Tenerife 100
A model of Renewable Energy Sources integration

To establish a general guideline for the integration of RES on any European island is a complex task. Resources vary in a large amount, as well as needs and island characteristics. Obviously, the approach for powering with RES an island with 10,000 inhabitants is completely different than one with half a million.

Therefore, to cover the widest possible range of applications, it has been decided to study the case of a large island, where more difficulties come together. Afterwards, the method can be easily simplified locally, as an extreme example is given a solution, even though local parameters affect the results in a large extent. Nevertheless, the methodology will be similar, and as many technical challenges are addressed when approaching autonomous applications in a large scale, this example could be the basis for future studies.

The scenario chosen derives from the actual situation of the island of Tenerife, in the Canary Islands. Tenerife and the whole archipelago of the Canary Islands have been very conscious on environmental concerns and the reduction of pollutants and dependence on imported fuels, mainly by the use of renewable energies. Nevertheless, only 1.4% of the energy consumed in the archipelago during 1997 was produced with clean energy sources; the rest was generated mainly in steam, diesel and gas plants. The annual consumption of the Canary Islands reaches 6,000 GWh. These figures clarify the pressure that is being made on the environment. It is essential that a higher effort be made to reduce this impact, increasing the penetration rates of RE technologies.

For an appropriate integration scheme, strategies should be developed for a regional high-level water and energy production with RE and desalination systems, taking into account local characteristics. They must specifically reflect the needs and behavior of consumer daily and seasonal patterns, taking into account the economic development and human needs that have an impact on energy consumption. Moreover, the challenge of supplying a vast area with renewable energy in an autonomous mode is a technical, human and decision-making challenge.

The large scale installation of renewable energy generation plants, together with the appropriate policies and regulations on energy savings and rational use of energy, is important for a sustainable development, as pollutants are not produced like when using conventional fuels. The tendency of the RE market and operators is the increase on the RE installed power, allowing higher densities of installed power. This will enable a more efficient use of areas with the required natural resources. The most important technical challenge is the assessment on regulation, integration and storage solutions, which are surely bottlenecks for the large-scale implementation of renewables. Several approaches should be considered, including for example the use of fuel cells, hydrogen solutions, batteries, hydro power storage, thermal storage, etc. For a complete approach of a 100% RES island, solutions for transports should also be studied, like the progressive substitution of traditional vehicles to the use of fuel cells, electrical or hybrid vehicles with batteries or natural gas.

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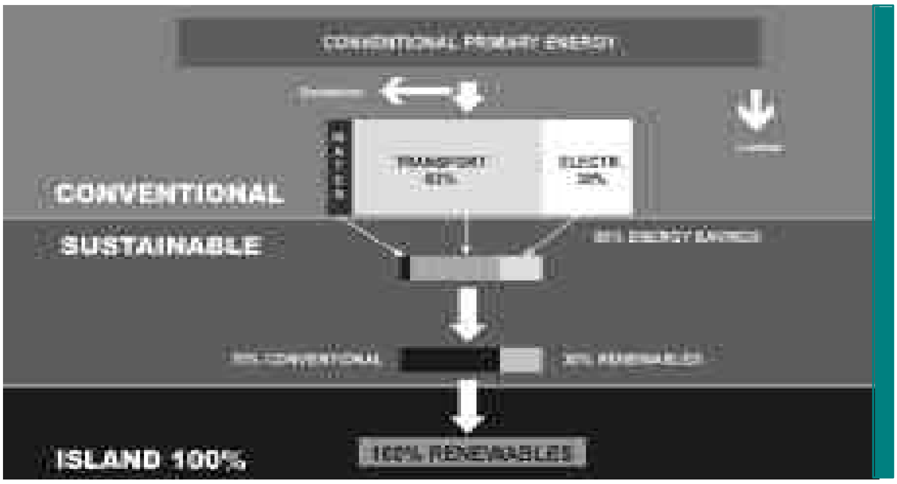
The overall approach, as already mentioned, includes the application of RUE regulations to reduce consumption. The diagram with the process to evolve from conventional to renewables is the following:



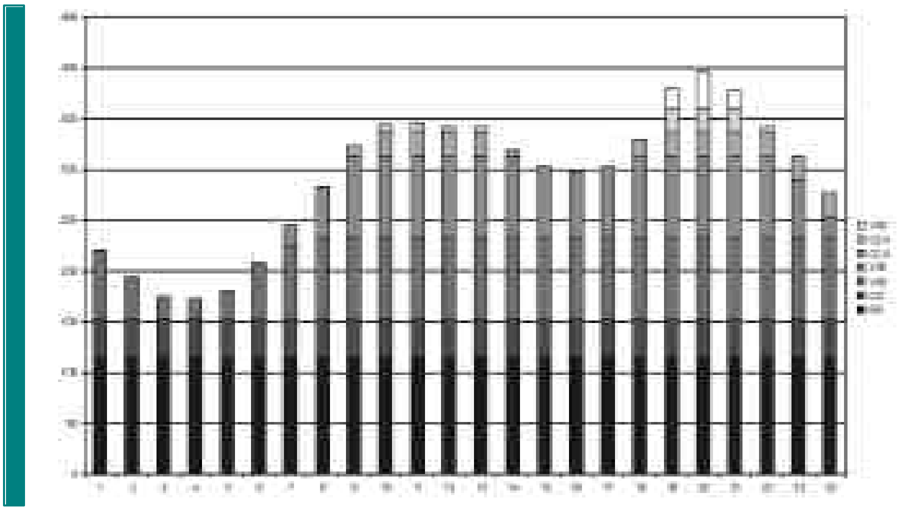
The strategy for the 100% RES must be based on the energy demand and the conventional powered groups used in the island. Several steps have to be taken prior to the complete supply with RE sources. But two scenarios should be analysed:

- RES with Constant Energy Output: Large hydro, geothermal or biomass resources
- RES with Variable Energy Output: Wind, Solar, etc.

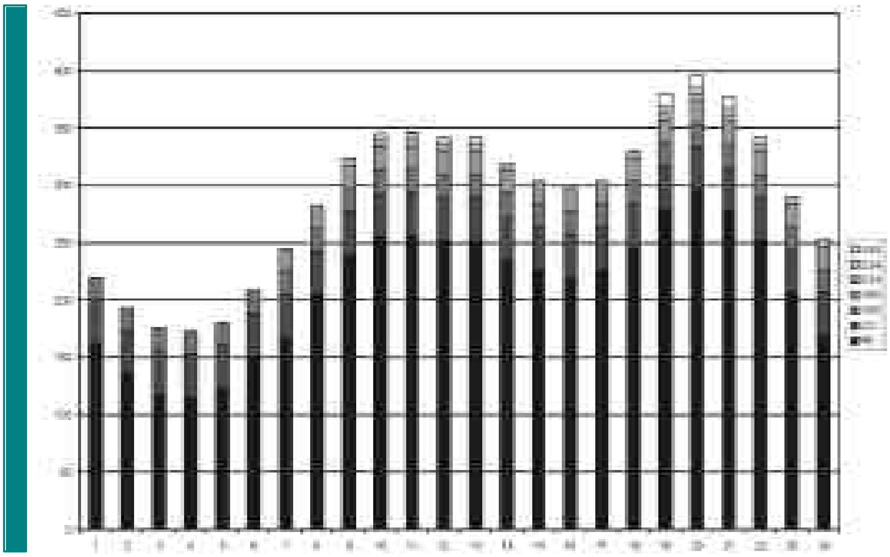
RES with Constant Energy Output: Large hydro, geothermal or biomass resources

RES can be installed to reach 75% of conventional groups working in the lowest consumption hour. For example, in an insular network with 100 MWh consumption in the valley hour, with three vapour turbines of 40 MW each, 70 MW of RES may be installed. This will ensure that the conventional turbines keep working at a minimum, without having to turn them off, and afterwards requiring a fast turn on that may not be possible.

The next diagram will be the scheme of the 1st integration step, with 115 MW RES installed:



In a next step, RES power may be installed up to 75% of conventional groups working in the peak consumption hour. Regulation is required in this step, switching off RES groups to limit its power to the mentioned 75% for each hour.



For a 100% supply, a progressive substitution of conventional groups to RE is made, until peak demand is supplied with RES (396 MW in this example). Adding storage to our equation may flatten the energy production curve, but it will significantly increase costs. No special integration requirements exist in this scenario, as we are simply replacing fossil fuels powering the turbines with biofuels (biomass), heat (geothermal) or waterfalls (hydropower).

RES with Variable Energy Output: Wind, Solar, etc.

The main difference for variable energy output RES integration is that storage is a must, and it should be able to supply peak energy demands for an estimated period when the resource is scarce. Moreover, in a first step, RE production in optimum conditions should not exceed 25% of the conventional power in use for valley energy demands.

Integration for this scenario should follow the next step:

1 No regulation: RE power lower than 25% of power of operating conventional groups
2 With regulation (both RE and conventional) and RE requiring external excitation (wind energy with asynchronous generator): RE power up to twice the power of operating conventional groups
3 With regulation (both RE and conventional) and RE not requiring external excitation (wind energy with synchronous generator): same RE power of power of operating conventional groups
4 With RE Park disconnection: RE power not limited
5 With conventional plant disconnection and RE not requiring external excitation: RE power up to five times the power of operating conventional groups
6 100% RES: no conventional plants + synchronous control + storage.

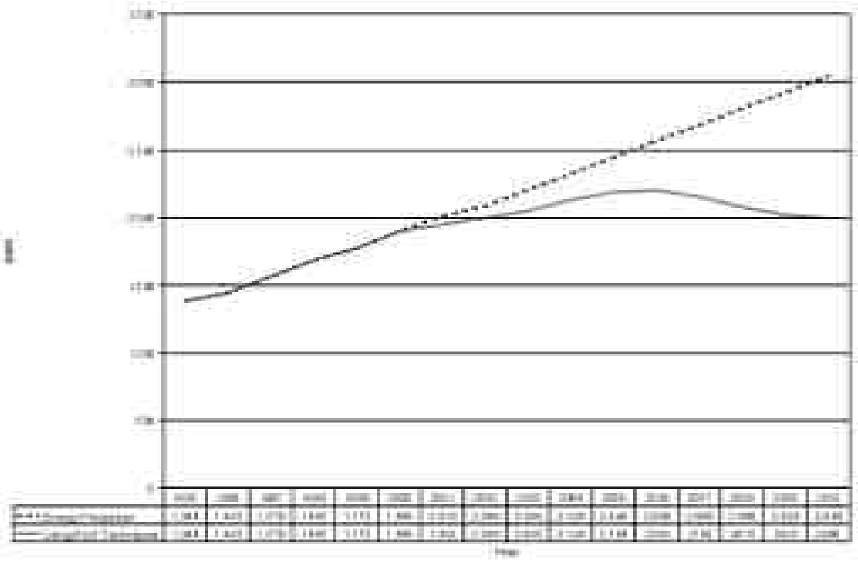
Regarding storage, it should be noted that it must be dimensioned to meet remaining energy requirements for peak hours after deducing constant energy output RES (e.g. cogeneration or hydro plants) for adverse climatologic conditions (no generation from RE variable sources). That is, if we have a peak demand of 296 MWh at a certain time, and 100 MWh are guaranteed with constant energy output RES, our system should have a storage capacity of 196 MWh.

The diversity of resources available, depending on the island, makes it extremely difficult to outline a model that covers all existing possibilities. In previous chapters, assessment on the available technologies depending on the resource has been given, as well as required changes in policies and regulations and the "obligation" of RUE as a previous and continuing step to implement islands 100% RES.

An example on a real case scenario will help the understanding of the approach. We will gather the information for the real island network of Tenerife Island. The power demand curve of the island is highly foreseeable, like in other insular contexts with long period data available, and there are no unexpected changes in consumptions. Additionally it is important to take into account that there are consumptions associated to the generation plants (7,4%) and losses in the distribution and transport system (7,46%).

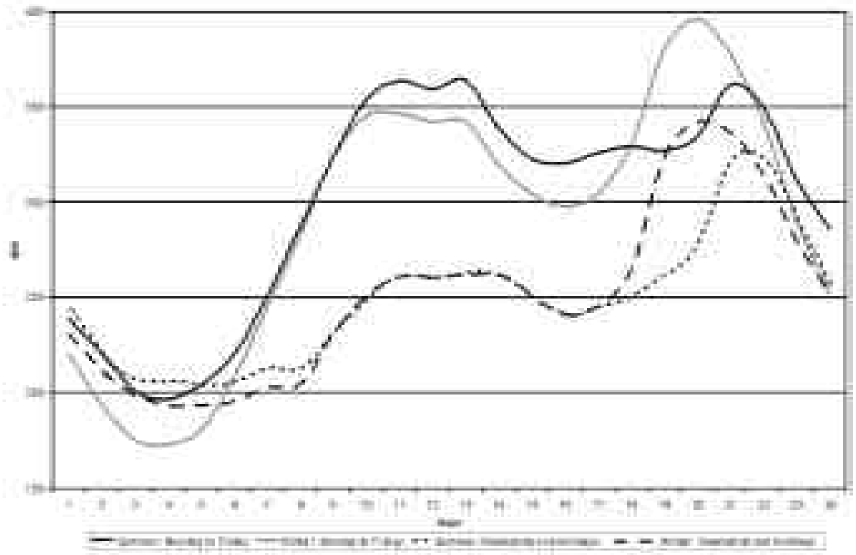
The increase in the demand was 7,7% during 1999. If the percentage of increase is maintained, the consumption figure will reach 3 millions of MWh per year in 2010. Nevertheless, taking into account that RUE requirements should be followed for a 100% approach, this figure can be reduced to approximately 2 millions.

Estimated increase of Energy Needs



The curves on power demand for our case study, both in winter and in summer, are:

Average Power Demand during the day



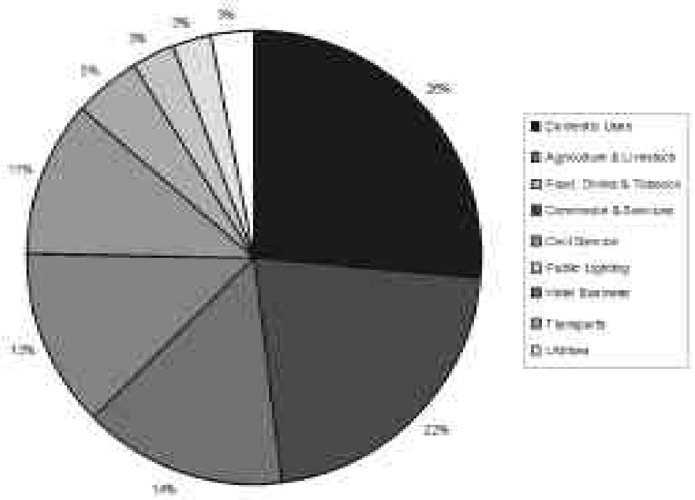
In our case scenario, we have a population of 692.366 inhabitants and the following conventional groups for energy production:

Technology	Power	Number of Turbines	TOTAL
Vapour	40	4	160
Vapour	22	2	44
Diesel	12	3	36
Gas	37,5	2	75
Gas	17,2	1	17,2
Vapour	80	2	160
Diesel	24	2	48
Gas	37,5	1	37,5
Cogeneration	38	1	38

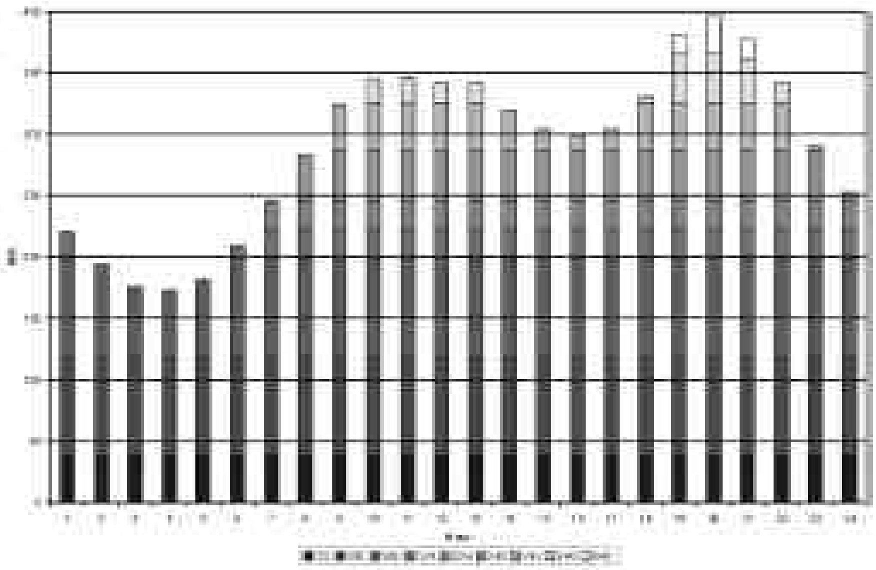
The average consumption per client/family in the island is 468 kWh per month. The highest hour demand during 1999 was 396 MWh and the lowest demand 173 MWh.

If we have available RES with constant energy output, that will reduce energy requirements of other RES. For example, in Tenerife there are installations for small hydro systems. Photovoltaics is an expensive alternative for a centralized energy production plant, so the energy percentage obtained from PV panels in buildings is negligible for our purposes. Biomass could be an alternative if soil is available for energy crops and there are no non-polluting natural resources. The same applies to geothermal energy, but Tenerife geothermal resources are not appropriate. Nevertheless, the island has excellent wind resources that could provide the required energy for island consumption, complemented with a small percentage of small hydro, photovoltaics, thermal collectors for DHW, cogeneration and maybe biomass. The next graph illustrates which generation groups are in operation in a standard winter working day, where V means Vapour, D Diesel, G Gas, and CO Cogeneration. The adjacent number is the rated power in MW.

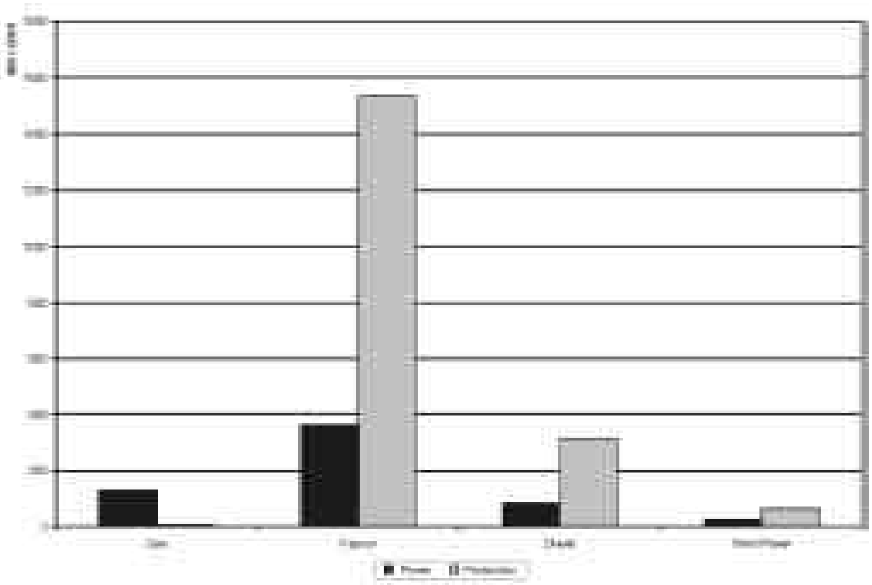
Energy Consumption per sector



Hourly Power Demand

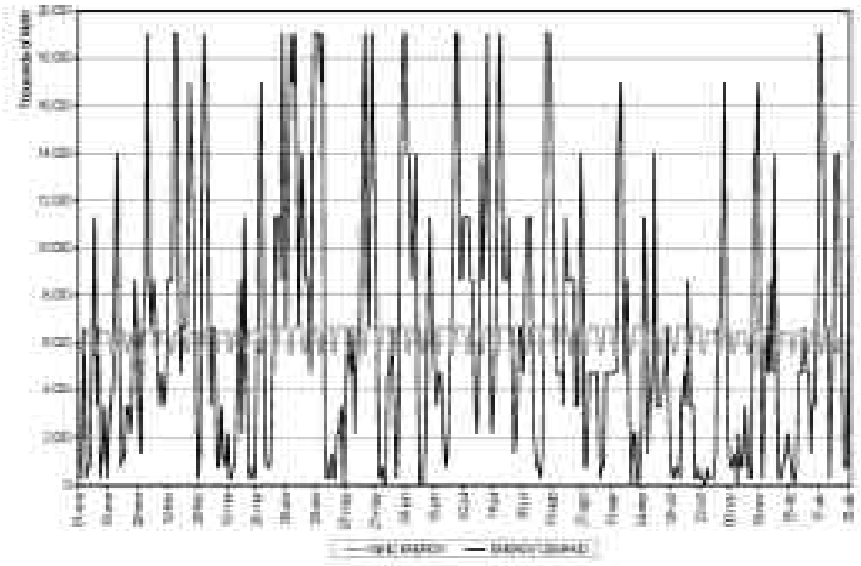


Installed Power and Annual Production in Tenerife



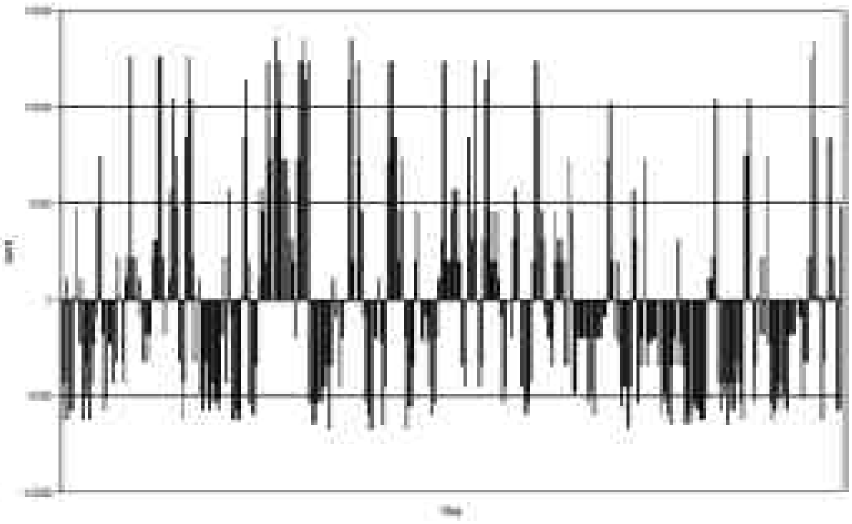
The southern coast of the island has a wind resource with 3000 equivalent hours. That means that, if supplied only with wind power, the island would require 794 MW installed. But that is a rough figure, as it only takes into account the energy needs over the year. But wind resources are climate dependant, which means that it is not adaptable to the energy demand. Taking into account daily average wind speeds, the energy generated for 794 MW wind power and the consumption of the island is the following:

Demand vs. Wind Energy Production



Therefore, the period where wind resource exceeds demand will charge the storage system, which will supply the required energy where wind resource is low:

Starage: Charging and Discharging Periods



Nevertheless, peak power demand should be taken into consideration. Up to now, we have considered only energy supply in rough figures, but the peak power demand (396 MW) is an important matter. Let us assume we have that peak consumption simultaneously to a scarce wind resource. Our storage system should be dimensioned for that power. That means that the power from batteries + pumping station from hydropower + turbines powered with biofuels + flywheels should equal the power of consumption. To avoid excessive costs, diesel or biofueled turbines may be used for consumption peaks.

A different path for the dimensioning of the storage is required, balancing powers to be able to supply the peak demand. Moreover, costs for each vector should be analysed to balance the total investment. It may be wiser for some scenarios to increase installed wind power even at the cost of losing energy, but reducing storage costs significantly.

The evolution for a 100% RES is not lineal, it should be done in progressive steps, each of them at a higher cost. The last step for 100% RE is extremely expensive, as we have to guarantee a small energy percentage that will occur during days only throughout the year. A global approximation of the cost evolution without figures is given below.