the following can be emphasised; noting that some of them have been inherited from the Real Time Spatial Delphi, and that, therefore have been taken from the original paper of this method:

- It provides an opportunity to share expertise and to benefit from local knowledge and fresh perspectives;
- It allows the participation of different actors in the analysis, and does not limit them to just being data providers;
- Simultaneous computation and delivery of participant responses;
- Any type of supporting material can be included;
- Experts are not forced to respond a fixed number of times and at present time intervals;
- Respondents are not compelled to complete the entire questionnaire in one working session;
- Easy and fast in responding (simply locating points on a WebGIS interface);
- The interpretation of the results is simple and does not require statistical processing;

- The scale and extent of the map are modifiable in real time;
- The expert can instantly consult a number of different supporting GIS map layers;

The most important constraints identified are:

- Difficulty in understanding how the proposed scheme can improved what has been done so far by EIA, or either benefit the environmental assessment process;
- Likely signs of resistance from those practitioners familiar with traditional GIS, and usual methods used for environmental assessment;
- Possible misunderstandings about the proposed approach for spatial development options, specially among those with an extensive experience in Multiple-Criteria Decision Analysis (the classic comparison of alternatives carried out in multi-criteria evaluations is not considered in the proposed application);
- The preparation of the survey and the configuration of the system interface requires a comprehensive study and collection of data, project management skills as well as specific coding knowledge, which makes the preparatory phase rather difficult;
- Emergence of possible prejudices about the ease of use of the system;
- The success or failure in the application of the archetype depends essentially on the commitment, professionalism, knowledge and availability of the participants;
- The problem of drop-out is still present, although lower than in the conventional Delphi;
- There is some resistance and disbelief in adopting this type of technology with a strong subjective basis.

Based on the results observed and discussed earlier, key insights of the evaluation exercise are:

1. It was possible that through a novel geotechnical web application, the members of a multidisciplinary panel of experts based in Mexico, with little or no technical expertise in geographic information science and the use of decision support systems, were able to interact, from their different perspectives, experiences and interests of its members, proposing the most suitable locations for the development of wind energy facilities, under an interdisciplinary consensus approach, and taking into account environment and sustainability issues.

2. Following the above, it was not achievable to come up with a clear consensual area, which is considered to be of the highest priority and strategic relevance for wind energy development in the country (plausible explanations were discussed in the previous chapter).

3. In relation to the previous question, and taking into consideration possible cumulative effects, it was feasible to choose an area where it is deemed that a greater environmental degradation will be caused as a result of the construction of such wind-generated energy complexes.

4. Regardless of these outcomes and the interpretation of consensual areas, the findings of this research, and more concretely those related to the experimental component of it, demonstrate that it is feasible the conduction of an analysis of collective intelligence aimed at reaching a convergence of opinions relative to spatial locations in an energy transition context. This is remarkable in terms of new implications for the processes of environmental assessment, land-use management, strategic planning, and policy development. Therefore, it can be concluded that the stated objectives were fulfilled.

At this point, it is necessary to clarify something important:

Although consensus is advocated, the degree of complexity that this entails has been recognised during the development of this research. It is well known that in the history of humankind and today, decisions are not necessarily taken by consensus, and precisely for this reason, in this work has been encouraged an exercise that seeks to balance and counteract polarisation in decision-making. Certainly, in the collective intelligence analysis a consensus was sought, but it was not forced to build it. Accordingly, for purposes of complexity, like the one implied in the analysis at issue, it is sufficient to find the convergence of opinions of the participants, bearing in mind the definition of this process given in Chapter 2.

I want to express the firmly belief that in Mexico and in the world, it is necessary to promote further an exercise of convergence of views and a healthy exchange of ideas and knowledge (I do not believe in an *absolute consensus*). In Mexico, we have very much experienced what happens when there is social exclusion, scarce or no public participation, as well as when the social and environmental dimensions of sustainability are put aside. The history and level of degradation present in many places has shown us the result of ignoring something as fundamental as this, and especially the consequences of decisions made unilaterally, whether by a single person, few people or small groups that only impose their visions and serve their own interests.

Having responded to the questions that gave rise to this thesis, the following contributions can be highlighted:

a. Proposal of a GSDSS-based SEA approach with practical focus to improve the understanding and future formalisation of SEA in Mexico.
b. Application of the Real-Time Spatial Delphi method in a new spatial planning context.
c. Promotion of a structured sustainability impact management framework useful for the transition process to renewable energy.

d. Implementation of an open and transparent stakeholder engagement and publication consultation exercise in line with international SEA principles.
e. Collaboration in the development of a technological application of Collective Intelligence for the geospatial analysis from an interdisciplinary perspective.

Derived from the outputs of this investigation, with the adoption and implementation of the proposed approach, it is expected to provide the following future benefits.

i. To participate in the development of a systematic approach for assessing the planning of infrastructure projects in renewable energies, adopting the SEA philosophy as an instrument that will enhance sustainability.
ii. To foster a proactive process of identification, evaluation and proposal of spatial development options during SEA, which in turn helps strengthen a framework for transparency in strategic decision making.
iii. To help consolidate the application and adaptation of a tool of territorial strategic intelligence of great utility for the implementation of SEA.
iv. To assist the urgent need to incorporate the considerations of energy transition and climate change into environmental assessment and PPP-making processes. In the belief that through this kind of initiatives, this crucial transformation can be supported, thus contributing to the development of a conceptual framework for the planning of human adaptation to global warming.
v. To provide a broader prospect of alternatives for sound decision-making, among which it is possible to identify strengths and vulnerabilities of geographical locations, that subsequently allow to plan, organise and execute the necessary actions aimed at avoiding or favouring their occurrence with respect to the desired scenario.
vi. Finally, it is intended to influence the construction of a shared structure of strategic thinking that reflects sharper perspectives, and encourages diversity about the changes and opportunities related to the circumscribed study context.

6.2 On more theoretical and conceptual aspects of the research

This research supports the claim to raise the level of consideration given to sustainable development concerns on strategic documents such as policies, plans and programmes, identifying and proposing affected areas in the context of the Mexican wind energy transition that may arise as a result of the implementation of these instruments and its alternative approaches. Furthermore, it is aimed at providing support for more transparent strategic decision-making, delivering relevant and reliable information for those involved in timely and effective PPP making.

The proposed approach openly envisages a shift in focus under a philosophy of strategic thinking, and a coherent, consistent, transparent and sustainable management of environmental impacts sustained over time through the SEA. Accordingly, it can be stated that there are interesting proposals to face the dilemma and the questions posed by sustainable development. One of the most relevant perhaps, Strategic Environmental Assessment, includes a number of important measures that can be taken to address the challenge at its root, which goes beyond the traditional concept of Environmental Impact Assessment of projects (a fundamental approach of separate evaluation, hence, usually limited and isolated under certain circumstances).

Finally, it can be argued that the conduction of a comprehensive Strategic Environmental Assessment will lay the foundations for a review not only of the environmental system, but also the economic, social and geopolitical model of the nation and those regions where it is carried out. This in turn will enable to achieve other solutions more prospective in nature, e.g., boosting and consolidating certain productive sectors as key drivers of regional and national economy i.e., renewable energy, and in parallel promoting a deep decabornisation of the power system as well as a greater independence from the traditional exploitation of energy sources such as oil, gas and nuclear. In the same way, leading to the gradual transition *-yet accelerated and sustained-* towards renewable energy, and the ultimate goal of sustainable development.

In the view of the foregoing and the findings of this thesis, according to the methodology adopted, the present investigation can be considered complete, since the designed artifact has addressed the problem and met the research objectives.

6.3 Future research

At the end of this work, it is crystal clear that more questions and goals may arise, but also the extension of this innovative research line in the environment under study. Concerning scope for future research, there are the new opportunities to be explored which are mentioned in the following bullet points:

- An interesting exercise would consist of comparing the outcomes of a Multi-Criteria Analysis of the study area with the proposed stakeholder's consensus approach; or either using such outcomes (like exclusion zone maps) as some of the input data added to the system, which in turn could be used as a valuable reference information during the analysis. It should be noted that the configuration of the platform allows and supports this feature. Whether it be a comparison of methods or a complementary assistance for provision of information for the evaluation, it should be underlined that both, the purpose of this research and the tool itself, is not to replace well-known methods but to encourage conduction of further experimental research in this field.

- It is suggested that additional evaluation exercises are undertaken with the proposed application incorporating more key stakeholders, not only to obtain new results, but also to advance understanding of SEA fundamental principles such as consultation, public participation, early consideration of sustainability concerns in PPP making, etc. Therefore, contributing to the cause of the future formalisation of SEA in the national legislation.
- In the same line, considering the significant potential of renewable energy in the country. additional practical exercises are also recommended, including other sources such as biomass, solar and geothermal energy. Then eventually the results could be integrated into the National Renewable Energy Inventory (SENER, 2014b).
- Linked with the above, it would be also interesting to integrate into the platform the map layers *(zones considered with high potential and areas identified with high resource quality)* displayed in the new Mexican Atlas of Zones with High Potential of Clean Energies mentioned in Chapter 5. Subsequently, another exercise of collective spatial analysis could be carried out, where, for example, the participants seek to achieve a convergence of opinions about priority areas for renewable energy development considering this special information.
- Here a valuable idea of the authors of the RTSD is supported as well, which means another possible evolution of the system. That consists in taking into account the third dimension in space. In that case, the circle would become a sphere of convergence. This would allow the proposal of site location with even greater precision and from a very different perspective.
- Further experimental research might explore a consensus complemented by setting dates. That means asking the participants of the collective spatial analysis to come up with a target date when providing spatial opinions, for instance, in the case of proposing most suitable locations, priority regions, sensitive zones, etc. Likewise, following Castillo-Rosas et al., (2017) it is endorsed the recommendation to test the use of dates of occurrence proposed by each expert for each event (nearest date, most likely date and farthest date) integrated through a Fuzzy process for the Delphi prospective (Barrera Guarín & Escobar, 2003), aimed at achieving a convergence of opinions likely to happen at a future date.
- Since the system does not have components and applications specifically designed for its use on mobile devices; hence, further research could be undertaken for the adaptation, compatibility and use of the system on tablets and/or mobile phones.

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Glossary

Collective Intelligence: Capacity of human collectives to engage in intellectual cooperation in order to create, innovate and invent.

Collective Spatial Analysis: Situation in which a group of people (through its conclusions, assumptions, or solutions) studies, reflects, and responds to questions that help to determine useful locations to explore, explain, or predict the characteristics or properties necessary for decision-making, taking the complexity of the geographic space in account.

Environmental Assessment: Assessment of the potential environmental effects of a project, plan or programme. It entails the preparation of an environmental report, carrying out consultations, taking into account the environmental report and results of the consultations in decision-making, and providing information on the decision.

Environmental Impact Assessment: The process of examining the anticipated environmental effects of a proposed project from consideration of environmental aspects at design stage, through consultation and preparation of an Environmental Impact Assessment Report, evaluation of this report by a competent authority, and the subsequent decision as to whether the project should be permitted to proceed, encompassing public response to that decision.

Environmental Impact Statement: MIA by its acronym in Spanish, it is the document whereby reports, based on formal studies, the significant and potential environmental impact that would generate a work or activity, specifying how to avoid or mitigate it if it is negative.

Geographic Information System: Computer system for capturing, storing, checking, integrating, manipulating, analysing and displaying data related to positions on the Earth's surface. It is thus a way of linking databases with maps, to display information, perform spatial analyses or develop and apply spatial models.

Mexico: Country in the American continent. Officially the *United Mexican States* is located between latitudes 14° and 33°N, and longitudes 86° and 119°W in the southern half of North America. Covering 1,943,945 square kilometres of land and 20,430 square kilometres of water, Mexico is the 14th largest nation in the world with a total area of 1,964,375 square kilometres. With an estimated population of over 120 million, it is the eleventh most populous country in the world (INEGI, 2016).

Mitigation measure: Measures that avoid, reduce, remediate or compensate for the negative impacts of a strategic action.

Plan: Set of co-ordinated and timed objectives for the implementation of the policy. In the context of spatial planning means the framework for land use in a particular area (i.e. regional, county, city, town or local area).

Policy: Broad statement that sets preferred courses of action. Policies are choices made to carry out the objectives in the foreseeable future.

Programme: Set of projects in a particular area. In the context of spatial planning is the overall strategy that establishes the requirements to be incorporated into plans.

Prospective analysis: More than projections and forecasts, prospective analysis looks into the distant future. It aims not to project what will happen to existing structures over the long term nor to extend trends similar to those determined in the past; rather, it seeks to give shape to the future by introducing diverse scenarios involving different, imagined futures. It is intended to determine the long-term objective that society seeks. It is this long-term goal, this vision of the future, that informs the choices to be made today, thereby guiding decisions and actions.

Renewable energy: Energy that comes from resources which are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves and geothermal heat. Renewable energy is a subset of sustainable energy, and is from an energy resource that is replaced by a natural process at a rate that is equal to or faster than the rate at which that resource is being consumed.

Scoping: The process of determining what should be in an SEA (types of impacts, alternatives to consider) and how the SEA should be carried out (timeframe, methodology etc.). Carried out early in the SEA, ideally in consultation with the competent authority and affected groups.

Screening: The process of determining whether an SEA is needed or not.

S*patial Decision Support System*: Computer-based system that combines conventional data, spatially referenced data and information, and decision logic as a tool for assisting a human decision-maker. It usually includes a user interface for communicating with the decision-maker. A SDSS does not actually make a decision, but instead assists and analysing data and presenting processed information in a form that is friendly to the decision-maker.

Spatial planning: Array of methods and approaches used to influence the future distribution of activities in space. Spatial planning can also be defined as the coordination of practices and policies affecting spatial organisation.

Stakeholder: Someone affected by the strategic action: they have a stake in it.

Strategic Environmental Assessment: The process by which environmental considerations are required to be fully integrated into the preparation of Plans and Programmes and prior to their final adoption. The objectives of the SEA process are to provide for a high level of protection of the environment and to promote sustainable development by contributing to the integration of environmental considerations into the preparation and adoption of specified Plans and Programmes.

Sustainable Development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Appendix A. Existing inventory of wind farms in Mexico

State	Municipality	Items	Installed capacity (MW)
Oaxaca	El Espinal	31	26,35
Oaxaca	Juchitán de Zaragoza	68	102
Oaxaca	Santo Domingo	68	102
Oaxaca	Juchitán de Zaragoza	68	102
Baja California	Mulegé	1	0,6
Oaxaca	Juchitán de Zaragoza	104	84,2
Quintana Roo	Benito Juárez	1	1,5
Tamaulipas	Reynosa	36	54
Oaxaca	Unión Hidalgo	69	90
Oaxaca	Juchitán de Zaragoza	152	137,5
San Luis Potosí	Charcas	100	200
Oaxaca	Ixtaltepec	120	67,5
Baja California	Tecate	52	156
Sonora	Puerto Peñasco	1	2
Oaxaca	Santo Domingo	51	102
Oaxaca	Ixtaltepec	34	102
Oaxaca	Santo Domingo	121	102,85
Oaxaca	Juchitán De Zaragoza	124	164
Oaxaca	Santo Domingo Ingenio	80	160
Chiapas	Arriaga	16	32
Oaxaca	Juchitán de Zaragoza	35	70
Oaxaca	Juchitán de Zaragoza	37	74
Jalisco	Ojuelos de Jalisco	28	50,4
Nuevo León	Santa Catarina	8	22
Oaxaca	El Espinal	35	70
Oaxaca	Juchitán de Zaragoza	300	250,5
Oaxaca	Ixtaltepec	60	80
Oaxaca	Juchitán de Zaragoza	252	234
Oaxaca	Juchitán de Zaragoza	3	0,3
Baja California	Mexicali	5	10
Oaxaca	Juchitán de Zaragoza	82	101,9
Oaxaca	Santo domingo Ingenio	33	49,5
Puebla	Palmar del Bravo	33	66
Oaxaca	El Espinal	37	74
Nuevo León	General Bravo	84	126
Nuevo León	General Bravo	47	126

Appendix B. Doctoral Candidate Activity Report

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Details of the doctoral candidate
Name: José José Diez Rodríguez
Doctoral programme: PhD in Systems and Project Engineering
Barcelona School of Industrial Engineering (ETSEIB)
Title of the thesis: Addressing Strategic Environmental Assessment in Mexico's transition towards renewable energy. Geospatial approach of collective intelligence as prospective support in the planning process.

Thesis supervisor
Name: Lázaro V. Cremades Oliver

Thesis co-supervisor
Name: Brenda Ahumada Cervantes

Activities

Cross-training courses

	Term	Qualification
Research Article Abstracts and Introductions: an approach to writing research	2012-2013	Satisfactory
Guidelines for developing, structuring and writing a final academic work	2012-2013	Satisfactory
Open Access Publishing	2012-2013	Satisfactory
PhD Pathway: Academic Presentations in English	2012-2013	Satisfactory
Presenting in English: 3 steps forward	2012-2013	Satisfactory
Refworks: Bibliographic Reference Manager	2012-2013	Satisfactory
Research Publishing and Evaluation	2012-2013	Satisfactory
Scopus	2012-2013	Satisfactory
Web of Knowledge	2012-2013	Satisfactory
Mendeley Premium: Reference Manager & Academic Social Network	2013-2014	Satisfactory
Inspec, Compendex and IEEE Xplore	2014-2015	Satisfactory
Responsible Conduct in Research and Innovation	2015-2016	Satisfactory
How to publish scientific papers in international journals	2016-2017	Satisfactory

Registered concepts

Type of Studies	Subject Type	Group	Term	Qualification
Doctoral Programme	Tutorship	EPROJ	2012-2013	Satisfactory
Doctoral Programme	Tutorship	EPROJ	2013-2014	Satisfactory
Doctoral Programme	Tutorship	EPROJ	2014-2015	Satisfactory
Doctoral Programme	Tutorship	EPROJ	2015-2016	Satisfactory
Doctoral Programme	Tutorship	EPROJ	2016-2017	Satisfactory
Thesis Proposal	Project	1	2013-2014	Satisfactory

Appendix B. Doctoral Candidate Activity Report

Attendance and participation at congresses and conferences

- Workshop on the application and effectiveness of the Strategic Environmental Assessment - SEA Directive 2001/42/EC; organised by the European Commission. It was held at the Charlemagne Building, Brussels. [May 18th, 2016].

  The participants have examined the implementation of the SEA Directive in EU Member States and drawn out implications for its implementation across the EU as a whole, addressing main issues confronting successful SEA process, in particular: scoping, consideration of alternatives, baseline, and assessment of effects, mainly cumulative effects. Furthermore, integration of the SEA in the plan making process has been considered as a significant challenge for implementing the SEA Directive, yet it is vital to ensure compliance with its objectives as well as integration of the environmental objectives in the overall strategic planning. Last but not the least, it was analysed to what extent the SEA Directive is coherent with other parts of EU environmental law and policy, including environmental impact assessment and appropriate assessment.

- 11th International gvSIG Conference. It has taken place at La Petxina Sports-Cultural Complex (Valencia, Spain), and organised by the gvSIG Association. Participation as a lecturer with the presentation: *"Geospatial Collective Intelligence approach as prospective support in Strategic Environmental Assessment of Renewable Energy"*. [December 2nd - 4th, 2015].

- 19th International Conference on Project Management and Engineering, organised by the Spanish Project Management and Engineering Association (AEIPRO). It was held at the Higher Technical School of Civil Engineering from the University of Granada. Participation in the thematic area *Environmental Engineering, Integrated Environmental Assessment and Alternative Energies* as a lecturer with the paper entitled: *"Addressing Strategic Environmental Assessment of Mexico's transition towards renewable energy".* Published article. [July 15th - 17th, 2015].

- Strategic Environmental Assessment and Sustainability Appraisal Conference: *"Demystifying, easing and improving effectiveness"*. It took place at Oxford Brookes University, UK. [June 1st - 2nd, 2015].

  This conference has provided an opportunity to learn about and debate the effectiveness of SEA and propose measures to improve effectiveness, both in terms of direct benefits (more sustainable plans and programmes) and in more intangible terms such as more informed and involved stakeholders, fewer long-term risks, and organisational change.

- Collective Intelligence Conference 2015. Collaboration within SIGIC Project. Co-author of the paper entitled *"Geospatial System of Collective Intelligence: a technological application for the interdisciplinary study of the geographical space complexity"*, (published article). This conference was organised by the Center for the Study of Complex Systems of the University of Michigan, and it was held in Santa Clara, California, US. [May 31st - June 2nd, 2015].

- Eurodoc Conference 2015 & Annual General Meeting. It took place in Cluj-Napoca, Romania, and was co-organised by the Romanian Society of Doctoral Candidates and Junior Researchers. [April 27th - 30th, 2015].

  The conference "Empowering Young Researchers in Europe: Engagement and Participation" brought together representatives from NGOs across Europe to discuss what they are doing to support early stage researchers. Invited external speakers and Eurodoc members presented how they are dealing with the issues that affect them, and the projects they are working on.

The conference provided an opportunity for sharing ideas and exchanging good practice, and was followed by the Annual General Meeting, during which Eurodoc's projects, strategic aims and goals for the upcoming year were discussed, and the new board was elected.

- IAIA15: *"Impact Assessment in the Digital Era"*. This conference was organised by the International Association for Impact Assessment, and it has taken place at the Firenze Fiera Congress & Exhibition Center. Florence, Italy [April 20th - 23rd, 2015].

  The conference aimed to advance a multidisciplinary discussion on the challenges and opportunities associated with the use of new digital technologies for promoting sustainability.

- IV Symposium des boursiers CONACYT en Europe 2014. It held at the European Parliament in Strasbourg, France. Participation in the Energy panel as a lecturer with the paper entitled *"Abordando la Evaluación Ambiental Estratégica de la transición de México hacia las energías renovables"*. [November 5th - 7th, 2014]

- Annual General Meeting & 10th Anniversary of the Project Management Institute - PMI Barcelona Chapter. It held at the School of Industrial Engineering of Barcelona, [May 29th, 2014].

- Cooperation meeting CONACYT-Catalonia. *Gathering of Conacyt's fellows.* It has taken place at the Polytechnic University of Catalonia BarcelonaTech, Campus Nord, [May 22nd, 2014].

- Eurodoc Conference 2014 & Annual General Meeting. It took place at the Hungarian Academy of Science, the Hungarian Institute of International Affairs, as well as the European Youth Centre Budapest; and organised by the European Council of Doctoral Candidates and Junior Researchers, and the Association of Hungarian PhD and DLA candidates, [March 25th - 30th, 2014].

  This event brought together Early Stage Researchers (ESRs) from across Europe and various other stakeholders in the European Research Area (ERA) and European Higher Education Area to discuss the position of ESRs, and how to face the challenges ahead.

  The conference included a number of plenary sessions and workshops which considered a variety of issues affecting ESRs such as the structural changes being made to improve the position of ESRs and the professional development of researchers, as well as issues such as women in science and Interdisciplinarity.

  Finally, the conference was followed by Eurodoc's AGM, during which Eurodoc's members reviewed the work of the previous year, outlined the plan for the next, and elected a new administrative board.

- 9th International gvSIG Conference: Matter of sovereignty. It has taken place at La Petxina Sports-Cultural Complex (Valencia, Spain). Organised by the gvSIG Association, [November 27th - 29th, 2013].

  The purpose of this conference was getting involved with the gvSIG Project -which raises a new business model around Open Source Software democratic values, based on cooperation and shared knowledge- and familiarising with geospatial information studies through attending a training workshop based on this Geographic Information System.

- Homo Scietificus Europaeus: Seeking a sustainable future for European Science. It held at Ateneu Barcelonès, and co-organised by The Barcelona Knowledge Hub of the Academia Europaea, Euroscience and La Caixa Foundation, [November 8th, 2013].

This event brought together some of the most engaged scientists involved in drawing a better future for European science. The meeting aimed at achieving a balance between evaluating the needs to address the current difficulties, and devising the next steps, to reach the path to recovery.

- The intersection of Society and Nature in Sustainability Research. Celebrated at Uppsala University, Sweden; and organised by the Uppsala Centre for Sustainable Development (CSD Uppsala), [October 1st - 3rd, 2013].

  With the aim of reconciling environment and development concerns, the objective of this conference was to explore how to analyse socio-ecological relations within broader conceptions of sustainability imaginaries and practices. Scientists, social scientists and scholars with various backgrounds were invited to participate. Several approaches were represented at the conference included political ecology, ecological economics, resilience, common pool resource theory and governance, among others.

  The conference was intended to be an important occasion for deepening and developing these various approaches, clarifying where they converge and diverge and what the socio-ecological implications might be. The conference also highlighted remarkable opportunities for cross-fertilization across boundaries that exist amongst academic practitioners, with the view of developing enriched and innovative perspectives.

- Energy Democracy conference, within the programme activities of the Ecoverd Project - *Fira de Cooperació I Sostenibilitat,* during Sustainable Energy Week 2013. It has taken place at the CCIB - International Convention Centre Barcelona, [June 29th - 30th, 2013].

- Open Innovation 2.0: Sustainable Economy & Society - Stability. Jobs. Prosperity. It held at Dublin Castle, Ireland; and co-organised by The European Commission, Open Innovation Strategy & Policy Group, Intel Labs Europe, Dublin City Council and Trinity College Dublin, [May 20th - 21st].

  The objective of this conference was to bring together thought leaders, senior decision makers, policy leaders, leading executives and social innovators to initiate the development of a manifesto, as well as a platform and roadmap for sustainable economy and society development. The event was organised under the patronage of the Irish Presidency of the European Union 2013.

- II Symposium de boursiers et ex-boursiers du CONACYT - Europe Edition. It held at the European Parliament in Strasbourg, France, [November 29th - 30th, 2012]

- Barcelona Forum on PhD - 2012 edition, “PhD as innovation catalyst for the industry”. It has taken place at the Polytechnic University of Catalonia BarcelonaTech, Campus Nord [October 15th, 2012].

Specialised training on the research topic

- Certificate course in *Spatial Multicriteria Analysis for Environmental Decision-Making*. It held at the Department of Civil, Environmental and Mechanical Engineering. University of Trento, Italy. [17th - 19th February, 2016].

  This course has provided the essential principles of Multicriteria Analysis (MCA) and Spatial Multicriteria Analysis (SMCA) applied to environmental decision-making, generally covering the following topics:

  a. Basic concepts of decision theory and problem structuring.
  b. The philosophy of SMCA for environmental decisions.

c. *Methodological steps in MCA and SMCA (value function and weight assessment, criteria aggregation, sensitivity analysis, result presentation). Overview of main MCA and SMCA methods.*
d. *Using Decision Support Systems (DSS) and GIS-based DSS.*
e. *Real-life case studies in different domains.*

- Training course in *Cumulative Effects Assessment and Management (CEAM)* delivered by the International Association for impact Assessment in cooperation with Levett-Therivel Sustainability Consultants. It was held at the Firenze Fiera Congress & Exhibition Center. Florence, Italy [April 18th - 19th, 2015].

    The course aimed to teach participants what cumulative effects are, how to identify and predict them, and how to mitigate them. CEAM considers effects on receptors rather than the effects of a plan/project, and so requires a different mindset from "normal" impact assessment. The course has also discussed how to identify affected receptors, techniques for assessing and evaluating cumulative effects, and what "other plans and projects" should be considered in CEAM. Cumulative effects usually require "cumulative mitigation", which in turn requires the collaboration of multiple institutions: the course have addressed some of the issues surrounding this, and how to overcome institutional constraints. It has examined several successful CEA analyses and mitigation measures, including a range of workshops.

- UVP-Tutorial 2014. Sustainability Impact Assessment (SIA) of Policies, Plans and Programmes – A methods workshop. It took place at the Seminaris Hotel (Bad Honnef, Germany). This was a joint Workshop from the German EIA Association in cooperation with LIAISEoffspring - Early career support for Impact Assessment [September 29th, 2014].

    The tutorial brought together early stage researchers and practitioners who work or are interested in various types of SIA, ranging from plan, programme and policy-level appraisals. Participants with diverse backgrounds were invited - from planners, engineers to social scientists. The workshop aimed at providing the participants with fundamental knowledge of SIA procedures and methods and at fostering interdisciplinary exchange between the participants.

- Certificate course in *Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA). Applying Systems Analysis and Spatial Decision Support tools*. It held at the Faculty of Geo-Information Science and Earth Observation. University of Twente, Enschede, the Netherlands [July, 2014].

    This training was taught by the International Institute for Geo-Information Science and Earth Observation (ITC University of Twente); an institution that enjoys international prestige and recognition in the field of Environmental Assessment. The event brought together leading personalities from various academic and professional spheres of different countries around the world. Participants with different backgrounds, who share practical experience and affinity in the implementation of EIA and SEA were selected through a careful evaluation process. As a result of this phase a multidisciplinary elite group composed of scientists and academics involved in development planning, as well as representatives of NGOs, government agencies, reviewers, consultants, experts, students and professionals working in the environmental field was formed.

    The course approach involved task-based learning that blended theory and practice. Likewise, it provided a unique opportunity to strengthen the spatial planning process through environmental assessment using spatial information and spatial decision support tools. The course had a problem-solving, hands-on approach, using examples and data from different parts of the world. Hence, the working sessions offered a good opportunity to meet and exchange ideas with an international group of students and professionals with a shared interest in Environmental Assessment, Disaster Risk Management and Sustainable Development.

Appendix B. Doctoral Candidate Activity Report

Evolution of the studies

- Scientific Groundwork for Research Skills Development.
- Study of relevant technical literature.
- Development of theoretical framework and methodological approach.
- Implementation of effective research strategies.
- Access to specialised training on the research topic.
- Conduction of empirical research and fieldwork.
- Analysis of results and final remarks.

Doctoral stays abroad

- Research stay and scientific collaboration with the *Environmental Assessment and Management Research Centre of the University of Liverpool* aimed at strengthening an innovative Strategic Environmental Assessment methodological approach as prospective support in the spatial planning process [March - May 2016].

- Research stay at the *Faculty of Geo-Information Science and Earth Observation (ITC)* of the *University of Twente (UT)* in order to deepen the study of Strategic Environmental Assessment; addressing the energy transition process, developing and promoting a participatory approach to sustainable planning when applying systems analysis and Spatial Decision Support Tools [starting date: early June 2015 / target completion date: end-September 2015].

Publication in scientific journal

- Co-author of the paper entitled: *"Collection and Integration of Local Knowledge and Experience through a Collective Spatial Analysis".* International Journal of Geo-Information. Published: January 24th, 2017].

Reviewer for scientific journal

- Reviewer of the manuscript entitled: *"Guidelines for consideration of bats in environmental impact assessment of wind farms in Brazil: a collaborative governance experience from Rio Grande do Sul".* (2017). Oecologia Australis, (Environmental impacts: case studies in South America). A publication of the Postgraduate Program in Ecology of the Federal University of Rio de Janeiro. Retrieved from http://oecologiaaustralis.org/

Affiliation

- Associate Member of the Global Network of Highly Qualified Mexicans | Barcelona Chapter, [September 2016]. The Barcelona Chapter of the Global Network MX is an association whose mission is to contribute to the development of Mexico by creating a network of people based in Spain that establish links between strategic sectors for the successful generation of business, technology development and as well as the exchange of ideas and human resources between the two countries.

- Member of the Grameen Creative Lab Community, [October 2014]. The Grameen Creative Lab is a social platform as well as social business promoter and incubator co-founded by Nobel Peace Prize laureate Prof. Muhammad Yunus. This project aims to contribute to poverty reduction and sustainable development by promoting, developing and implementing social business ideas and projects.

Appendix B. Doctoral Candidate Activity Report

- Member of Euroscience, [May 2014]. Euroscience is a pan-European grassroots organisation for the support and promotion of science and technology in Europe. This association represents European scientists of all disciplines (natural sciences, mathematics, medical sciences, engineering, social sciences, humanities and the arts), institutions of the public sector, universities, research institutes as well as the business and industry sector.

- Member of the LIAISE Community, [April 2014]. The LIAISE community brings together researchers and practitioners from different disciplines and policy domains in the spirit of problem-oriented, inter- and transdisciplinary, excellent research for Impact Assessment. This collective is composed of several groups of researchers with backgrounds in environmental sciences, economics, modelling and policy analysis. Essentially, LIASE works as platform to support Policy Impact Assessment for Sustainable Development.

- Affiliation to the Project Management Institute (PMI®), [February 2014]. The PMI is the world's leading not-for-profit professional membership association for the project, program and portfolio management profession. PMI delivers value for project management professionals working in nearly every country in the world through global advocacy, collaboration, education and research. PMI advances careers, improves organizational success and further matures the profession of project management through its globally recognized standards, certifications, resources, tools, academic research, publications, professional development courses, and networking opportunities. Moreover, joined and forming part of PMI Barcelona Chapter.

- Association to the European Council of Doctoral Candidates and Junior Researches [December 2013]. EURODOC© is an international federation of 32 national organisations of PhD candidates from the European Union and the Council of Europe. Furthermore, appointed Official Delegate of the National Spanish Association. *It should be noted that the federation currently operates its platform through nine working groups: Career Development, Gender Equality, Interdisciplinarity, Mobility, Policy Research, Open Access, Governance, Finance, and PhD training.*

- Affiliation to the International Association for Impact Assessment (IAIA©), [July 2013]. The IAIA is the leading global network on best practice in the use of impact assessment for informed decision making regarding policies, programmes, plans and projects. IAIA members are an interdisciplinary group of individuals and organisations whose aim is the development of better environmental outcomes. Representing over 120 different nations, IAIA members also have varied interest areas, such as health, economics, public participation, biodiversity and ecology, corporate stewardship, and strategic environmental assessment, among many others.

Appendix C. Response history.
Raw data - Site location of onshore wind energy in Mexico.

fecha	estado	argumento	idpregunta	x	y
07/02/2017	1	Mayor impacto ambiental: Península de Yucatán por su riqueza natural y la migración de aves en esa zona.	57	-88,920801	21,217443
07/02/2017	1	Mayor prioridad: el noreste del país porque existe un gran potencial eólico y también una gran demanda por electricidad.	56	-98,808496	25,849088
07/02/2017	1	Para la región sur: Oaxaca, Yucatán, Campeche y Quintana Roo.	55	-96,149805	17,444728
07/02/2017	1	Para le región centro del país: Aguascalientes y Estado de Hidalgo	54	-102,56582	22,522451
07/02/2017	1	Para la región norte del país: Baja California, Baja California Sur, Chihuahua, Tamaulipas, Nuevo León, Zacatecas y Sinaloa.	53	-102,917383	22,563038
07/02/2017	0	Para la región norte del país: Baja California, Baja California Sur, Chihuahua, Tamaulipas, Nuevo León, Zacatecas y Sinaloa.	53	-112,497461	27,146899
29/11/2016	1	Zona ambientalmente sensible	57	-87,580469	20,807213
29/11/2016	1	Recurso eólico abundante	56	-94,348047	16,30933
29/11/2016	1	Recurso eólico abundante.	55	-95,051172	16,351503
24/11/2016	0	Zona ambientalmente sensible	57	-87,228906	20,889349
24/11/2016	0	Recurso eólico abundante.	55	-95,095117	16,267149
24/11/2016	0	Recurso eólico abundante	56	-94,348047	16,182759
09/12/2016	1	Esta zona de Veracruz cuenta con alta densidad de potencia eólica y está identificada en el inventario de energía eólica potencial. Además, cuenta con líneas de transmisión de electricidad y el Estado de Veracruz es de los que cuentan con mayor población en México además de las actividades industriales que se desarrollan cercanas a esta zona por lo que se tienen bastantes clientes potenciales para la venta de la energía renovable que se produzca.	54	-96,248682	19,103387
09/12/2016	1	En la región de Tamaulipas se tiene grandes áreas con alta densidad de potencia del viento, ya cuenta con algunas plantas de energía eólica por lo que se tiene infraestructura de conexión a la red nacional de electricidad y está cercano a algunos estados con alta actividad industrial (Nuevo León, S.L.P., Guanajuato, etc.) por lo que tiene varios clientes potenciales para la venta de energía renovable.	53	-97,92959	24,916081
20/11/2016	0	En la parte norte de Baja California por la zona de la Rumorosa se tienen fuertes vientos con un alto potencial de energía eólica y se cuenta con líneas de transmisión de electricidad que pueden conectar la energía producida a las principales ciudades del estado (Tijuana, Mexicali, Ensenada), así como la posibilidad de exportar energía eólica al estado de California en EUA que tiene el objetivo de incrementar de manera importante su porcentaje de energía renovable.	53	-116,179555	32,449368

Appendix C. Response history.
Raw data - Site location of onshore wind energy in Mexico.

fecha	estado	argumento	idpregunta	x	y
20/11/2016	0	En la parte norte de Baja California por la zona de la Rumorosa se tienen fuertes vientos con un alto potencial de energía eólica y se cuenta con líneas de transmisión de electricidad que pueden conectar la energía producida a las principales ciudades del estado (Tijuana, Mexicali, Ensenada), así como la posibilidad de exportar energía eólica al estado de California en EUA que tiene el objetivo de incrementar de manera importante su porcentaje de energía renovable.	53	-116,157582	32,486444
20/11/2016	1	Considero que se podría tener una mayor degradación ambiental en zonas cercanas al mar porque quizás haya ecosistemas que sean más sensibles por estar entre zona terrestre y marina, por lo que en este caso considero que las zonas más vulnerables en cuanto a posibles daños estarían en zonas del estado de Tamaulipas cercanas al Golfo de México que son las franjas donde hay mayor densidad de potencia del viento.	57	-97,898305	25,299174
20/11/2016	1	Considero que el Golfo de Tehuantepec sería zona prioritaria por el alto potencial de energía eólica y por las necesidades de las poblaciones locales por lo que se requiere considerar esquemas de desarrollo de energía eólica que beneficien de manera importante a las comunidades donde se desarrollen estos proyectos, incluyendo el desarrollo regional.	56	-94,844106	17,082868
20/11/2016	1	El Golfo de Tehuantepec en el Estado de Oaxaca es donde se muestra las mayores densidades de potencia del viento en el documento de Diagnóstico de Energías Renovables de México.	55	-94,492543	17,040857
20/11/2016	0	En el documento de Diagnóstico de Energías Renovables de México se puede observar que la región de Tamaulipas tiene grandes áreas con alta densidad de potencia del viento. En principio podría decirse que Tamaulipas es parte del Norte de México por estar en la frontera norte del país colindando con Estados Unidos, sin embargo, por su ubicación geográfica está cercano a estados del centro del país (San Luis Potosí, Guanajuato, etc.) por lo que podemos considerarlo como parte del Centro de México.	54	-97,986196	24,711741
20/11/2016	0	En la parte norte de Baja California por la zona de la Rumorosa se tienen fuertes vientos con un alto potencial de energía eólica y se cuenta con líneas de transmisión de electricidad que pueden conectar la energía producida a las principales ciudades del estado (Tijuana, Mexicali, Ensenada), así como la posibilidad de exportar energía eólica al estado de California en EUA que tiene el objetivo de incrementar de manera importante su porcentaje de energía renovable.	53	-116,231444	32,557417
21/11/2016	1	Dada la escasez de líneas de transmisión, esta es probablemente la zona más importante ahora por su cercanía con consumidores de alto volumen.	56	-101,154753	23,577094

Appendix C. Response history.
Raw data - Site location of onshore wind energy in Mexico.

fecha	estado	argumento	idpregunta	x	y
21/11/2016	1	Zona con el mayor potencial eólico en México. Sin embargo, hay problemas sociales importantes, poblaciones indígenas en el área y la autoridad ambiental debe dar a conocer la mortandad de aves que puede estar ocurriendo. Esto es muy importante para la evaluación de potenciales efectos negativos acumulativos sobre las mismas.	55	-94,76071	16,481408
21/11/2016	1	Zona con buen potencial, cerca de los centros de consumo.	54	-101,500822	25,476025
21/11/2016	1	Es la zona con menores impactos ambientales y sociales.	53	-116,189543	32,345641
30/11/2016	1	La zona noreste	56	-98,039453	25,264319
30/11/2016	1	Yucatán	57	-88,788965	21,268642
29/11/2016	1	La zona norte y en particular la zona noreste de México ya que tiene una gran calidad de viento con Factores de Planta de +/- 43%. Esto aunado a un muy bajo impacto en el medio ambiente y pocas comunidades indígenas.	53	-98,127344	24,216658
23/11/2016	0	Yucatán	57	-89,030664	21,606108
23/11/2016	0	La zona noreste	56	-97,51211	27,712466
23/11/2016	1	El estado de Yucatán posee buena calidad de viento, pero es una zona selvática y con especies endémicas, donde la flora y la fauna pueden ser un problema para el desarrollo normal de proyectos eólicos. También la zona posee una fuerte población de comunidades indígenas (mayas). Sin embargo, actualmente se están desarrollando varios proyectos eólicos en la zona.	55	-88,854883	20,950922
23/11/2016	1	La zona centro de México tiene buenos factores de planta (+/-33%), pero con la ventaja de que cuenta con infraestructura de evacuación y cercano a centros de consumo.	54	-100,895899	20,539963
23/11/2016	0	La zona norte y en particular la zona noreste de México ya que tiene una gran calidad de viento con Factores de Planta de +/- 43%. Esto aunado a un muy bajo impacto en el medio ambiente y pocas comunidades indígenas.	53	-97,204492	27,47879
07/12/2016	1	La misma zona	56	-95,312806	18,302589
07/12/2016	1	Hay un potencial eólico muy fuerte	55	-95,049134	16,541641
19/11/2016	1	Guerrero Negro tiene un potencial de producción de 18 GWh/año sin embargo es una zona de extremada fragilidad ecológica.	57	-114,060975	28,526816
19/11/2016	1	Cozumel-Cancún tiene un potencial de producción de 175 GWh/año, para abastecer la principal zona turística del país.	56	-87,518006	20,416923
19/11/2016	1	La venta es el sitio más propicio para el desarrollo de la energía eólica en el país, con un potencial de 6132 GWh/año.	55	-96,504823	16,141027
19/11/2016	1	El Estado de Hidalgo tiene un potencial de producción de 201 GWh/año.	54	-98,96576	20,437514

Appendix C. Response history.
Raw data - Site location of onshore wind energy in Mexico.

fecha	estado	argumento	idpregunta	x	y
19/11/2016	1	Esta es una zona tiene un potencial de producción calculado de 175 GWH/año.	53	-109,996034	23,302103
08/12/2016	1	La zona de Quintana Roo cercana a la costa presenta unas condiciones ambientales que pueden hacer más difícil la compatibilidad de proyectos. Sin embargo, se trata de una zona con una antropización y un nivel de afectación muy altos derivados de las infraestructuras turísticas de todo tipo.	57	-87,020349	20,996845
08/12/2016	0		57	-87,665796	20,24366
08/12/2016	1	Por los motivos de sostenibilidad anteriormente apuntados, el Estado de Tamaulipas y regiones aledañas presentan unas condiciones idóneas para el desarrollo de la energía eólica. El tema de la seguridad constituye, no obstante, un handicap para el desarrollo de proyectos.	56	-98,135767	23,71698
08/12/2016	0	Por los motivos de sostenibilidad anteriormente apuntados, el Estado de Tamaulipas y regiones aledañas presentan unas condiciones idóneas para el desarrollo de la energía eólica. El tema de la seguridad constituye, no obstante, un handicap para el desarrollo de proyectos.	56	-89,533472	13,284873
08/12/2016	0	Por los motivos de sostenibilidad anteriormente apuntados, el Estado de Tamaulipas y regiones aledañas presentan unas condiciones idóneas para el desarrollo de la energía eólica. El tema de la seguridad constituye, no obstante, un handicap para el desarrollo de proyectos.	56	-98,179712	23,938078
08/12/2016	1	El Istmo de Tehuantepec es uno de los mejores emplazamientos desde el punto de vista de recurso eólico. Sin embargo, la situación social puede hacer que los proyectos presenten serios problemas, tanto en fase de construcción como en fase de operación y mantenimiento. Falta seguridad jurídica y, en ocasiones, física para el desarrollo de los proyectos. El Gobierno Federal tiene menor proyección de la necesaria.	55	-94,827326	16,470722
08/12/2016	1	La parte sur del Estado de Tamaulipas presenta buenas condiciones por los motivos apuntados en la cuestión 1. No obstante, la variable indígena en esta zona sí que es una cuestión a estudiar, ya que si se produce afectación a comunidades indígenas el proyecto estará sometido a un proceso de consulta con las comunidades que puedan resultar directamente afectadas por el proyecto.	54	-98,704126	22,527525
08/12/2016	1	El Estado de Tamaulipas presenta unas condiciones idóneas desde el punto de vista de sostenibilidad. Su incidencia ambiental es más baja que en otros lugares (menor afectación a la cubierta vegetal, así como a aves y mamíferos). A nivel social, no existe apenas presencia ni afectación a comunidades indígenas, por lo que el proyecto no está sujeto a consulta. La densidad de patrimonio cultural es baja.	53	-98,671167	24,351849

Appendix C. Response history.
Raw data - Site location of onshore wind energy in Mexico.

fecha	estado	argumento	idpregunta	x	y
01/12/2016	1	El desarrollo de proyectos eólicos en la región de la península de baja california, es de suma relevancia, ya que el sistema de interconexión de la Península actualmente se encuentra aislado.	56	-112,454194	26,85309
01/12/2016	1	Esta región, tiene un alto potencial geotérmico.	54	-100,577973	20,055522
01/12/2016	1	La región norte del país, presenta un alto potencial para el desarrollo de proyectos de tipo híbrido (eólico-fotovoltaico), además de que esta región del país no presenta tantos retos de zonas naturalmente protegidas o municipios con alta población indígena.	53	-103,865288	27,927605
01/12/2016	0	La región norte del país, presenta un alto potencial para el desarrollo de proyectos de tipo híbrido (eólico-fotovoltaico), además de que esta región del país no presenta tantos retos de zonas naturalmente protegidas o municipios con alta población indígena.	53	-113,011406	28,044025
01/12/2016	0	La región norte del país, presenta un alto potencial para el desarrollo de proyectos de tipo híbrido (eólico-fotovoltaico), además de que esta región del país no presenta tantos retos de zonas naturalmente protegidas o municipios con alta población indígena.	53	-104,003647	28,00402
01/12/2016	0	La región norte del país, presenta un alto potencial para el desarrollo de proyectos de tipo híbrido (eólico-fotovoltaico), además de que esta región del país no presenta tantos retos de zonas naturalmente protegidas o municipios con alta población indígena.	53	-103,874558	27,705333
01/12/2016	0	Esta región, tiene un alto potencial geotérmico.	54	-100,542954	19,554526
01/12/2016	1	Esta es una región de alta concentración de especies de flora y fauna. Además de ser áreas naturales protegidas y parte del corredor biológico mesoamericano.	57	-91,001328	16,691359
01/12/2016	0	El desarrollo de proyectos eólicos en la región de la península de baja california, es de suma relevancia, ya que el sistema de interconexión de la Península actualmente se encuentra aislado.	56	-113,501328	28,122779
01/12/2016	1	Alto potencial de energía eólica, lo que incluso permitiría el desarrollo e implementación de proyectos híbridos.	55	-96,56041	16,248868
01/12/2016	0	Esta región, tiene un alto potencial geotérmico.	54	-99,966171	18,929582
01/12/2016	0	La región norte del país, presenta un alto potencial para el desarrollo de proyectos de tipo híbrido (eólico-fotovoltaico), además de que esta región del país no presenta tantos retos de zonas naturalmente protegidas o municipios con alta población indígena.	53	-103,218125	26,816634

Appendix D. History of geoconsensuses.
Raw data - Site location of onshore wind energy in Mexico.

radio	area	idpregunta	x	y	fecha
624431,8892	1,22495E+12	53	-98,671167	24,351849	07/02/2017
838577,2693	2,20921E+12	53	-103,865288	27,927605	07/02/2017
728712,9964	1,66826E+12	53	-98,671167	24,351849	09/12/2016
890000,126	2,48846E+12	53	-103,865288	27,927605	08/12/2016
1187606,775	4,43093E+12	53	-103,865288	27,927605	01/12/2016
671892,0855	1,41824E+12	53	-113,011406	28,044025	01/12/2016
1175919,964	4,34416E+12	53	-104,003647	28,00402	01/12/2016
1183353,467	4,39925E+12	53	-103,874558	27,705333	01/12/2016
1238856,199	4,82161E+12	53	-103,218125	26,816634	01/12/2016
1332421,875	5,57742E+12	53	-116,189543	32,345641	29/11/2016
1332421,875	5,57742E+12	53	-116,189543	32,345641	23/11/2016
673071,1988	1,42322E+12	53	-116,189543	32,345641	21/11/2016
1100000	3,80133E+12	53	-107,0738356	27,9559313	20/11/2016
1100000	3,80133E+12	53	-107,0738356	27,9559313	20/11/2016
1100000	3,80133E+12	53	-107,0738356	27,9559313	20/11/2016
1100000	3,80133E+12	53	-107,0738356	27,9559313	19/11/2016
1100000	3,80133E+12	53	-107,0738356	27,9559313	06/11/2016
296449,8973	2,76091E+11	54	-98,96576	20,437514	07/02/2017
251737,2665	1,99088E+11	54	-98,96576	20,437514	09/12/2016
251737,2665	1,99088E+11	54	-98,96576	20,437514	08/12/2016
371030,7838	4,32484E+11	54	-98,96576	20,437514	01/12/2016
371030,7838	4,32484E+11	54	-98,96576	20,437514	01/12/2016
371030,7838	4,32484E+11	54	-98,96576	20,437514	01/12/2016
526854,8248	8,72031E+11	54	-97,986196	24,711741	23/11/2016
464611,3767	6,78156E+11	54	-97,986196	24,711741	21/11/2016
665000	1,38929E+12	54	-99,8886117	20,2005524	20/11/2016
665000	1,38929E+12	54	-99,8886117	20,2005524	19/11/2016
665000	1,38929E+12	54	-99,8886117	20,2005524	06/11/2016
123172,1083	47662259057	55	-95,049134	16,541641	07/02/2017
71564,66936	16089672748	55	-94,76071	16,481408	08/12/2016
126740,9472	50464243820	55	-95,049134	16,541641	07/12/2016
163649,6173	84135612499	55	-95,051172	16,351503	01/12/2016
132534,3147	55183157461	55	-95,051172	16,351503	29/11/2016
134845,9134	57124899855	55	-94,76071	16,481408	24/11/2016
198127,1575	1,23321E+11	55	-94,76071	16,481408	23/11/2016
134845,9134	57124899855	55	-94,76071	16,481408	21/11/2016
850000	2,2698E+12	55	-94,1283205	17,0880271	20/11/2016
850000	2,2698E+12	55	-94,1283205	17,0880271	19/11/2016
793907,4021	1,98011E+12	56	-98,135767	23,71698	07/02/2017
869469,2726	2,37497E+12	56	-98,135767	23,71698	08/12/2016
866668,5283	2,3597E+12	56	-89,533472	13,284873	08/12/2016
888690,1712	2,48114E+12	56	-95,312806	18,302589	08/12/2016
895779,3686	2,52088E+12	56	-95,312806	18,302589	07/12/2016
1040463,07	3,40097E+12	56	-94,844106	17,082868	01/12/2016
1040463,07	3,40097E+12	56	-94,844106	17,082868	01/12/2016
972662,8746	2,97218E+12	56	-94,844106	17,082868	30/11/2016
974133,754	2,98117E+12	56	-94,844106	17,082868	29/11/2016
974133,754	2,98117E+12	56	-94,844106	17,082868	24/11/2016

Appendix D. History of geoconsensuses.
Raw data - Site location of onshore wind energy in Mexico.

radio	area	idpregunta	x	y	fecha
1043404,829	3,42023E+12	56	-101,154753	23,577094	23/11/2016
974133,754	2,98117E+12	56	-94,844106	17,082868	21/11/2016
1760000	9,7314E+12	56	-102,0165041	24,4768985	20/11/2016
1760000	9,7314E+12	56	-102,0165041	24,4768985	19/11/2016
386426,5766	4,6912E+11	57	-87,580469	20,807213	07/02/2017
592611,9449	1,10329E+12	57	-88,788965	21,268642	08/12/2016
558348,264	9,794E+11	57	-87,665796	20,24366	08/12/2016
859115,372	2,31874E+12	57	-88,788965	21,268642	01/12/2016
1125618,799	3,98045E+12	57	-88,788965	21,268642	30/11/2016
1084142,37	3,69252E+12	57	-89,030664	21,606108	29/11/2016
1084142,37	3,69252E+12	57	-89,030664	21,606108	24/11/2016
1463973,969	6,73312E+12	57	-97,898305	25,299174	23/11/2016
1760000	9,7314E+12	57	-102,0165041	24,4768985	20/11/2016
1760000	9,7314E+12	57	-102,0165041	24,4768985	19/11/2016

Appendix E. Unconditional offer for a doctoral stay at the University of Liverpool

UNIVERSITY OF LIVERPOOL

School of Environmental Sciences

School Support Office (South Campus)
Gordon Stephenson Building
Bedford Street South
Liverpool
L69 7ZQ

T 0151 794 2874
F 0151 794 3125
E envsci@liv.ac.uk

www.liv.ac.uk/environmental-sciences

Jose Diez Rodriguez
Plaza Sagrada Familia 13
Fifth Floor, Second Door
Barcelona
Spain 08025

19 November 2015

Dear Jose (201175578)

I am pleased to inform you that we have agreed to accept you as a full time Visiting Research Student to work under the supervision of Professor Thomas Fischer in the School of Environmental Sciences. You will register as a General Postgraduate Research student for the period of 1st March 2016 to 31st May 2016.

The tuition fee for the duration of your research is £500.

The offer is unconditional as you have met the requirements of entry.

Please note that you will also need to meet any requirements set by the UK authorities in connection with obtaining a visa for studying in the UK. Please consult the UK Visas and Immigration website directly at https://www.gov.uk/government/organisations/uk-visas-and-immigration

Please note that Ailen will not be in receipt of any payments whilst registered at the University of Liverpool.

Yours sincerely

Professor Hill Kulu
School Director of Postgraduate Research

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UNIVERSITY OF TWENTE.

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

PAGE
1 of 1

CERTIFICATE

Hereby I, the undersigned, lecturer of the Department of Natural Resources of the University of Twente, certify that **José José DIEZ RODRÍGUEZ**, with Dutch ID number NLD92952890, and PhD candidate from the Polytechnic University of Catalonia BarcelonaTech (UPC) has conducted a doctoral stay in our department as a visiting scientist, covering the period from 1st June 2015 until 1st October.

This activity is framed within the academic programme as part of the development of his doctoral thesis. In recognition whereof, I sign the present letter.

Enschede, The Netherlands, 1st October, 2015.

Drs. Joan Looijen

Academic tutor during the stay
Department of Natural Resources
Faculty of ITC
University of Twente

UNIVERSITY OF TWENTE
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