# Practical Experiences as part of Engineering Education for Sustainable Development: The Ollagüe Smart Microgrid Energy Project

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## Abstract

This paper describes a practical activity in engineering education, whose purpose is to expose students to a real project bringing renewable energy to an isolated community. The project is based on a smart microgrid, which coordinates wind and solar resources to deliver energy in Ollagüe, a small one-hundred people town located in the Atacama Desert in the north of Chile. The paper explores how a real project, based on sustainable principles, can contribute significantly to enhance the new skills needed by engineers so they can be more effective in dealing with problems in an increasingly complex and constrained world. The project exposes the students not only to technical challenges but also to uncertainty, environmental limits and social acceptability. The project was led by a professional team belonging to the Energy Center of the Faculty of Physical and Mathematical Sciences at Universidad de Chile and the students involved in this initiative have different backgrounds: industrial design, natural resources engineering, civil engineering, and architecture. Formally, for some students the activities in this project were incorporated into the curricula as a final senior project, which is a requirement to obtain the engineer diploma. For the rest of the students it was an extracurricular activity that provided a unique experience to deal with real problems involving both technological as well as social interaction problems with the community. The paper discusses different alternatives to incorporate this type of initiatives formally into the engineering curricula.

## 1 Introduction

Universities play a significant role in promoting the concept of sustainability from different key areas, such as new educational programs, research, and the use of demonstration projects in real-life applications (Vargas et al., 2012).

In the case of education, there is a need to develop and implement new courses that prepare engineers, scientists, and energy planners to work with renewable resources for producing sustainable energy generation systems (Jennings, 2009). Also, in the field of renewable energies didactic competencies covering learning arrangements for educators, trainers, and lecturers in adult education have been developed (Acikgoz, 2011). Other approaches have been based on the creation of centers oriented towards education for sustainable development (Itoh *et al.*, 2008). These canters are characterised by an integrated approach where different target groups are involved (e.g. schools, NGO's and industry) and where a local university plays a catalyst role (Leal Filho and Schwartz, 2008). This has promoted discussion about the roles and responsibilities of universities in the task of promoting sustainable resource energy development in society (Axelsson et al., 2008; Mochizuki and Fadeeva, 2008).

A different course of action has been the promotion of demonstration projects as campus initiatives (Krizek et al., 2012). These works have raised the level of awareness about environmental issues on campuses, and have increased the interest on the part of the students (Ghosh, 2011). The goal of these initiatives is to show policymakers ways to use current higher education partners as role models for promoting green policies, and ways to use the enormous potential impact colleges and universities can have in the development and deployment of renewable energy. However, there has been only a limited number of specific field projects, in which the university plays a leading role in the design, building and implementation of renewable energy projects focusing on satisfying real needs of people and industry.

This paper attempts to show the contribution of demonstration projects in the promotion of renewable energy based on a pilot experience in the School of Engineering, at the University of Chile. The paper describes an energy project undertaken in an isolated community located in the Atacama Desert in the north of Chile.

## 2 The Ollague Township Description

Ollague township is located in the county with the same name, it belongs to Loa province, Antofagasta Region, at 21º 13' latitude south 68º 43' West Longitude. Ollague's boundaries are: Tarapacá Region at the north, Calama´s county at west and south, and Bolivia at the east, with a altitude of 3700 meters above the sea level. The county's total area is 2912 m2. According to municipality data, by September 2011 the township population was of 154 people. The main economic activity of the location was the non-metallic mining; however, nowadays this is related to public and other minor services, followed by the activity of the FCAB railway company, which also presents a high infrastructure presence (station, workers' houses and workshop) in the township. The layout of Ollagüe is shown in Figure 1.


Figure 1: Layout of Ollagüe

Thus, Ollagüe is a small isolated town, nearly 200 kms far from the closest City of Calama. As a consequence, its energy system is not connected to the major electrical grid of the northern part of Chile and it has to provide its own energy from a diesel generator.

## 3 The Ollagüe Technical Project Description

The Ollagüe Project consists of the design and implementation of an isolated Smart Power micro grid to supply the electrical demand of the Ollagüe township. This micro grid is going to replace a diesel based power system that provides service for 16 hours per day.

The micro grid designed for Ollagüe is composed of the following equipment:

- 200 kW PV power plant of thin film panels,
- 30 kW vertical axis wind turbine,
- 1100 kWh Li-ion battery energy storage system, and
- 250 kW existing diesel engine.

According to the above energy resources the forecasted production to satisfy the annual energy demand is as shown in figure 2.

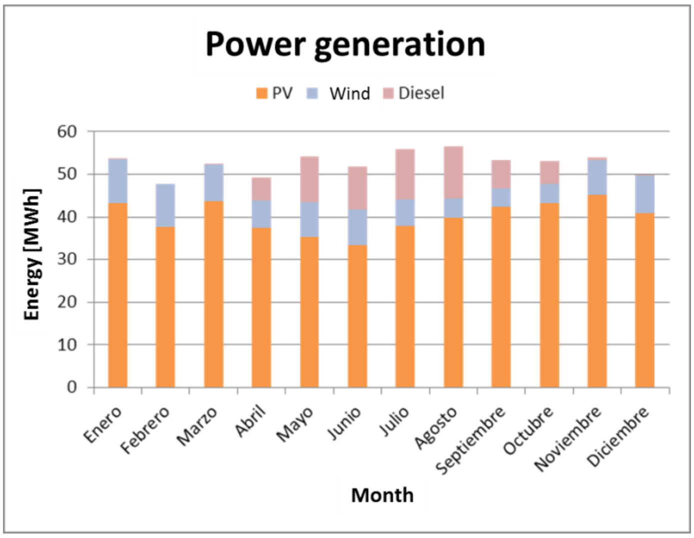


Figure 2: Forecast of monthly power generation for Ollagüe's microgrid.

The monthly energy demand of Ollagüe is in the range of 48 to 57 MWh, and there are small seasonal fluctuations.

As seen in Figure 2, it is noticeable the high share of renewable energy production of the project. In fact, it is expected that during 5 months, from November until March, the overall share of renewable energy (PV and wind power) will be around 100%. Moreover, by taking the year round, the renewable energy share is approximately 85%.

The project execution has comprised three stages:

- Feasibility study. A feasibility study was carried out to define if a renewable based microgrid is the best choice for a continuous power supply in the town. Different scenarios were evaluated, such as: grid connected, full diesel based, renewable based microgrid and a grid connected with distributed generation integration. The final comparison showed that the microgrid scenario was the one that presents clear advantages from both technical and economical points of view. Once the microgrid option was selected as the more adequate choice, the second stage was initiated.
- Detailed engineering. A complete detailed design of the Ollagüe's microgrid was carried out from the following areas: electrical engineering, civil engineering, and mechanical engineering
- Social intervention. This stage constitutes a great contribution of the project because provides a validated proposal for the sustainability of the microgrid. The intervention it is established as a community based administrative and operational organization, which is in charge of guarantying the long term sustainability of the microgrid. More details of the social intervention processes are described in the next section.

Finally, it is important to state that the development of these tasks involve a team composed by senior researchers, engineers of the three technical specialities, social sciences professionals, industrial designers and undergraduate students. The students involved in this initiative have different backgrounds: industrial design, natural resources engineering, civil engineering, and architecture.

## 4 Social Intervention

In addition to the technological solution the Ollague's micro grid project also includes a proposal for community based operation and maintenance schemes, in order to pursue social acceptance of the project as well as its long term sustainability.

There is a joint community intervention program that goes on in parallel with the technical solution. This community intervention process plays a key role when developing this kind of projects, allowing the creation of trust between project developers and the community, working in a "co-construction" way (for instance, the community participates in the decision-making process) and providing enough tools to endow the community itself to take care of the operation and maintenance of the micro grid, which finally ensures the sustainability of the project in the long term. In order to achieve these goals, a number of meetings with local persons were undertaken.

Based on previous experiences of the developers (Alvial, 2011), the community intervention program comprises there stages:

a) Building trust
b) Co-construction
c) Ensuring sustainability

The objective of the first stage called Building Trust is to generate a preliminary vision of the locality to intervene, as well as identify the main stakeholders of the systems and their own visions and narratives. The second objective is to understand the social structure of the community, in order to understand the power structures and organization where the participatory process is to be developed. The third objective is to build trust between stakeholders, specially the community. It is also in this stage where the viability of the project is defined, considering technical, environmental, social and financial constraints. During this stage a set of different meetings are arranged in order to perceive the community visions. In figure 3, a picture of a meeting with the community is portrayed.

Figure 3: Community meeting to inform about Ollagüe's microgrid project

The Co-construction stage is aimed to discuss the different visions and narratives previously identified among relevant stakeholders, and from these discussions, to build consensus and guidelines that encompass the complexity of multiple visions and objectives that each stakeholder brings to the project. This is a crucial stage since it allows generating a long-term action plan for the project. It is expected that this stage also comprises he capacity building tasks, which are aimed to provide the necessary knowledge and abilities to the people so they can perform maintenance and small repair tasks when they are needed. Major maintenance and repairs are performed by a crew of students and technicians from the Energy Centre at University of Chile.

Finally, the Ensuring Sustainability stage has the objective of identifying socio-environmental components that could be affected by the project (positive and negative impacts); and create a monitoring systems to identify impacts and potential conflict and problems.

## 5 Introducing these activities in the curricula

The Electrical Engineer career at University of Chile takes six years in total and every lecture year is divided into two semesters. The first two years are set as a core program in mathematics, physics and computer science. The next four years include obligatory and elective courses to complete the specialization inside the Electrical Engineering Department.

Formally, for some students the activities in the Ollagüe project were incorporated into the curricula as a final senior project, which is a requirement to obtain the engineer diploma. In order to achieve this, a tutor professor participating in the project leaded the work of the student, who has to write a senior project and present the work in front of a commission.

For the rest of the students the Ollagüe project was an extracurricular activity that provided a unique experience to deal with real problems involving both technological as well as social interaction problems with the community.

As there are a number of similar activities undergoing in the Electrical Engineering Department, such as the construction of a micro satellite, the robocup team contest, and the solar car race contest, a discussion to create different alternatives to incorporate these types of initiatives formally into the undergraduate engineering curricula was carried out.

After consideration of the time scope and work load of these activities, two tracks of courses were created. Both tracks are designed as elective courses, which can be taken by any student in the Faculty of Engineering.

### *5.1 Technological Development Course*

This is a course with a burden of 20 *docent units*, which means that the work load is 20 hours per week on average. It requires a professor to lead the work of the student and must be approved by the undergraduate chairman.

The concept of the course is a well-designed project with a short time frame to accomplish it, usually within 14 weeks. At the end of the term the student has to submit a report, which will be revised and marked by the professor.

### *5.2 Applied Project Courses*

These are a set of three consecutive courses that can span one year and a half, the work load of each course is 10 *docent units*, i.e., the students are supposed to dedicate 10 hours per week on average during 14 weeks.

These courses are designed for projects that are longer in time, but the burden in each semester is lower than the Technological Development course. If a project takes less time, for example one year, the students just take two consecutive courses.

## 6 Conclusion

The Ollagüe project provided a unique experience for students to deal with real problems involving both technological challenges as well as social interaction aspects with the community. It is highlighted that the involvement of the community is a crucial component to ensure the sustainability of the project.

From a curriculum point of view, this initiative leaded to the incorporation of four new elective courses in the undergraduate program of the Electrical Engineering Department at University of Chile. These courses capture the complexity of real application projects, which include different time scope and work load for the student activities.

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