



**National Renewable Energy Laboratory**

*Innovation for Our Energy Future*

The following represents a reprocess to specific questions provided by Paul Loeffelman of American Electric Power on the 21<sup>st</sup> of January, 2009 regarding the San Cristobal Wind Project. The responses provided are based on personal experience and publically available information obtained through publication searches.

Most information regarding the San Cristobal Wind Project was obtained through personal communications with staff of American Electric Power, the article "Top Plants: San Cristobal Wind Project, Galapagos Islands, Ecuador" from Power Magazine ([http://www.powermag.com/issues/cover\\_stories/Top-Plants-San-Cristobal-Wind-Project-Galapagos-Islands-Ecuador\\_1571.html](http://www.powermag.com/issues/cover_stories/Top-Plants-San-Cristobal-Wind-Project-Galapagos-Islands-Ecuador_1571.html)), a report produced by the e8 on the project titled, e8 The San Cristobal Wind and Solar Projects, and the Eolica San Cristobal web site (<http://www.eolicsa.com.ec/>).

No representation is made to the completeness of the below information and this review should not be considered of a level approximating scientific rigger. To allow such a detailed comparison, much more detailed data on the San Cristobal Wind Project and the other comparison power systems would be required.

If additional information is required, I would be happy to assist to the extent that I am able,

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**1) Could you describe in detail how this project is different from the following high penetration hybrid power systems?**

- a. Ascension Island: The Ascension Island power system includes four 225kW turbines and two 900kW turbines. The system can be described as a high penetration power system with no implemented power conditioning, although publically available information about the plant is limited. The primary difference between the this project and the San Cristobal Wind Project is that the Ascension Island project is owned, operated, and maintained by the U.S. Air Force and is not a community based project. The development and funding of this project was also supported by the military and thus does not reflect the level of efforts that was undertaken to implement the San Cristobal wind project. (Primary references: personal communication and previous project experience)

c. St. Paul, Alaska: The St Paul power system is one of the few power systems currently operating where all of the diesel engines can be switched off, relying completely on the wind to provide power for long periods of time. It is however implicitly different from the San Cristobal wind-diesel project in that it supplies power primarily to an independent industrial center, not a community, and is much smaller in size. The average load of the St. Paul system is around 70kW, compared to ~1,000 kW at San Cristobal and has an installed wind capacity of 225kW compared to 2400kW at San Cristobal. The size and type of load of the San Cristobal power system in comparison to the St. Paul system involve very different implementation and technology strategies. (Primary references: personal communication and previous project experience)

d. King Island, Tasmania: The King Island power system is likely the closest in scope to that of San Cristobal in that the wind is used to provide a large portion of the load for a large island community. King Island has a larger load than San Cristobal at approximately 1.8 MW with a range between 1.2 and 3.3 MW. In 2005/2006 the power system produced approximately 33% of the energy from wind, the same percentage as at San Cristobal. This however is where the similarities end. The power system on King Island has 2.43 MW of total wind capacity (from five wind turbines) and a 200kW Vanadium Redox battery. Recently a 1.5MW frequency controlling resistor bank has been added to allow use of the higher wind penetrations, up to 45% annual average. The diesel plant at King Island is also large and uses large generator sets, the smallest being 1.2MW, which make it difficult to operate at low load ratings, something that is less of an issue with the smaller diesel gensets in San Cristobal. The King Island facility is owned by one operator, Hydro Tasmania, as compared to the Independent Power Provider (IPP) model used in the San Cristobal project, the first of its type at this scale. These last two issues are important for several reasons, since the diesels on San Cristobal are smaller, theoretically they will be able to provide more control flexibility, allowing higher penetrations without the need for energy storage. Additionally, the IPP model defines a different contractual arrangement for managing the project and resulting power quality. Additionally the IPP model breaks new ground from a contractual perspective, allowing external companies to provide green energy services to a utility or power sector that would normally not make that investment and are generally hesitant to invest in unproven technologies. This model does however have weaknesses in that the final power provider, in this case Elecgalapagos, may be responsible for insuring power quality, while the penetration of wind may be largely out of their control. As the power penetrations of the San Cristobal wind farm increase, which it is expected to do, it will have to be shown if the IPP model can work successfully given the different checks and balances put in place through the specific power purchase agreement. (Primary references: Presentation by Ryan Willems – Hydro Tasmania (2008))

e. Crete: The power system of Crete is intrinsically different from that of San Cristobal and in truth can not really be used for comparison. The mean load on the Island of Crete is over 350 MW (2007) – compared to 1MW for San Cristobal. The Crete power system is comprised of three large thermal power stations using coal, gas, and diesel with a total installed capacity of 725 MW. This island has 90MW of installed wind potential. Even under ideal circumstances, the penetration of wind under the current conditions on Crete would be much less than current penetrations in San Cristobal and by almost all definitions, Crete should not be considered high penetration. The power structure however is similar, with most wind plants being operated as IPP's, relying on other entities to perform the required power balancing between the wind and other dispatchable generation sources. (Primary references: On the wind power rejection in the islands of Crete and Rhodes, Katsaprakakis, Papadakis, Christakis, Zervos Wind Energy, Volume 10, Issue 5, 2007; Transient Analysis of Crete's Power System with Increased Wind Power Penetration, Karapidakis, POWERENG 2007, April 12-14, 2007, Setúbal, Portugal)

f. Sagar Island, India: This project was implemented in 2002 to combine wind turbines with modified diesel engines. Initially 2 nominally 65kW wind turbines were installed with an additional 2 added in 2004. There were plans to install an additional 3 turbines but they were never installed. The diesel plant installed capacity (as of 2004) was 280 kW and little indications of the existing load are provided, potentially as low as 60 kW. Very limited technical information is available on this project, but every indication is that it is much smaller in scope than the San Cristobal project and uses technology that is inherently different. (Primary references: Another Look at Renewables on India's Sagar Island, Sam Shrank Stanford)

University PESD Working Paper #77 (2007); India-Canada Environment Facility (ICEF) Progress Review of Sagar Islands Wind – Diesel Hybrid Project, Jami Hossain (2005)

g. A system planned for Bonaire, NA: Very limited technical information (or general information) about this project is currently available. Most information dates to 2007 with the latest article from early 2008 which indicates implementation in to start early in 2009, however no information is provided to indicate that the project has actually moved forwards. In any case, the project plans to install a 10 MW wind farm to operate in conjunction with a 13MW diesel plant, which may eventually use bio-diesel in place of standard diesel. No information on the energy needs for Bonaire were provided but the article states that the power system is expected to provide approximately 40% of the nation's energy from wind, a similar amount in percentage terms that is to be expected currently in San Cristobal, although at a much larger total size. It is also referenced that the system will incorporate battery storage, which will make it more similar to the King Island power system in scope and design. Once constructed and proven operationally, this project could represent the best example of a high-penetration power system for large islanded community loads, however at this point this is not the case. (Primary references: Easy as ABC? Bonaire set to become Caribbean's first island with 100% renewable energy, Eize de Vries, Renewable Energy World, Volume 11, issue 1 (2008); Bonaire Insider – local newspaper – various dates)

Closing Comments: As the costs of diesel fuel increase and a better understanding of the impacts, both economic and environmental, of continued dependence of remote communities on diesel is determined, the implementation of wind to decrease the dependence on diesel will increase. However, to date most projects have been implemented for smaller loads and/or at lower penetration levels. Although not clearly demonstrated, this fact sets the San Cristobal project apart given its relative large size and expected high penetration level, without storage. As a secondary consideration, the management structure of the San Cristobal project is also almost unique. Most other wind-diesel projects have been implemented by the primary power supplier and in many cases have been developed to provide dedicated loads, such as military and research facilities. The IPP model that has been implemented at San Cristobal, if it indeed turns out to be sustainable and replicatable, which at this point is undemonstrated, will provide another model for communities interested in implementing wind projects without the potential financial risk associated with what many consider to be an un-tested application of wind technology. It should also be mentioned that the level of efforts put into the environmental assessment of this project and the way that the project is designed to return payments to the community through outreach, education and environmental stewardship is generally unique. For these reasons I feel the San Cristobal project is currently unique amongst the array of operating wind-diesel systems.

## **2) Are there any peer-reviewed articles regarding this project?**

No, at this time there appear to be no peer-reviewed articles regarding the San Cristobal Wind Project. A detailed project history is available in hard print through the e8 organization and limited information about the operation and performance of this plant have been made available by the plant operators, primarily through the Eolica San Cristobal web site (<http://www.eolicsa.com.ec/>). Although this is insufficient to assess the plant performance to a high degree nor is it independently verifiable, it does provide sufficient information about the general wind plant operation and gross total power system performance. The public availability of this data, even at the gross level provided, is not common in the industry and does represent a clear desire to provide this information to the public. It should be noted that in most cases information about specific projects pertains to public stories regarding its implementation and then research reports in the years following its installation. Since the San Cristobal project is relatively young, it is not expected that many peer reviewed papers would be available. Although likely premature, open access to information on the ongoing project economics and the impact of the wind turbines on the diesel plant owned by Elecgalapagos and resulting consumer power quality would be of interest, primarily to provide further evidence of the success of this unique implementation model.