Neven Duić
Luís Manuel Alves
Maria da Graça Carvalho

ISSN 1331-2758

POTENTIAL OF KYOTO PROTOCOL IN TRANSFER OF ENERGY TECHNOLOGIES TO INSULAR COUNTRIES

UDK 504.03.054, 620.92
Preliminary note
Prethodno priopćenje

Summary

In order to reduce the cost of meeting targets, the countries committed to greenhouse gases reductions under the United Nations Framework Convention on Climate Change will depend on cheaper reductions elsewhere. This will give a financial incentive, through Clean Development Mechanism, for dissemination of clean energy technologies. The paper focuses on the case of small island developing states and shows, by assessing the case of the island of Santo Antão, Cape Verde, that even when the emission reduction is small, there is a potential for establishing strong market presence of renewable energy technologies. The implications of different scenarios of development of electrical energy system are studied, comparing renewable energy scenarios to a baseline scenario. The potential for financing the technology transfer is quantified and its influence on different electricity system planning scenarios estimated.

Key words: *greenhouse gases, energy system, renewable energy*

UTJECAJ KYOTO PROTOKOLA NA TRANSFER ENERGETSKE TEHNOLOGIJE U MALE ZEMLJE U RAZVOJU

Sažetak

Da bi smanjile trošak ispunjavanja kvota, zemlje koje su pod okriljem Okvirne konvencije Ujedinjenih naroda o klimatskim promjenama obećale smanjenja emisija stakleničkih plinova ovisit će o jeftinijim smanjenjima drugdje. To će kroz “Mehanizam čistog razvoja” dati finacijsku potporu diseminaciji čistih energetskih tehnologija. Ovaj se rad usredotočuje na slučaj malih otočnih zemalja u razvoju i pokazuje, prosuđujući slučaj otoka Santo Antão, jednog od Zelenortskih otoka, da čak i kada su smanjenja emisija mala, postoji veliki potencijal za značajan udio obnovljivih izvora energije na tržištu. Implikacije različitih obnovljivih scenarija razvoja elektroenergetskog sustava uspoređene su s baznim scenarijem. Potencijal za financiranje transfera tehnologije je kvantificiran.

Ključne riječi: *staklenički plinovi, energetika, obnovljivi izvori energije*

1. Introduction

In the course of two last decades it has become clear from the measured evidence that the carbon dioxide concentration in the atmosphere has significantly increased since the early nineteenth century. There is a strong evidence that the increase in the stock of carbon dioxide could be, due to the greenhouse gas effect, a cause of the significant global warming in the coming decades. Acknowledging that, the United Nations started a mitigation process at the "Earth Summit" in Rio de Janeiro in 1992 with the UN Framework Convention on Climate Change (UNFCCC). The process was later continued by yearly Conference of the Parties sessions starting in 1995. The Kyoto Protocol to the UNFCCC was signed in 1997 at its third session. The Convention is signed and ratified by 186 countries, while the Kyoto Protocol is signed by 84 countries and ratified by 40, [1] and [2].

The Kyoto Protocol carries legally binding greenhouse gas (GHG) emission targets for the so-called Annex I (to the UNFCCC) parties. These, mainly developed countries and economies in transition, are obliged to reduce their overall GHG emission level by at least 5% below the 1990 levels during the commitment period 2008-2012. The Kyoto Protocol allows Annex I parties to meet these commitments partly by achieving emission reductions abroad, thus enabling them to improve the cost-effectiveness of emission reduction, because reducing GHG emissions at an emission source in another country may be cheaper than doing so domestically. Several studies find that the marginal costs of GHG emission reduction vary greatly among the UNFCCC parties, [3], [4] and [5]. Since the process of global warming is caused by the total accumulation of greenhouse gases in the atmosphere, it does not matter where these pollutants are emitted or reduced. If parties could use these cost differences, the overall costs of mitigating climate change would be reduced by half compared with domestic action only, [3] and [4].

There are three cross-border emission reduction mechanisms that Annex I countries can apply in order to reduce the cost of their commitments: Emissions Trading (ET), Joint Implementation (JI) and Clean Development Mechanism (CDM). Within the Annex I region, a country may purchase assigned amounts (AAs) by means of ET, or emission reduction units (ERUs) from JI projects conducted in another Annex I country. An Annex I party may also buy certified emission reductions (CERs) from developing countries by means of CDM projects. Policy makers in Annex I countries have to decide how much money to invest and in which of the flexible Kyoto mechanism, depending on the estimate which mechanism will be most effective and efficient. Although there is a carbon futures market [6], it will only properly develop after 2008. Until then the market will not be able to help the policy makers to make strategic investment decisions which have to be taken in the short term.

Several environmental economists claim that emission reduction entitlements from ET will be more environmentally sound and cheaper than from JI or CDM, [7], [8] and [9]. However, contrary to their findings, some authors are arguing that JI and CDM will be more effective, efficient and politically acceptable than ET in implementing the Kyoto protocol [10], [11], [12] and [13]. This paper will argue that the CDM projects could be economically sound while at the same time respecting the additionality condition [14]. The promise of technology transfer that accompanies CDM could also have an effect of facilitating the acceptance of the Kyoto Protocol in the non-Annex I countries [15].

The paper will show how the Clean Development Mechanism could function in the case of Cape Verde, an insular developing country. The country belongs to the group of Small Island Developing States (SIDS) and the group of the Least Developed Countries (LDC), and has a low carbon intensive economy based on an expensive low scale energy system. In order to simplify the example, only one of the energy systems will be taken into account, the electricity generation on the island of Santo Antão. That system will be assessed in detail, in order to get profound knowledge of the influence of the potential CDM project. The results could then be used in similar cases. The entire population of SIDS, as represented by the interest group AOSIS at UNFCCC, is relatively small, i.e. 0.6% of the total world population, but since 36 of these states are independent members of the UN (plus 6 more autonomous territories), their political importance is far exceeding their population and economic importance. That has been felt during the entire UNFCCC process, and has to be given its due attention. There are SIDS of various population sizes, starting from 2000 of Niue and 11000 of Nauru and Tuvalu, and going up to 5 million of Papua New Guinea.

2. The case of Santo Antão, Cape Verde

Cape Verde is a small island country situated in the Atlantic Ocean, off the African western coast. It has a population of 405000 spread over 9 islands. Subsistence farming is the main occupation for the majority of the rural population that currently makes half of the entire population.

The patterns of economic growth are relatively hard to predict. A very strong employer in Cape Verde is the administration, and since only a limited level of decentralisation is predicted, it will mainly be concentrated in the capital Praia. Tourism will create another set of growth centres, depending on infrastructure, health level and attraction of certain places. Sal is best placed, with the international airport and the best tourist infrastructure, to profit from tourism led growth taking nearly a half of tourist arrivals and income. Neighbouring Boavista has a potential in its particular dune beauty. The development of the tourist industry in Santo Antão is hindered by difficulties in access. The tourist arrivals to Cape Verde were 52000 in 1998, growing by 33% from the previous year [16]. The hotels are already making 7% of GDP, according to the estimates from the National Institute of Statistics.

Cape Verde has a relatively high nominal GDP per capita of 1090 USD (1997 [17]), but a significant part of it is due to remittances of emigrated relatives, 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 1700 USD/capita in 2000 [18].

The lack of natural resources is partially assuaged by relatively high level of literacy (71% in 1995 [18]), which is reaching the developed countries levels for population younger than 20, and by nearly general spread of elementary education. Unfortunately, the comparative advantage of well-educated population is used mostly for labour export.

After long periods of low growth, the last three years showed much better results, i.e. 8% GDP growth in 1998 [19], 5% in 1999 [20], and 6% in 2000 [18]. Nevertheless, such exceptional growth is most probably due to the capital inflow induced by privatisation. The long-term growth is assumed to average a more conservative 3.5% until 2030.

Apart from the island of São Vicente, the electricity production in Cape Verde was until recently being developed locally. That could partially be explained with a relatively low demand and retail price of electricity not covering the investment cost. The electricity consumption per capita had grown from only 55 kWh in 1980 to 104 kWh in 1996 [21], with the island of Santo Antão having per capita consumption of 59 kWh in 1996 [22] and 129 kWh in the year 2000 [23]. The consumption is expected to grow to 310 kWh by 2010 and to more than 1000 kWh by 2030. Such exponential growth will mainly be caused by further electrification of the island as planned [21].

Nearly 50% of Santo Antão population is connected to the electricity grid and 70% of the population is served, meaning they can be connected if they choose. The connection ratio is expected to grow to 70% by 2010 [21], and further to 80% by 2020 and 90% by 2030. Certain parts of hard to reach and poor rural population will most probably be left out of electrification, but that might change as poor rural population increasingly moves to towns and richer population builds second homes in rural zones. The unconnected population will be a potential market for off-grid electricity generation, including from renewable sources.

At the moment there are around 10 independent electricity grids, two of them larger and the rest isolated village grids. The larger grids started by being extended from county capitals, two of those, Ribeira Grande and Paul, connected in the year 2000. Connecting the third grid, the one of Porto Novo on the other side of the island will come several years later. This paper assumes that the main three grids will be connected at the latest in 2003, in order to enable planning 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 for much longer. We have not assumed connecting Santo Antão with the neighbouring island of São Vicente before 2030, since such a connection would probably not be commercially viable.

Judging from the growth in demand and the problems in covering it by production, [21] and [22], with a high loss of load probability, any newly built capacity automatically creates new demand. With the conservative growth forecast [21], the electricity generation will have to satisfy the demand of 6 GWh in 2000, 14 GWh in 2010 and 50 GWh in 2030, roughly doubling every ten years. That demand will be staying relatively stable around the year since there are no strong seasonal changes, while the daily variations will somehow be dampened by the refrigeration capacity and possibly by desalinisation, if ever necessary on Santo Antão.

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

Table 1. Electricity production in Santo Antão [21], [24]

Tablica 1. Proizvodnja električne energije na otoku Santo Antão [21], [24]

	2000	2010	2020	2030
electrification rate, %	50	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	129	310	600	1000

According to the study carried out in 1997 [21], that demand will mostly be satisfied by the Diesel capacity. Cape Verde has a superb eolic condition, like, for example, the zone between Porto Novo and Janela, where average wind velocity is over 11 m/s. Unfortunately, Santo Antão does not have a single grid, but two minuscule ones and several even smaller. Because of the grid stability, it is not viable to install any significant wind capacity at the moment. When the grid gets connected, it is expected that only small wind turbines (e.g. 250 kW) could be installed, only one at the beginning, adding new capacity later, as necessary. 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 only for some specific uses.

3. Baseline scenario

The baseline scenario, modelled on business as usual electricity strategy for Santo Antão, as reported in the latter study [21], envisages installation of 6 Diesel units of 800 kW by 2010 to cover the demand and replace the old installed capacity. Such relatively large units will only be viable 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 for increasing the capacity and there is a large hidden demand that will be revealed only with the growth of the installed capacity, such a situation is temporarily justified.

After the year 2010 nine more units of that size would be installed, falling under 15% of the total installed capacity only in 2015. After that year larger units could possibly be installed instead of the 800 kW ones, but not bigger than 1.2 MW. The total installed capacity reached 3.3 MW in 2000 [23] and will grow to 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 required capacity was N-2 and at least 15% reserve, whichever is stricter. The resulting development of capacity is shown in 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 the local know-how in operating and maintaining Diesel plants and there is an infrastructure built for fuel handling. The main disadvantage for Cape Verde is highly oscillating price of fuel, which is currently very high and which is the most important component in the price of electricity produced by that technology. The ecological concern is more of a global reach, since Diesel technology has relatively high intensity of GHG per unit product.

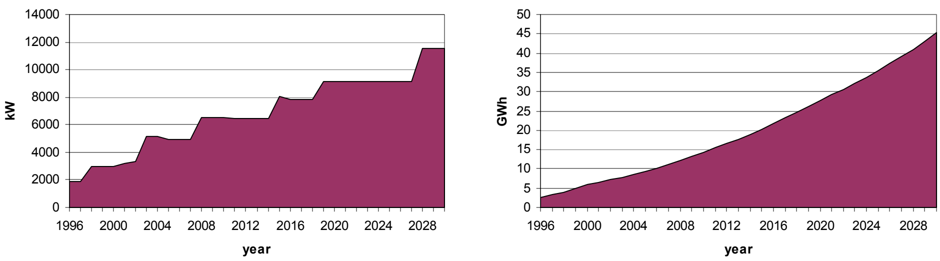

Figure 1. Installed capacity and electricity production for business as usual scenario, Diesel only

Slika 1. Instalirani kapacitet i proizvodnja električne energije za *business as usual* scenario, samo Diesel

4. Thirty percent electricity from renewable sources

There are many different ways how emissions of GHG could be reduced, but we have decided to focus on two technologies that are readily available. The first 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, with a total of 2.8 MW installed on 6 islands [23]. 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. Nevertheless, it will be taken here as an electricity source for isolated regions, in off-grid applications, assuming that it would replace equal amount of Diesel produced electricity.

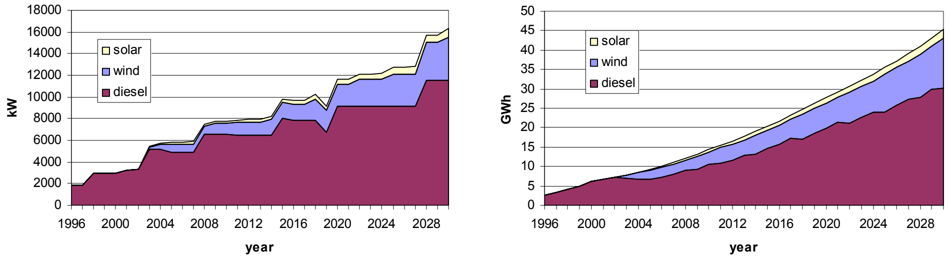

Figure 2. Installed capacity and electricity production for 25% wind electricity and 5% solar PV electricity scenario

Slika 2. Instalirani kapacitet i proizvodnja električne energije za scenario u kojem se 25% električne energije dobiva energijom vjetra a 5% solarnom fotovoltaičnom

The wind/solar scenario limits the production of electricity from renewable sources to 30%, of which 25% from eolic power and 5% from solar photovoltaic cells starting from 2003. The best place for a wind field is the 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. The location is close to the planned main grid link connecting Porto Novo and Paul, next to the planned location of the new Diesel power plant. Between 2003 and 2005 three 250 kW wind turbines could be installed. Until 2015 three more wind turbines of that size would be installed, reaching the total of 1.5 MW. After 2015, every several years, a unit of 500 kW could be installed, four of them by 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, in small units, starting with a total of 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 would 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 reduction of CO_2 emission 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 assumed 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 baseline scenario.

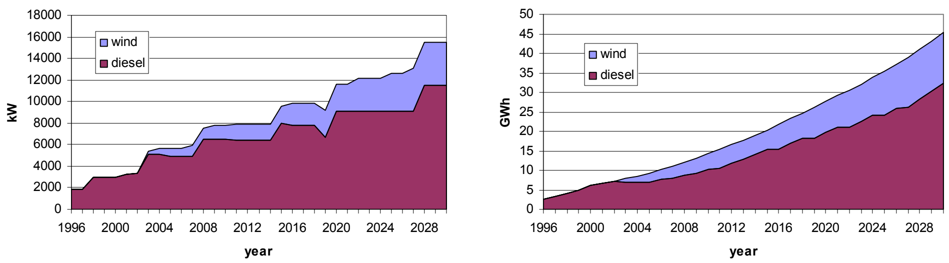

Figure 3. Installed capacity and electricity production for 30% wind electricity scenario

Slika 3. Instalirani kapacitet i proizvodnja električne energije za scenario u kojem se 30% električne energije dobiva iz energije vjetra

The third scenario (Figure 3) envisages the production of 30% electricity from wind power, starting in 2003 with 10% electricity generated. At 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 by 2011 reaching the total of 1.5 MW. After that 500 kW turbines would be added every several year reaching 4 MW by 2030.

Figure 4 shows a comparison of CO_2 emission for two scenarios of the electricity generation. The difference between two scenarios represents the CO_2 emission avoided due to producing 30% of electricity from renewable sources. The methodology used to calculate emissions is based on IPCC rules (Diesel Carbon Emission Factor of 20.2 tC/TJ [25]) and known average values for specific fuel consumption (0.236 kg/kWh). Since harnessing the wind and solar energies does not produce significant on the place GHG emission, it reduces the total emission by 30%. The figure also shows the potential emission reduction value. If the GHG emission reduction is financed by an Annex I country through Clean Development Mechanism, it could be used by the donor country towards its GHG target.

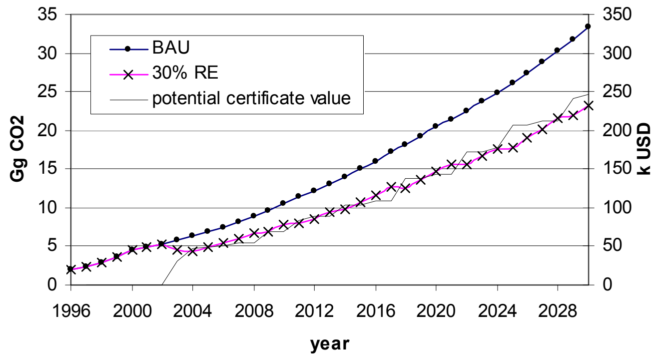

Figure 4. Reduction of CO_2 emission due to 30% of electricity produced from renewable sources and the maximum potential value of emission certificates due to Clean Development Mechanism

Slika 4. Smanjenje emisija CO_2 zahvaljujući proizvodnji 30% električne energije iz obnovljivih izvora i maksimalna potencijalna vrijednost emisionih certifikata Mehanizma čistog razvoja

The OECD [3] concludes that in case of unlimited emission trading the average price of CO_2 emission reduction would be 25 USD/tCO_2. The carbon futures are already trading at prices of 0.3-1 USD/tCO_2 [6]. As the market develops the price is likely to rise. World Bank's Prototype Carbon Fund forecasts a price of 4-11 USD/tCO_2 [6], while some authors expect it to be higher, up to 17 USD/tCO_2, [4] and [26]. The theoretical price of abatement of 25 USD/tCO_2 is used to demonstrate the potential of the CDM for the investor. The total amount is shown in Figure 4.

5. 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 a small wind field installed at the beginning. Meanwhile, after the initial period, the price should fall to that level or even further. Since the wind power cannot be used as guaranteed power, 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.

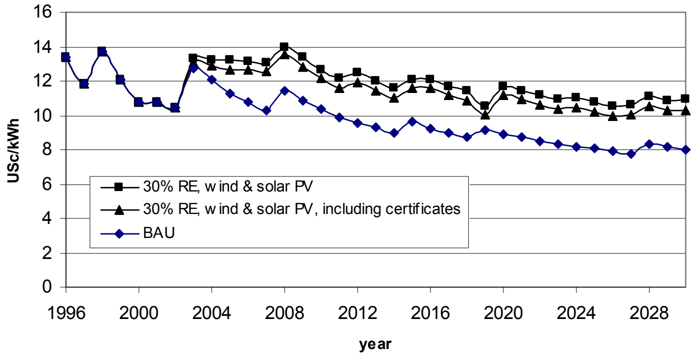

Figure 5. Comparison of electricity price generated in baseline and wind/solar scenarios, with the influence of the emission certificates

Slika 5. Usporedba prosječne proizvodne cijene električne energije za bazni scenario sa scenarijem s eoličkom i solarnom energijom, uz utjecaj emisionih certifikata

The comparison of electricity price between the baseline scenario and wind/solar scenario is shown in Figure 5. Consistently, the renewable scenario is more expensive. The possible and maximum influence of CDM certificates value being taken into financial consideration shows that it is of too small influence. Similar comparison with only wind power being installed as renewable is shown in Figure 6. Although 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.

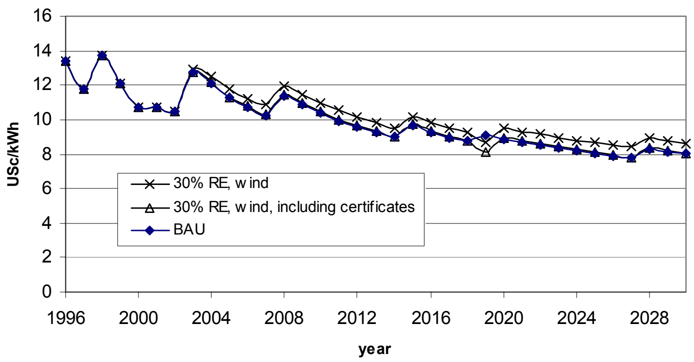

Figure 6. Comparison of electricity price generated in baseline and wind scenarios, with the influence of emission certificates

Slika 6. Usporedba prosječne proizvodne cijene električne energije za bazni scenario sa scenarijem sa 30% eoličke energije, uz utjecaj emisionih certifikata

Both renewable scenarios were calculated using constant prices of renewable energy technologies, which does not reflect the reality properly. Some RET prices are falling by a third or a quarter per year. The same refers to wind technology, although 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 [27]. If we envisage a yearly fall in price in the wind technology of 2% and in solar PV technology of 5%, a comparison shown in Figure 7 can be made for the wind/solar scenario.

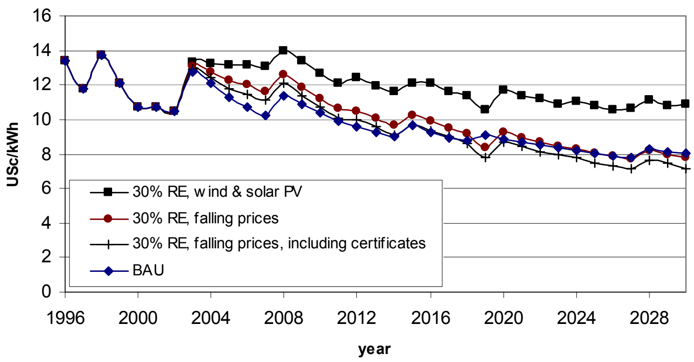

Figure 7. The influence of the declining prices of renewable energy technologies on the electricity price

Slika 7. Utjecaj pada cijena tehnologija koje koriste obnovljive izvore na proizvodnu cijenu električne energije

With falling prices our energy mix will become economically viable compared with the baseline scenario, but it will happen only in 2018. In the case of taking into account the potential value of CDM certificates it would already happen in 2014, four years earlier.

6. Implications to SIDS

Due to a relatively high price of electricity produced from Diesel and to small electricity systems, the island states offer good potential to CDM linked technology transfer, although on a small absolute scale. The potential depends on the magnitude of an isolated area electricity system, being limited to an island, or a part of an island, or to a country. Most of the renewable small islands are those that are connected to mainland grid [28], thus avoiding the technical problems of grid stability and supply security. On the other hand, on most of small islands, which are often the least developed countries, small isolated electricity systems do not operate 24h per day, and the loss of load probability is running high. That makes intermittence of renewable electricity sources more acceptable than in developed countries.

For very small isolated systems, up to several kW, the photovoltaic power can be a competitive one, especially if the Diesel fuel is expensive to deliver. In the case of small electricity grids, the wind electricity production will be competitive or close to being competitive with Diesel electricity. The competitiveness depends very much on the need to build up reserve Diesel capacity to ensure a backup when there is no wind. In cases when there is a small difference between the prices of electricity coming from Diesel and wind, Clean Development Mechanism can significantly help the attractiveness of investing into the wind energy by reducing the wind electricity price by 5-10%. The problem with wind energy in such small grids is that the units installed have to be small, compared to the latest technology (wind turbines of up to 2 MW). Although very small grids can depend on only one wind turbine, backed by a Diesel generator, if necessary, if one wants to reduce the loss of load probability in systems, turbines bigger than 15% of the total load should not be constructed. That adds to the investment cost, plus the fixed cost of the wind field, which will in such a situation have only several small wind turbines. Together with higher transportation and installation costs, wind electricity will typically cost at least double than in Denmark, the market leader. The problem of small and inefficient units will be avoided in systems bigger than 2 MW, since the units of 250 kW can be used in that case. Those are already highly efficient units offered by many producers.

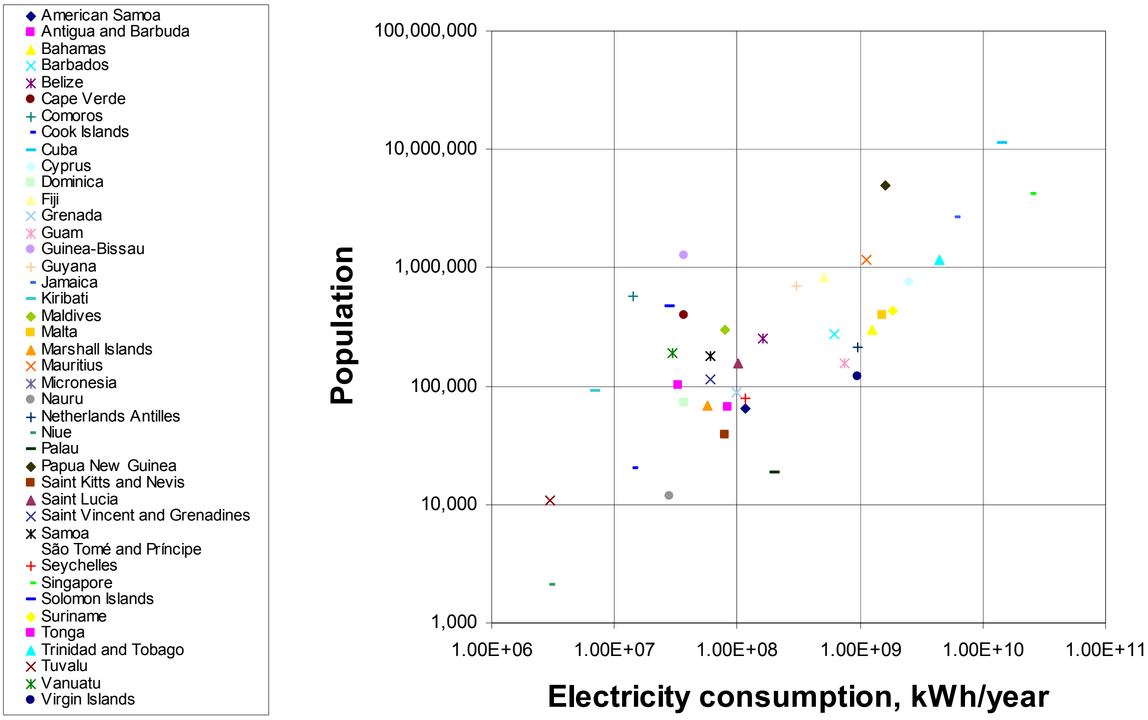

Figure 8. Distribution of SIDS according to population and electricity consumption [20]

Slika 8. Raspodjela malih otočnih zemalja u razvoju prema stanovništvu i potrošnji električne energije

When an electricity system reaches 70 MW of installed power, allowing for the installation of 10 MW units, then it should be viable to install combined cycle blocks for covering the base load. Since combined cycle is more efficient in electricity production than Diesel technology, it could also earn CDM credits. Depending on fuel, combined cycle could earn even more. That is especially true for natural gas, but most islands do not have sources of gas. Therefore kerosene, which has similar carbon intensity as Diesel fuel, must be used. Kerosene is relatively practical since most islands do already have storage and handling in place due to the air transport network.

Figure 8 shows the distribution of SIDS according to population and electricity consumption. Only the countries that have electricity consumption higher than 1 billion kWh per year in one connected electricity system are possibly too big to profit from the comparative advantage of the high price of Diesel electricity. Many of the islands, not only the ones making SIDS, but also a number of other developing countries have grids that are smaller than the threshold for building viable steam cycle power plants.

7. Conclusion

Small islands, as well as isolated regions, have to take a different path to the development of their electricity power systems, bound to the limits of geography and unable to profit from the economies of scale. Meanwhile, the disadvantage that makes the electricity produced on small islands significantly more expensive than in big connected grids can be turned into an advantage through the Clean Development Mechanism. The environmentally friendly technologies for electricity production are either not far from being economically viable, or are already viable financially, but are not being built because of barriers to new technologies, thus making marginal cases in which CDM could make a difference. There are several technologies that could be helped by CDM induced technology transfer, such as renewable energy technologies or supply side efficiency technology.

The paper has shown a 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. Santo Antão, Cape Verde, is shown as an example of good natural resource for renewable energy exploitation and poor energy infrastructure.

The future trend of clean technologies will be the main parameter, together with the existing natural conditions, to be taken 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. However, 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.

REFERENCES

[1] UN Framework Convention on Climate Change site, http://www.unfccc.de/
[2] Joy Hyvarinen, In defence of the Kyoto Protocol, IEEP, London, 2000
[3] OECD study “Meeting the Kyoto targets”, COM/ENV/EPOC/CPE(99)76, 1999
[4] E3M Lab, P. Capros, L. Mantzos, The economic effects of EU-wide industry-level emission trading to reduce greenhouse gases. Results from PRIMES energy systems model, 2000
[5] T. Kram, D. Hill, A multinational model for CO2 reduction - defining boundaries of future CO2 emissions in nine countries. Energy Policy. 24(1):39-51, 1996
[6] The Economist, Greenhouse gases - Cost free, January 22, 2000
[7] T. Tietenberg, Relevant experience with tradable entitlements, Combating Global Warming: Study on a Global System of Tradable Carbon Emission Entitlements, United Nations, New York, pp. 37-54, 1992
[8] Z.X. Zhang, A. Nentjes, International tradable carbon permits as a strong form of joint implementation. In: J. Skea, S. Sorrell, (Eds.), Pollution for Sale: Emissions Trading and Joint Implementation, Edward Elgar, Cheltenham, pp. 322-342, 1999
[9] T. Tietenberg, M. Grubb, A. Michaelowa, B. Swift, Z.X. Zhang, Greenhouse Gases Emissions Trading: Defining the principles, modalities, rules and guidelines for verification, reporting and accountability, UNCTAD, Geneva, 1998
[10] C. Philibert, Emissions Trading and Developing Countries, OECD, 1999
[11] C. Philibert, The Clean Development Mechanism: An economic approach to “environmental additionality”, UNEP, 1998
[12] C. Philibert, How could emissions trading benefit developing countries, Energy Policy 28(13):947-956, 2000
[13] E. Woerdman, Implementing the Kyoto protocol: why JI and CDM show more promise than international emissions trading, Energy Policy 28: 29-38, 2000
[14] CDM SUSAC, Draft Discussion Paper 1 - Engaging the European Union Private Sector in CDM in ACP Countries
[15] N. Duić, A. Costa, L.M. Alves and M.G. Carvalho: Facilitating the Acceptance of Kyoto Protocol Objectives by Promoting the Technology Transfer to Developing Countries, Invited lecture to the *Working Party on Climate Change informal Workshop of the Portuguese Presidency*, Sintra, Portugal, 7-8 February 2000.
[16] UNCTAD report on Least Developed Countries, Cape Verde sheet, http://www.unctad.org/ldcs/
[17] The Human Development Report 1999, UNDP, http://www.undp.org/hdro/report.html

[18] The World Factbook 2001, CIA, Washington, 2001, http://www.odci.gov/cia/publications/factbook/index.html
[19] The World Factbook 1999, CIA, Washington, 1999
[20] The World Factbook 2000, CIA, Washington, 2000
[21] Jansénio Delgado et al.: Perspectivas de desenvolvimento, Plano director de electricidade de Santo Antão, 1997, Cape Verde
[22] Jansénio Delgado et al.: Diagnóstico de situação local, Plano director de electricidade de Santo Antão, 1997, Cape Verde
[23] Statistcis of Electra, SA, http://www.electra.cv/dadosestatist.htm
[24] N. Duić, L.M. Alves, M.G. Carvalho, Kyoto Protocol objectives by promoting the technology transfer to small island developing countries: Santo Antão, Cape Verde, CD Proc. of the New and Renewable Technologies for Sustainable Development, Madeira, 9pp., 2000
[25] IPCC/OECD/IEA, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, J.T. Houghton, L.G. Meira Filho, B. Lim, K. Treanton, I. Mamaty, Y. Bonduki, D.J. Griggs and B.A. Callender (Eds), UK Meteorological Office, Bracknell, 1996, http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm
[26] IPTS, Preliminary Analysis of the Implementation of an EU-Wide Permit Trading Scheme on CO2 Emissions Abatement Costs, Results from the POLES model, 2000
[27] ABB, Renewable Energy, Status and Prospects, ABB, 1998
[28] Thomas Lynge Jensen: Renewable Energy on Small Islands, Second Edition, Forum for Energy and Development (FED), 2000

ACKNOWLEDGEMENT

The authors would like to acknowledge the Portuguese Ministério da Ciência e Tecnologia for the financial support for the scholarships of Dr. Luís Alves and Dr. Neven Duić as part of the programme Praxis XXI.

The financial support of the THERMIE program (DGXVII of the European Union), DG Development 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.

Predano: 10.05.2001.
Submitted:

Prihvaćeno: 20.12.2001.
Accepted:
(in revised form)

Dr. sc. Neven Duić
Faculty of Mechanical Engineering and Naval Architecture
University of Zagreb

Dr. Luís Manuel Alves
Prof. Maria da Graça Carvalho
Instituto Superior Técnico
Lisbon, Portugal