KYOTO PROTOCOL OBJECTIVES BY PROMOTING THE TECHNOLOGY TRANSFER TO SMALL ISLAND DEVELOPING COUNTRIES: SANTO ANTÃO, CAPE VERDE

Neven Duic, Luís Manuel Alves, Maria da Graça Carvalho

Instituto Superior Técnico, Technical University of Lisbon
Dept. of Mechanical Engineering
Av. Rovisco Pais
1049-001 Lisboa, PORTUGAL

ABSTRACT

Cape Verde is an example of a state that consists of several islands, with its particular energy situation. The electrical energy system is split into nine islands, and some of the islands, as well as Santo Antão, are further split into several independent electrical energy systems, which makes it hard for modern energy planning. The electricity generation is heavily dependent on Diesel engines of various powers, while on some islands there are some wind capacities installed, particularly on São Vicente. Diesel power is expensive and polluting, but still the most appropriate for such small scale electricity generation. This paper studies implications of different scenarios of development of electrical energy system on the island of Santo Antão, one of the most undeveloped and hard to electrify because of geography and lack of resources. An estimate of electricity demand for the period until 2030 is given. Business as usual scenario based on Diesel capacity is compared to two renewable energy scenarios, one envisaging 30% of the electricity generated by the wind power, and the other combining 25% of wind power with 5% of photovoltaic power. Further scenarios were generated and compared to the previous by the assumption of declining prices of renewable energy technologies. The scenarios were compared from the point of view of electricity generation prices, but also from the point of view of greenhouse gases (GHG) emissions. The possible influence of Clean Development Mechanism as a part of satisfying the United Nations Framework Convention on Climate Change objectives were assessed. A certain potential for financing the technology transfer was quantified and its influence on different electricity system planning scenarios estimated.

INTRODUCTION

It became clear in the course of the second half of the twentieth century that owing to human activities the carbon dioxide and other greenhouse gases concentration in atmosphere has significantly increased since the early nineteenth century. There is strong evidence that carbon dioxide might significantly influence the global warming process due to the greenhouse gas effect in the coming decades. The United Nations have started the abatement process by the UN Framework Convention on Climate Change (UNFCCC) at the "Earth Summit" in Rio de Janeiro 1992, to be continued by yearly sessions of the Conference of the Parties (COP) to the UNFCCC. They were held in Berlin in 1995, in Geneva in 1996, in Kyoto in 1997, in Buenos Aires in 1998 and in Bonn in 1999. The Kyoto Protocol was signed in 1997 laying down the formal promises from 42 developed countries to reduce the greenhouse gases (GHG) emission by average of 5.2%. Those countries are collectively known as Annex I countries. The developing countries also promised to participate in the process, but without formal limits pledged. Those countries are known as non-Annex I countries. The Convention is signed and ratified by 182 countries, while Kyoto Protocol is signed by 84 countries and ratified by only 22 due to open negotiations on mitigation mechanisms [1].

Republic of Cape Verde has signed the Convention in 1992 and ratified it in 1995 as a non-Annex I country [1], but it has not signed the Kyoto protocol yet. As a non-Annex I country it can participate in the GHG emission mitigation process through Clean Development Mechanism, one of mechanisms designed to reduce the cost of abatement while maximising the benefit. According to the Article 4.5 of the Convention "the developed country Parties ... shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention". Clean Development Mechanism of the UNFCCC process is exactly a vehicle that should enable such a transfer. It envisages that a technology transferred to a non-Annex I country from an Annex I country that has resulted in a reduction of GHG emission from the baseline could use that reduction as certificates that could be traded or used against the investing country GHG emission target. The baseline is still not formally defined for the non-Annex I countries, but it could be estimated as business as usual scenario of GHG emission projection.

With only around 300 kg per capita CO_2 emission in 1996 [2], Cape Verde has a GHG emission of minuscule value, even with the comparison with Africa (1200 kg per capita). Nevertheless, this paper is going to show that there is a potential, if not to seriously decrease the global GHG emission, but to help the technology transfer to the developing countries by actually helping the mitigation process.

As an example of a really low emission territory the island of Santo Antão was chosen. The CO_2 emission is estimated to be at 39 kg per capita in 1996, which is due to the fact that there is practically no industry on the island, and no other important sources of GHG, apart from electricity generation and transport.

The projections shown in this paper are based on the plan of power system development for the island of Santo Antão [3] for the period until 2010. The period after 2010, important for the UNFCCC process, is forecasted on the assumptions of expected growth of population, GDP and energy and electricity consumption. The paper predicts a very limited increase in population, due to migration to other islands and emigration, and expects that the total population of the island will stay around 50000. That will only change if there is a significant change to the economy of the island of Santo Antão. The economy is now heavily dependent on the primary sector, much of it on subsistence level, that makes 43% of its GDP, while the secondary sector makes 19% of its GDP and the rest are services, in all some 700 USD of GDP [4].

There are only three significant GHG emission sources on the island of Santo Antão, one being the electricity generation, the other transport, and the third use of fossil fuels for cooking. We have here looked only on the electricity generation sector although other sectors might be influenced by the technology innovations having a spill over effect on Cape Verde.

This paper takes into account only CO_2 emission while neglecting the other greenhouse gases. That is acceptable, because of qualitative results and conclusions of this paper.

SITUATION

Cape Verde is a small island country situated in the Atlantic Ocean, in front of African western coast. It has a population of 405000 (1999 est. – [5]) spread over 9 islands. The population is very young with high birth rate of 33 per thousand and low mortality rate of 7 per thousand, but with a fertility rate of still high 5 born children per woman that has started to fall. Since the islands are not managing to provide employment opportunities for all the demographic population growth there is an extremely high emigration rate of 12 per thousand. Due to uneven development of different islands there is also important internal migration, mainly from rural areas to urban areas on main islands, Santiago and São Vicente, and also to the island Sal because of its international airport.

Subsistence farming is main occupation for the majority of the rural population that currently makes half of population. The rural areas are saturated and it is presumed that the new population stemming from the demographic growth in rural areas will migrate to urban areas or to abroad. It is expected that the birth rate will steadily decrease, first relatively slow, but after 2010 rapidly, to reach 22 per thousand in 2020. It is also expected, but it might prove wrong, that the net immigration will slow down with better standard of living and better job opportunities brought with new economies like tourism, fisheries and energy to 1 per thousand in 2020.

Internal migrations will follow the patterns of economy growth, which is relatively hard to predict. A very strong employer in Cape Verde is the administration, and since only a limited level of decentralisation is predicted the capital Praia will be the strongest magnet for the surplus coming from the saturated rural areas. Tourism will create another possible set of growth centres, depending on infrastructure, health level and attraction of certain places. Sal already has strong attraction in the international airport, the best tourist infrastructure already in place and relatively small number of inhabitants currently. Neighbouring Boavista has great potential in its particular dune beauty. Santo Antão might develop strong tourist industry if it becomes more accessible. The island of São Vicente and its main town Mindelo was for a long time an economy powerhouse of Cape Verde, but it is recently loosing its prestige. Nevertheless, it is still expected to attract rural surplus from northern islands of Santo Antão and São Nicolau.

The island of Santiago, where the capital Praia is located, already holds more than half of the population of Cape Verde, which will reach 60% in 2010 and 65% in 2030. Most of this growth will continue to go to Praia as it does since the independence created job opportunities in the capital, so Praia will reach 340000 in 2030 or 50% of the population of Cape Verde unless there is a strong investment in decentralisation.

Cape Verde has a relatively high nominal GDP per capita of 1090 USD (1997 [2]), but a significant part of it is due to emigrated relatives sending money, which means that when the links start to wither, the main income source will disappear. The purchase power parity based GDP was estimated to be 1450 USD/capita in 1998 [5].

The lack of natural resources is partially assuaged by relatively high level of literacy (71% in 1995 [5]), which is reaching developed countries levels for population younger than 20, and nearly general spread of elementary education. Unfortunately, the comparative advantage of well-educated population is used mostly for labour export.

After long periods of mediocre growth the last two years shown much better results, 8% GDP growth in 1998 [5], and again in 1999 [6]. Nevertheless, such exceptional growth is most probably due to the privatisation induced capital inflow. The long-term growth is expected to average a more conservative 3.5% until 2030, still, a very high rate for a country without any absolute advantage.

One of the most important growth sectors will be the production of desalinised water, which will grow twentyfold between 1996 and 2012, to 7.6 million m^3 per year, due to lack of water and such a concentration of population. Desalinisation will then create a strong growth in electricity demand.

Apart from the island of São Vicente the electricity production in Cape Verde was until recently being developed locally, without understanding the positive effects of grid connection. That could be partially explained with a relatively low demand. The electricity consumption per capita has grown from only 55 kWh in 1980 to 104 kWh in 1996 [2] with the island of Santo Antão having per capita consumption of 59 kWh in 1996. That is expected to grow to 133 kWh in 2000, 310 kWh in 2010, 600 kWh in 2020 and more than 1000 kWh in 2030. Such exponential growth will mainly be caused by further electrification of the island and very low current consumption.

Currently only 29% of Santo Antão population is connected to the electricity grid, mainly in the northern zone of Ribeira Grande and other two county capitals, Porto Novo and Paul. That is expected to grow to 70% in 2010, 80% in 2020 and 90% in 2030. Certain parts of hard to reach and poor rural population will most probably be left out of the electrification, but that might change as poor rural population increasingly moves to towns while richer population builds second homes in rural zones.

There are at the moment around 10 independent electricity grids at the island of Santo Antão. The grid is being extended from three county capitals, while it is expected that two of them, Ribeira Grande and Paul will be connected in year 2000. Connecting the third grid, the one of Porto Novo on the other side of the island will probably come several years later, depending on which strategy is chosen. This paper assumes that the main three grids will be connected at last in 2003 to enable the construction of viable wind capacity in the zone between Porto Novo and Janela. Some smaller conglomerations in the western half of the island will stay with isolated grids much longer. We have not assumed connecting Santo Antão with neighbouring islands São Vicente before 2030, since probably such connection would not be commercially viable.

Judging from the growth in demand and problems in covering it by production, with high loss of load probability, any new capacity built automatically creates new demand. With the conservative growth forecast the electricity generation will have to satisfy the demand of 6 GWh in 2000, 14 GWh in 2010, 28 GWh in 2020 and 50 GWh in 2030, roughly doubling every ten years. That demand will stay relatively stable during around the year since there are not strong seasonal changes, while the daily variations will be somehow damped by the refrigeration capacity and possibly by desalinisation if it will be required on Santo Antão.

The peak load in the main network will nevertheless grow from 0.7 MW in 1996 to 1.3 MW in 2000, and further to 2.6 MW in 2010, 4.6 MW in 2020 and 7.5 MW in 2030, doubling the capacity needed each decade. Table 1 shows basic electricity demand data.

Table 1. Electricity production in Santo Antão

	2000	2010	2020	2030
electrification rate, %	29	70	80	90
demand, GWh	6	14	28	50
peak load, main netw., MW	1.3	2.6	4.6	7.5
consumption, kWh/capita	133	310	600	1000

According to the study done in 1997 [3] that demand will mostly be satisfied by the Diesel capacity. Cape Verde has a superb eolic condition, like for example a zone between Porto Novo and Janela where average wind velocity are over 11 m/s. Unfortunately, Santo Antão does not have a single grid but three minuscule ones and several even smaller. Because of grid stability it is impossible at the moment to install any serious wind capacity. When grid gets connected it is expected that only small wind turbines (e.g. 250 kW) could be installed, only one in the beginning, and later periodically new capacity could be added. Such an approach would significantly increase the investment cost in the beginning, since the infrastructure would have to be laid down for the whole field, while its installation would last for a long time. Solar power, due to its high price, can be expected to be used only where there is no economic viability for grid connection or even a micro Diesel generator, and that only for some specific uses.

BUSINESS AS USUAL SCENARIO

The business as usual scenario for Santo Antão, based on the latter study, envisages installation of 6 Diesel unit of 800 kW between until 2010 to cover the demand and replace the old installed capacity. Such large units can only be installed if the island grid is connected into one, and only because of the lower cost of unit capacity for bigger units. In the beginning such a unit will be more than 20% of the network installed capacity, but since there is an urgent need of increasing capacity and there is a large hidden demand that will reveal only with the growth of installed capacity, such a situation is temporarily justified.

After the year 2010 nine more units of that size would be installed, falling under the 15% of the total installed capacity only in 2015. After that year possibly larger units could be installed instead of the 800 kW ones, but not bigger than 1.2 MW. The total installed capacity will reach 3 MW in 2000, 6.5 MW in 2010, 9 MW in 2020 and 11.5 MW in 2030, all of it Diesel. The criteria used to calculate the capacity needed was N-2 and at least 15% reserve, what ever is stricter. The resulting development of capacity is shown on *Figure 1*.

Diesel has several advantages for Cape Verde. It is a relatively simple technology that has been used for a long time in Cape Verde and in similar situations, there is local know-how in operating and maintaining Diesel plants and there is infrastructure build for fuel handling. The main disadvantage for Cape Verde is the highly oscillating price of fuel, which is currently very high and which is the most important ingredient in the price of electricity produced from that technology. The ecological concern is more of a global reach, since Diesel technology has relatively high intensity of GHG per unit product.

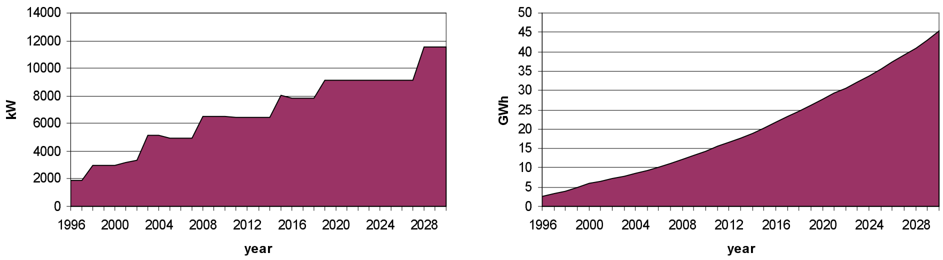

Figure 1. Installed capacity and electricity production for business as usual scenario, Diesel only

30% ELECTRICITY FROM RENEWABLE SOURCES

There are many different ways how emissions of GHG could be reduced, but we have decided to concentrate on two technologies that are readily available. The first of them is wind power, for which Cape Verde has superb conditions (including parts of the island of Santo Antão) and relatively good experience and popularity among local stakeholders. The second one is solar photovoltaic electricity generation. That technology is still not commercially viable but with the increase of interest in the abatement of GHG emissions there is a strong push in the direction of making PV a viable grid connected electricity source. We shall take it here, still, as a source for isolated regions.

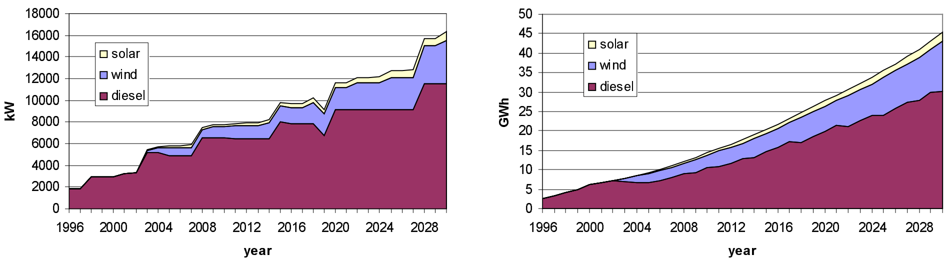

Figure 2. Installed capacity and electricity production for 25% wind electricity and 5% solar PV electricity scenario

The wind/solar scenario envisages the production of 30% electricity from renewable sources, 25% from eolic power and 5% from solar photovoltaic cells starting from 2003. The best place for a wind field is a zone between Porto Novo and Janela, on the north-eastern side of the island with average yearly wind velocities of more than 11 m/s. That zone is on the way of the proposed main grid link that is supposed to connect Porto Novo and Paul, and where is the possible location of the new Diesel power plant. Starting with 2003 three wind turbines could be installed, every year adding 250 kW of capacity. Until 2015 three more wind turbines of that size would be installed, reaching that total of 1.5 MW. After 2015 every several years a unit of 500 kW could be installed, four of them until 2030, pushing the total wind capacity to 3.5 MW and covering 25% of the electricity generation.

The solar PV panels can be installed anywhere, since there is a lot of sun in Santo Antão. It can be installed in small units, starting with 20 kW in 2003, and reaching the installed capacity of 200 kW and 5% of electricity generation in 2007. Until 2030 the total PV capacity could reach 800 kW in order to cover 5% of the demand from this source.

That would enable generation of around 30% of electricity from renewable sources (*Figure 2*) and to reduce the emission of CO_2 from electricity production by the same percentage. The main drawback of this scenario is that installing wind turbines and solar PV cells will not significantly reduce the Diesel capacity needed to satisfy the reserve. The wind (and solar) was taken to account for guaranteed power supply with only 4% of its installed capacity. The reserve was taken into account in the same way as in the business as usual scenario, having in reserve at least two largest blocks (N-2 criteria) and at least 15% of installed capacity, which ever criteria is stricter.

The third scenario envisages the production of 30% electricity from eolic power starting in 2003 with 10% electricity generated. In the beginning the dynamics of increasing the wind capacity is the same as in the second scenario, with three units of 250 kW and 30% of electricity generated by 2006. Then the process gets faster, enabling the installation of 3 more units until 2011 reaching 1.5 MW. After that 500 kW turbines would be added every several year reaching 4 MW by 2030. The main idea behind the inclusion of this scenario is its financial comparison with the second one.

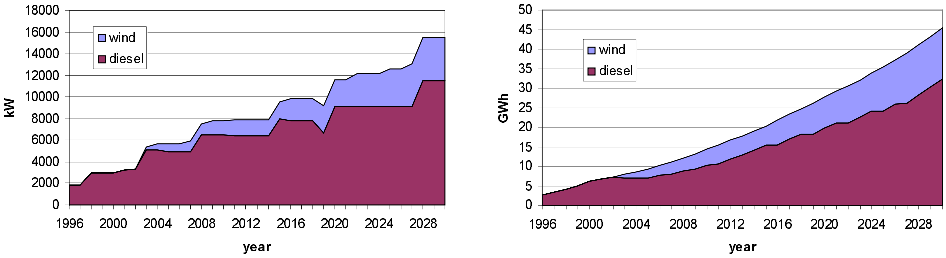

Figure 3. Installed capacity and electricity production for 30% wind electricity scenario

Figure 3 shows reduction of CO_2 emission from the electricity generation due to producing 30% of electricity from renewable sources. Since harnessing of eolic and PV energies does not produce significant on the place GHG emission, it reduces the total emission by 30%. That reduction of GHG emission if financed by an Annex I country through technology transfer might be used through a Clean Development Mechanism to increase the GHG target in the donor country.

The OECD study "Meeting the Kyoto targets" [7] concludes that in case of unlimited emission trading the average price of CO_2 emission reduction would be 90 USD per tonne of carbon. The carbon futures are already trading at prices of 1-3 USD per tonne of carbon [8]. As the market develops the price is likely to rise. World Bank's Prototype Carbon Fund forecasts a price of 15-40 USD per tonne of carbon [8]. The theoretical price of abatement of 90 USD/tC is used to demonstrate the potential of the CDM for the investor. The total amount is shown on *Figure 4*.

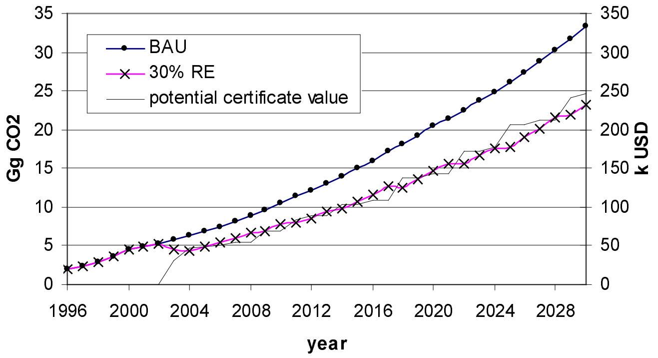

Figure 4. Reduction of CO2 emission due to 30% of electricity produce from renewable sources and the maximum potential value of emission certificates due to Clean Development Mechanism

FINANCIAL ANALYSIS

The estimated price of Diesel electricity in Cape Verde is 8 US¢/kWh for a unit that operates on 45% of load. The loads on the island of Santo Antão are much lower, and there is a need to adjust the price for that. The easiest way is to spread the fixed cost over the actual load, which results in the actual price of Santo Antão Diesel electricity of up to 13 US¢/kWh.

The price of wind electricity is estimated at 7 US¢/kWh, due to superb eolic conditions, although that is an underestimation due to very small wind field installed in the beginning. Meanwhile, after the initial period, the price should fall to that level or even further. The problem is since the wind power cannot be used as guaranteed it will increase the price of Diesel electricity, which will have to cover the lower load factor.

The price of solar photovoltaic power is estimated at 50 US¢/kWh, due to small units that have to be installed in remote areas.

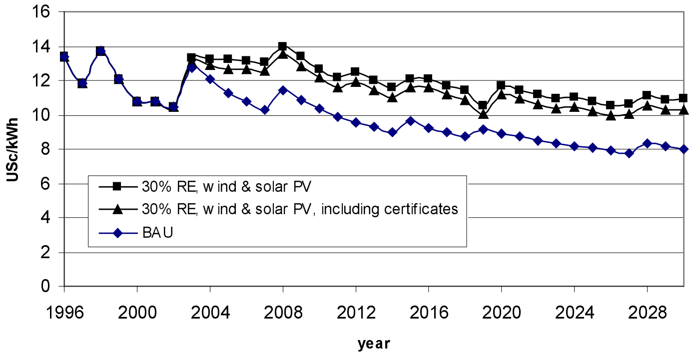

Figure 5. Comparison of electricity price generated in business and usual and wind/solar scenarios, with the influence of the emission certificates

The comparison of electricity price between the business as usual scenario and wind/solar scenario is shown on *Figure 5*. Consistently, the renewable scenario is more expensive. The possible and maximum influence of CDM certificates value being taken into the financial consideration shows that it is of too small influence. Similar comparison with only wind power being installed as renewable is shown on *Figure 6*. Although with estimated prices, the price of renewable scenario is higher than the Diesel only one, the influence of CDM certificates is crucial, since they push the wind into economic viability. This example should be understood in a qualitative way, as a good example of additionality of CDM.

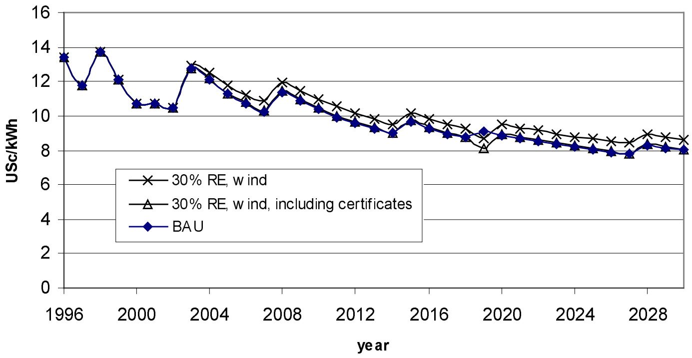

Figure 6. Comparison of electricity price generated in business and usual and wind scenarios, with the influence of the emission certificates

Both renewable scenarios were calculated using constant prices of renewable energy technologies, which is not properly representing the reality. Some RET prices are falling by a third or a quarter per year. Wind is such a technology, although it is expected that the fall in the price of wind turbines is saturated and will only be prolonged by the increase of the size of turbines offered on the market. If we envisage yearly fall in price in the wind technology of 2% and in solar PV technology of 5%, a comparison shown on *Figure 7* can be made for wind/solar scenario.

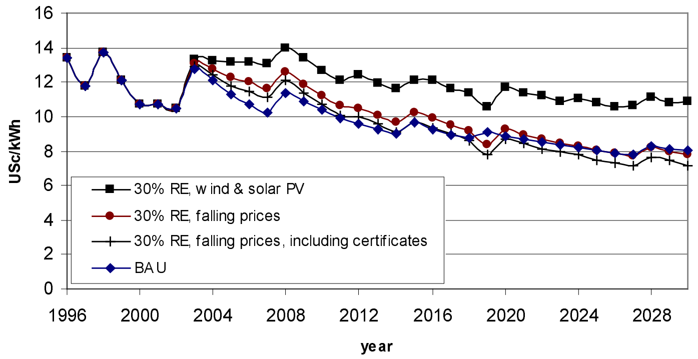

Figure 7. The influence of the declining prices of renewable energy technologies on the electricity price

Even though with falling prices our energy mix will get economically viable compared with the business as usual scenario, it will get so only in 2018, while with taking into account the potential value of CDM certificates that would already happen in 2014, four years earlier.

CONCLUSIONS

The paper has shown the potential influence of the UNFCCC process through its Clean Development Mechanism on the technology transfer to a developing region, in the case of very low carbon intensity, as it is on the island of Santo Antão. Santo Antão is an example of good natural resource for renewable energy exploitation and poor energy infrastructure. It is also the case for several Island and Remote Regions.

The future trend of clean technologies will be the main parameter together with the existing natural conditions to take into account in the development of scenarios for GHG mitigation.

The renewable energy technology transfer would be helped by the incentive of possible use of carbon certificates obtained from the reduction of GHG emission growth against the investor country targets, though the additionality would be limited to some situations. Wind energy, which is basically commercial today on the global scale and locally competitive if natural conditions exist, can easily be helped in a crucial way by CDM. In this case, CDM can be an incentive for further penetration of wind energy in Island and Remote Regions.

The solar photovoltaic technology is still too expensive to be helped by CDM. Meanwhile, if the prices of renewable energy technologies continue to fall, it was shown that thanks to CDM a switch to economic viability might be forced to occur half a decade earlier than without the influence of the UNFCCC process.

LITERATURE

1. UN Framework Convention on Climate Change site: http://www.unfccc.de
2. The Human Development Report 1999, UNDP, http://www.undp.org/hdro/report.html
3. Delgado, Jansénio et al.: Perspectivas de desenvolvimento, Plano director de electricidade de Santo Antão, 1997, Cape Verde
4. Delgado, Jansénio et al.: Diagnóstico de situação local, Plano director de electricidade de Santo Antão, 1997, Cape Verde
5. The World Factbook 1999, CIA, http://www.odci.gov/cia/publications/factbook/index.html
6. Le Monde: Bilan du Monde, Edition 2000
7. OECD study “Meeting the Kyoto targets”, COM/ENV/EPOC/CPE(99)76, 1999
8. The Economist, Greenhouse gases - Cost free, January 22, 2000

ACKNOWLEDGEMENT

The authors would like to acknowledge the Portuguese Ministério da Ciência e Tecnologia for the financial support of the scholarships of Dr. Luis Alves and Dr. Neven Duic through the programme Praxis XXI.

The financial support of the THERMIE program (DGXVII of the European Union) and the Portuguese Direcção Geral da Energia is also acknowledged. The content of the publication is the sole responsibility of its authors, and in no way represents the views of the European Commission or its services.