7th International Conference on Wind Turbine Noise Rotterdam – 2nd to 5th May 2017

"Addressing a Management Strategy of Wind Farms Noise Control in Chile"

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Summary

During the last years, wind energy has grown exponentially around the world. Non-conventional renewable energies (NCRE) have had an important impact on society, seeking to establish itself as one of the main sources of energy in many countries.

One of the most important challenges in the development of wind energy is to promote the use of NCRE, avoiding the environmental impacts to the communities. To generate an assessment strategy and guidelines that allow the development of clean energy, in all its aspects, is the challenge that today stands out and addresses wind energy.

One of the goals committed in the Chilean National Energy Policy is that by 2050 at least 70% of the national electricity generation comes from renewable energies, for which, within the guidelines of the aforementioned policy, is to promote a high penetration of renewable energies in the electrical matrix. Likewise, in relationship to environmental effects, the National Energy Policy recognizes that the country's progress will require improving the regulatory framework through programs to review and elaborate new regulations, environmental management instruments and standards of environmental sustainability reaching the energy sector, with coordination between different government entities that can contribute to the sustainable development of the NCRE.

The present work aims to perform an evaluation of standards and tools of noise management of wind farms, generating also an analysis of the current situation of the System of Environmental Impact Assessment (SEIA) in Chile and the practices that must be improved for the management of the noise of this type of projects. It is intended to establish future work paths related to the sustainable development of wind projects in the country, presenting the guidelines for the development of a management strategy of wind farms noise (WFN) control in Chile.

Key words: Wind Farms Noise Assessment, Management Strategy, Wind Farms Noise Control, Government Alliance.

1. Introduction

Noise is one of the most important impacts generated by wind farms and is also a complex issue to tackle, so research, generation of knowledge and noise reduction of wind turbines are necessary for the progress of this renewable energy sector (5).

Wind power in Chile by December 2016, has 1039 MW operating and has a high potential to develop, especially in the regions of Antofagasta, Coquimbo, Biobío and Los Lagos. Thus, at the same date, there was 5,706 MW environmentally approved in the SEIA and 1,700 MW in the environmental qualification process. The northern part of the country has large tracts of land where projects have been set up without any impact on the community. However, as they approach the central and southern areas of the country, project areas tend to present rural communities due to development of agricultural and livestock activities in these areas.

Lately in Chile, noise from wind farms has caused negative reactions from some communities, with some projects already in operation being questioned. This has generated concern in the energy sector, especially in view of future projects, as the development of wind energy will continue to increase, which will require a proper study of noise phenomena that could have an impact on the community.

1.1 Renewables and Wind Energy in Chile

In recent years, there has been a large growth of non-conventional renewable energy (NCRE) in Chile. In 2005, there were 286 MW of NCRE capacity installed, while a total of 3018 MW was achieved in January 2017, to constitute 13% of the country's electricity generation.

One of the important characteristics of wind energy is its variability condition, as it depends on the atmospheric conditions. This leads to the need for wind measurements to determine the yield related to the capacity factor of the resource in the country.

Thus, the Ministry of Energy in Chile has developed important analyzes of the north, center and south of the country, establishing areas with an interesting wind potential, highlighting the significant wind profiles in the north and south of the country, mainly near coastal and mountainous areas. To date it has been possible to identify areas with great wind potential, reaching values close to 40 GW, among which are areas with a presence of population under schemes of different population density. In these areas, the objective is to promote the development of wind energy projects in a harmonious and compatible way with human activity, in order to move towards a sustainable energy and to be able to fulfill in this way with the goal established in the National Policy of Energy for the year 2050 that establishes that at least 70% of the national electricity generation must come from renewable energies.

Due to the development of wind energy, there is a need to generate, together with the Ministry of Environment, a Program for the Review and Development of new regulations and instruments for environmental management that affect the energy sector. In this process, the Ministry of Energy in coordination with the Ministry of Environment will address the environmental management issues that are considered necessary to include in the regulatory review. In this context, the current situation of evaluation of wind farms in the country should be modified, establishing new management instruments, particularly for the management of WFN control in Chile.

1.2 Energy Policy of Chile

The Energy Policy of Chile (1), "Energy 2050", proposes a vision of the energy sector by 2050 that corresponds to a reliable, sustainable, inclusive and competitive sector. This view is based on a systemic approach, which proposes as its main objective to achieve and maintain the reliability of the entire energy system, while meeting sustainability and inclusion criteria and contributing to the competitiveness of the country’s economy. In short, through these attributes, it is established as an objective to move towards a sustainable energy in all its dimensions.

To achieve this vision by 2050, the Energy Policy is based on 4 pillars: Security and Quality of Supply, Energy as a Development Engine, Compatibility with the Environment and Energy Efficiency and Education. On these bases, the various measures and plans of action proposed up to the year 2050 must be developed.

The Energy Policy 2050 recognizes that the country's progress will require the improvement of the regulatory framework on a regular basis, through programs for the revision and elaboration of new regulations and environmental management instruments and sustainability standards for the energy sector, in coordination between different government entities. These programs should reflect the interests of society, ensuring the maximization of social welfare, as well as progressively reducing the gaps between the existing environmental regulations in Chile and those in other countries of the Organization for Economic Co-operation and Development (OECD). The foregoing will also involve revising such regulations and standards to keep the country's regulatory framework updated with the best international practices.

Thus, at the end of 2016, an alliance is created between the Ministry of Energy and the Ministry of Environment, generating an agreement that will allow to develop a work for the sustainable development of wind energy, particularly addressing a management strategy of WFN control in Chile. The creation of this alliance aims to study the current regulatory framework for WFN and the management strategies of this source at the international framework, seeking to generate the management instruments that allow both the developer and the project consultant, an implementation in accordance with the current international standards, avoiding to generate impacts to the community in future projects. The strategy is sustained in three key stages: Diagnosis, Design and Implementation. Figure 1 shows the particular activities in a general view of each stage.

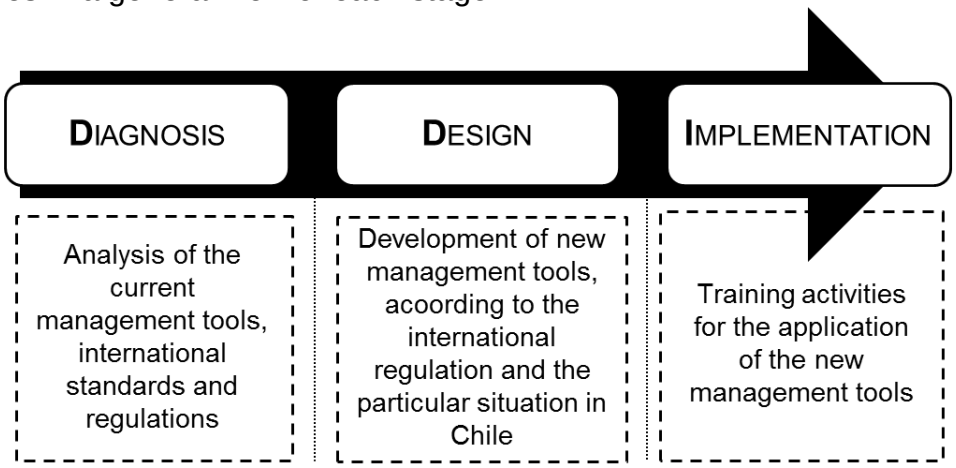


Figure 1: Stages of the strategy.

2. Environmental Impact Assessment of Wind Farms in Chile

The Law 19.300 of General Bases of the Environment (4), creates the System of Environmental Impact Assessment (SEIA) introducing the environmental variable in the projects analysis. The Environmental Assessment Service (EAS) is responsible for implementing the process of environmental evaluation of projects through a public on-line platform accessible to the community.

2.1 System of Environmental Impact Assessment (SEIA)

One of the main instruments to prevent the environmental deterioration of the country is the SEIA, being administrated by the Environmental Assessment Service (EAS). This instrument allows to introduce the environmental dimension in the design and execution of the

projects and activities that are carried out in the country. EAS evaluates and certificates that the initiatives, both in the public sector and in the private sector, can comply with the environmental requirements that apply to them (3).

SEIA generates a series of processes, which must demonstrate through an Environmental Impact Statement (EIS) or and Environmental Impact Assessment (EIA) to comply with current regulations in the country with a proper assessment and mitigation strategies of the environmental impacts produced by the project. Likewise, environmental authorities must certify and ratify compliance with current regulations, qualifying the mitigation and control measures proposed by the owner, and finally establishing a positive or negative environmental rating.

Each wind project that enters must present a study of acoustic impact to the EAS. This is because one of the environmental regulations in Chile, corresponds to a standard that regulates the noise of productive activities (stationary sources).

2.2 Noise regulation in Chile

Noise regulation in Chile (2) corresponds to the Supreme Decree No. 38/11 (DS 38/11) of the Ministry of Environment (In Spanish: Decreto Supremo N°38/11, Ministerio del Medio Ambiente). This normative regulates the noise of productive activities, characterized as stationary sources. There are multiple stationary sources defined by this normative. One of the productive activities that it is important to remark in this work is the energy facilities, defined as energy generation, distribution or storage facilities. These facilities qualify as stationary sources being regulated by the DS 38/11. Therefore, wind farm projects are being evaluated by this normative since they qualify as energy facilities.

This noise regulation presents the procedures to perform noise measurements. Measurements must be made at the receiver location with specific certificated equipment, presenting a detailed report of the location and sound pressure levels obtained in the exercise. Sound pressure levels must be measured in A ponderation (dB(A)), in nine positions defined by the operator, presenting the worst-case scenario of exposure to noise. The following table presents the noise limits, defined for five zones, according to the General Ordinance of Urbanism and Constructions (GOUC) in Chile.

Table 1: Maximum permissible noise levels according to DS 38/11.

Maximum permissible corrected noise levels (CNL) in dB(A)		
Zone	**7 to 21 hours**	**21 to 7 hours**
I	55	45
II	60	45
III	65	50
IV	70	70
Rural	Minimum between background noise level + 10 dB(A) or Zone III	Minimum between background noise level + 10 dB(A) or Zone III

2.3 Historic comparative analysis of environmental impact assessment of wind farms in Chile

In this section, results of a comparative analysis are presented. A review of every project under evaluation by the SEIA was made. A total of 106 projects were evaluated according a defined criterion. 83 projects are in approved status and 23 projects are in qualification status.

The analysis criterion was defined by the following points.

- Zoning
- Background noise analysis
- Noise prediction methodologies
- Noise monitoring proposals
- Applied mitigation measures

Results of the analysis are presented below.

2.3.1 Land-use

This type of project is usually located in rural areas, far away from the residential areas. Due to the distribution of the receivers in each project, some of them qualify as an urban receiver; however, in general, wind projects are evaluated according to the limits established in DS 38/11 for rural areas. In this way, the following table presents the limits that have been applying for wind farms in Chile.

Table 2: Maximum permissible levels applied in the WFN assessment in Chile.

Day limit	Night limit
Background Noise Level + 10 dB(A) or 65 dB(A)	Background Noise Level + 10 dB(A) or 50 dB(A)

Because the source remains in the time, the limits that must be fulfilled in the assessment corresponds mainly to the limit established for night time, as shown in table 2 (BNL[1] + 10 dB(A) or 50 dB(A)).

2.3.2 Background Noise Levels (BNL)

DS 38/11 establishes a background noise measurement methodology:

"The countinous equivalent sound pressure level (Leq) should be measured continuously, until the reading stabilized, recording the value of Leq every 5 minutes. Reading shall be understood as stabilized when the arithmetic difference between two consecutive registers is less than or equal to 2 dB(A). The considered level will be the last of the recorded levels. In any case, the measurement will not be extended for more tan 30 minutes."

It has been observed that the reviewed projects correctly apply this criterion, identifying each receiver and each source that contributes to BNL. Measurement campaigns are carried out from 1 to 2 days regularly, measuring in day and night periods. Once the BNL are established for each receiver, the maximum permitted noise levels are defined according to table 2, presented above.

On the other hand, special attention has been paid to the cumulative noise impact, carrying out assessment that considers the project under evaluation and the neighboring projects that could produce impact to the community.

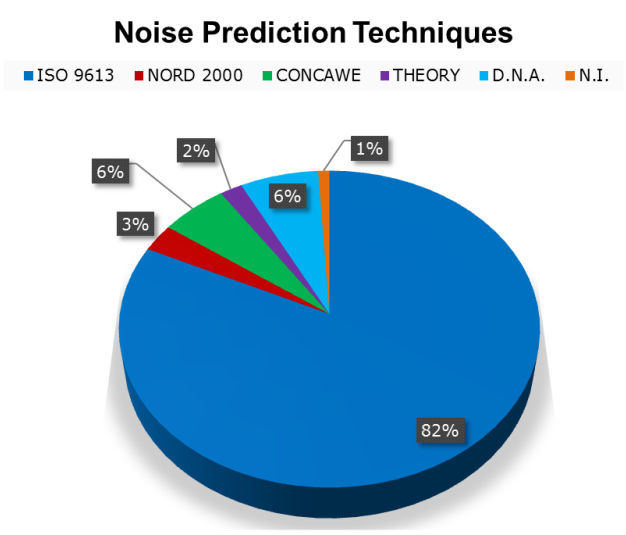
Within the shortcomings of the assessment has been revealed the lack of consideration of the operating conditions of wind turbines as one of the primary factors for the baseline survey of background noise, this is, wind speeds between 4 and 25 m/s. The current regulation

[1] BNL: Background Noise Level

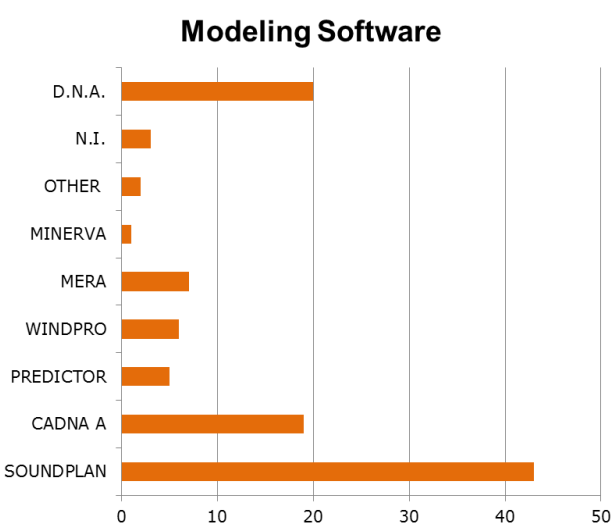
in Chile do not present requirements for wind analysis in measurements. Therefore, correlation between measured noise levels and wind speed are not considered in the assessment.

2.3.3 Noise prediction techniques

The trend of the use of certain acoustic prediction techniques has been observed. Particularly ISO 9613 (9) appears as the most widely used propagation model for the prediction of wind turbine noise in Chile. Other techniques have been applied by some consultants and some assessments are based on theoretical assumptions and international observations when a wind farm is far removed from the communities and would not require a modeling assessment.



Theory: Theoretical methodologies
D.N.A.: Does Not Apply
N.I.: No Information



OTHER: Alternative codes developed for modeling according to ISO 9613, for example.

Figure 2: Noise prediction techniques used in Chile.

ISO 9613 applies with the limitations of the model. The input parameters for the code (climatic conditions, considerations that could present errors, source data according to technical reports, etc.) are not correctly stated. On the other hand, the evaluator of the project has evidenced the limitations of ISO 9613, reason why recently in the country, has been requested the implementation of more advanced techniques or international ISO considerations that present a valid theoretical foundation in a certain range of action.

2.3.4 Post-installation noise monitoring

It is identified that some projects present noise monitoring plans, once it has been implemented, usually 2 monitoring by the first year and an annual monitoring from the second year. However, the monitoring plans presents lack of information by not presenting the considerations that were used to establish the methodology. It is important to note that the variability of atmospheric conditions is a very important factor when noise measuring is made, so the monitoring plan should contain an analysis of the variability of the climatic conditions to decide the number of measuring periods and how long will be the measure campaign, in order to characterize in the best way the variation of the noise levels during a year of monitoring, for example.

2.3.5 Noise control measures

When corresponds, noise control measures are applied to specific wind turbines in a wind farm, the one closest to the affected receiver. It is regularly proposed to vary the mode of

operation to a quieter mode. However, because the maximum levels allowed in the country are not strict, the projects comply with the regulations at the stage of operation. This generates that no mitigation strategies are presented recurrently. This could lead to future disputes, since without having a demanding entrance limit; a receiver could present future complaints and would have to incur expenses to control the noise emissions once the wind turbine has already been installed. This situation has been seen in Chile during the last years. On the other hand, this generates a poor development of noise control strategies for wind turbines noise in the country, since there is no defined management model for these cases.

3. Noise Regulation

3.1 International Regulation

In relation to the international noise regulation, different criteria are identified which allow to establish evaluation references. The criteria varies from the measurement techniques (equipment, atmospheric conditions considered, measuring time, quantity), prediction techniques, until the definition of the maximum permissible noise levels. Different practices in the international regulation that could be adopted in the development of a management instrument have been evidenced. Emphasizing the wind analysis in the measurements by establishing the appropriate correlations with the background noise as well as extending the measurement period to generate a better characterization of the variation of noise levels in relationship to the atmospheric conditions could be important guidelines for the development of a management strategy.

The development of an acoustic model that can represent the evaluation scenario is very important, since the noise level to be evaluated will be the one that the modeling software or the prediction technique presents. There is no international standard describing a specific method for modeling and the prediction of wind turbines noise. However, it is accepted by the UK acoustic consultants that noise from a wind farm is calculated according to the ISO 9613 regulation (9), “Acoustic – Attenuation of sound during propagation outdoors”. Although there are other sound propagation techniques, ISO standards are considered as very useful and efficient tools in the calculation of sound emission levels. However it is known that ISO 9613 has important limitations for the prediction of wind turbine noise (9, 10). In some of the countries the use of more advanced prediction techniques such as NORD 2000 or CONCAWE is recommended, which could generate better predictions due to the more specific considerations in calculations.

On the other hand, one of the important decisions is the definition of the separation distances between the wind turbines and the receivers. It is important to remark that in many cases there is no statutory separation distances stipulated in legislation. Recommendations or suggestions for separation are made generally through planning policy and guidance. The range of distances varies between 350m and 2km (14). Also, a separation distance according to the rotor diameter or hub height is established by many countries.

In the environmental noise regulation, one of the most important factors to study is the maximum noise level allowed in the receiver. For this type of sources have been evidenced noise levels that vary according to the levels of background noise, wind speeds or simply fixed limits that apply for certain situations. The following table (Table 3) shows maximum permitted noise levels for wind farms in rural and residential areas for different countries.

Table 3: Noise limits for wind farms in different countries (13).

Country	Descriptor	Rural Area	Residential Area
Germany	Leq dB(A)	**Day: 45 Night: 35 (Sensitive area)**	**Day: 50 Night: 35**
Belgium (Flanders)	Leq dB(A)	**Day: 45 Night: 43**	**Day: 44 Night: 39**
Belgium (Wallonia)	Leq dB(A)	**45**	**45**
Canada (Ontario)	Leq dB(A)	**40 – 4 m/s 45 – 8 m/s 51 – 10 m/s**	**45 – 4 m/s 45 – 8 m/s 51 – 10 m/s**
Denmark	Leq dB(A)	**42 – 6 m/s 44 – 8 m/s**	**37 – 6 m/s 39 – 8 m/s**
US (Indiana, Tipton Country)	Leq dB(A)	**45**	
Finland	Leq dB(A)	**Day: 45 Night: 40**	
France	Leq dB(A)	**Day: BN + 5 Night: BN + 3**	
Netherlands	Lden dB - Ln dB	**Lden: 45 Ln: 41**	**Lden: 45 Ln: 41**
New Zealand	L90,10 dB(A)	**35 ó BN + 5**	**40 ó BN + 5**
Norway	Lden dB	**45**	
UK (England)	L90, 10 dB(A)	**BN + 5 ó 40 BN + 5 ó 43**	
Sweden	Leq dB(A)	**35**	**40**
South Australia	L90, 10 dB(A)	**35 or BN + 5**	**40 or BN + 5**

3.2 Comparison of noise limits with Chile

From the above table it is possible to note that one of the less strict levels corresponds to 45 dB(A). The most demanding level corresponds to a level of 35 dB(A). According to the maximum levels allowed in Chile (Table 2), it can be observed that establishing a comparison between the less strict level for the international regulation, according to Table 3, and the strictest level in Chile, there is a difference of 5 dB(A), which places the country with one of the lowest international noise limit levels, being 50 dB(A) for the night. In comparison to the less demanding level in Chile, there would be a difference of 15 dB(A). Chile presents a day limit of 65 dB (A) for WFN. In addition, according to those countries that adopt the BNL analysis, Chile is at an undemanding level in the international framework, applying the criterion of BNL + 10 dB (A) for WFN. It can be concluded that noise regulation in Chile for WFN is undemanding for WFN.

On the other hand, it is important to remark that Chile does not present a specific regulation for WFN. This is very important in the comparison, because is being compared a general

regulation for noise in Chile with specific regulations for wind farm noise. The greatest disadvantage for Chile in this area is not the undemanding levels for WFN, because there is not a regulation for WFN, but the lack of specific regulation.

4. Development of a management strategy

4.1Scope

The scope of the strategy seeks to present guidelines for the implementation of new wind farm projects in the country, avoiding the generation of noise impact in the community. The alliance between the Ministry of Energy and the Ministry of Environment in Chile, is committed to act generating a set of proposals that allow addressing the problem in the short, medium and long term, ensuring the sustainable development of this energy sector

4.2 Considerations

4.2.1 Noise limits and descriptors

The study of noise limits is one of the key factors to promote the development of noise management of wind farms. The international regulation presents an important reference for noise limits. It is necessary to study the characteristics of noise limits that could be implemented in the country and whether or not they would depend on background noise and wind speeds. Also, the analysis of the most appropriate noise descriptor to apply the limits should be studied.

4.2.2 Noise modeling and measurement techniques

One of the important considerations of the work is to study sound prediction techniques. ISO 9613 appears as an important reference, however, due to its limitations, it is necessary to study its application range together with the implementation of new methods included in acoustic modeling software. The work proposal will also include acoustic measurements of wind turbines according to the international technical standard IEC 61400-11 (12), which will allow the generation of acoustic models according to measured wind turbine models commonly implemented in the country.

4.2.4 Land-use planning

The General Ordinance of Urbanism and Constructions (GOUC) in Chile, contains the statutory provisions of the law, regulates the administrative procedures, the urban planning process, land urbanization, construction and technical standards of design and construction required in urbanization and construction in the country. These provisions allow to establish the permitted areas and limits of construction for different buildings and facilities.

Land-use planning is a key factor to future wind projects, as it would allow establishing the distance boundaries between the source and the receiver, thus preventing the approach of wind projects to the community.

4.2.5 Wind turbines noise perception

The study of the perception of the noise is very important, since as it is known, the characteristics of this type of sources are very particular, in comparison to other sources. The perception of sound and people's reaction to noise is highly variable and subjective (6-8). Because of this variability, it is difficult to generalize about the impacts of wind farms. In this

sense, a perception analysis of WFN will be very important to raise information regarding the current situation of the country in relation to the noise of wind turbines.

4.2 Strategy proposals

The management tools visualized for the development of a WFN control strategy in Chile is detailed below. Figure 3 presents a summary of the strategy proposals detailed in the following paragraphs.

4.3.1 SEIA noise assessment guide

One of the proposals to start generating information considers the inclusion of "wind turbine noise" theme in the noise assessment guide that is being developed by SEIA. This would allow the establishment of references for consultants in the short-term, including recommendations for modeling and noise measurement along with establishing international references for the analysis and WFN assessment in relation to the improvement space identified in this work.

4.3.2 Good practice guideline for wind turbines noise assessment

A second proposal considers the development of a guide of specific good practice guidelines that will allow establishing in a more detailed way the factors to be considered in WFN assessment, also including international references and recommendations to carry out the assessment.

4.3.3 GOUC Modification

A modification of the GOUC will be one of the key factors in the development of the strategy. To define a specific distance between the receiver and the source will avoid future community problems with the project developers. This is a precautionary measure that could have a major positive impact on the sustainable development of wind energy in the country. In addition, there is the possibility of establishing agreements between the community and companies to create protected spaces to avoid the installation of future receivers in a certain area of land belonging to a private.

4.3.4 DS 38/11 Modification

In the long-therm, a modification of DS 38/11 could be important for national regulation of WFN. Excluding the source from DS 38/11 and regulate WFN with and international regulation or even the development of an specific standard for WFN in Chile, would allow establishing the necessary guidelines for the assessment, according to the definition of new maximum permitted noise levels, studied adequately for the national territory.

4.3.5 Social Information

The lifting of social information is a key factor in the short, medium and long-therm. One of the needs that the country has is to “demystify” and clean up the information that generates a rejection of this type of energy since it is often presents in an aggressive way due to the noise issues. It is necessary to inform the community about the noise issues of wind farms properly and also to inform the development of the work done in view of the problems. The results will be that it will weigh the issue to a level of high importance in the country, also generating reliable information for those affected.

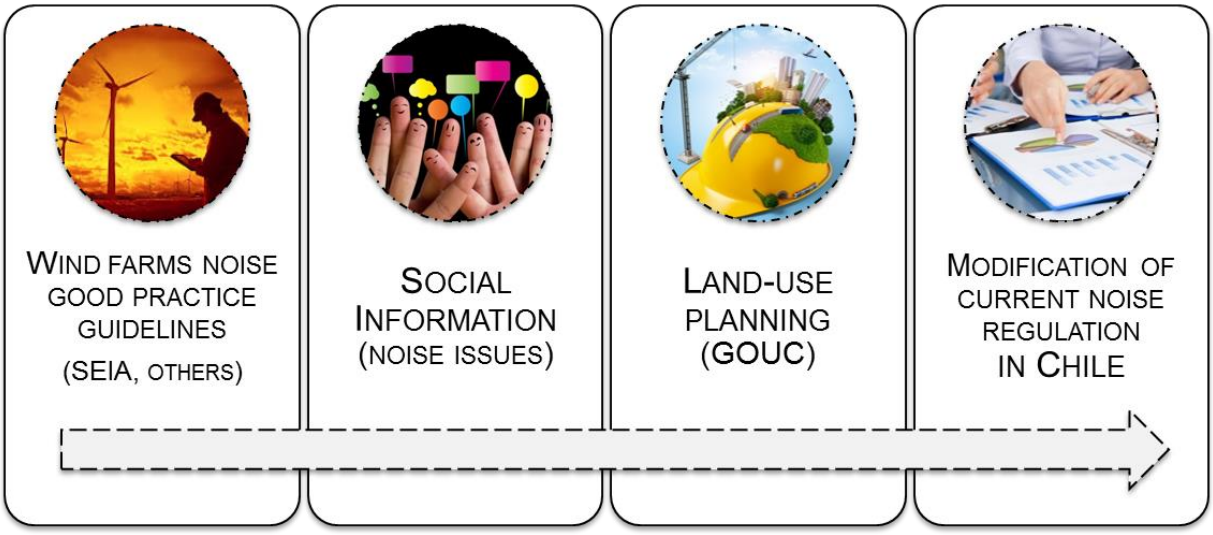


Figure 3: Strategy proposals.

5. Conclusions

It has been possible to highlight very important areas of improvement in the current regulation for Chile as presented in the proposals mentioned above, which allows the design of a set of elements that will be part of the strategy being applied in different time periods. Chile does not have a specific regulation for WFN, and the general regulation for noise in the country could results undemanding for WFN. Also, the guidelines for the evaluation of the noise of wind farms have not yet been defined, so the country is nowadays in a key space for the development of wind energy, particularly in the strategies of WFN control.

Guidance to project consultants and evaluators in the framework of the SEIA is fundamental for the generation of good practices in the WFN assessment. Short-term strategies can perfectly address the guidelines that will allow an adequate analysis of this type of sources in the country.

The review of international practices for measurement, modeling and maximum permissible noise levels, together with the perception phenomena and effects of wind turbine noise, are key factors for the development of a WFN management strategy in the country.

It is important to note that sustainable development of wind energy must consider in equal and congruent parts the growth of the economy, the well-being of the people and the care of the environment. In this way the reduction of the cost of energy and the low emission of noise, as far as wind projects are concerned, is essential for the development of wind energy.

Future works correspond to the design of the strategy and the implementation of each of the actions studied. It is expected that by 2018 the guidelines will be fully defined along with the implementation of those elements that are sought to address in the short-term.

Acknowledgement

This work has been supported by the Ministry of Energy and Ministry of Environment of the government of Chile.

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