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Energy Demand and Supply Issues - Scenario 2020 and Implications for CDM in West African Economic and Monetary Union. Case Study: Benin, Burkina Faso, Niger and Togo

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**Energy Demand and Supply
Issues - Scenario 2020 and
Implications for CDM in West
African Economic and
Monetary Union. Case Study:
Benin, Burkina Faso, Niger
and Togo**

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HWWA Discussion Paper

Energy Demand and Supply Issues - Scenario 2020 and Implications for CDM in West African Economic and Monetary Union. Case Study: Benin, Burkina Faso, Niger and Togo

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Energy Demand and Supply Issues - Scenario 2020 and Implications for CDM in West African Economic and Monetary Union. Case Study: Benin, Burkina Faso, Niger and Togo

ABSTRACT

The present study discusses energy supply challenge and assesses renewable energy potential in the studied countries. Moreover, energy demand as well as demand projection is assessed until 2020. Resulting CO₂-eq emissions are also projected.

The study reveals that the countries under examination lack accurate information on their renewable energy potentials. Based on cautious assumptions, countries renewable energy potentials have been assessed. Solar sources and biomass are not assessed. The study shows that countries are endowed with low renewable energy potentials.

Using GDP per capita and population grow as driving forces, countries' electricity demands are projected until 2020. As result, electricity demand in case study countries will not be very high, as economic development is projected to remain low. Consequently, despite an increase in CO₂ emissions, emissions will remain at a low level. Hence, the countries studied cannot be as competitive as current competing CDM countries, i.e., China, India, Brazil, etc. Strengthening energy co-operation within West African Economic and Monetary Union may reduce transaction costs, making it possible to use the available energy potential.

Keywords: Renewable energy potential, Energy supply and demand, energy demand scenarios, CDM market.

JEL classification: C22, C40, C53, C69, C87, C89, Q41, Q43

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ABBREVIATIONS

CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CNEDD	Conseil National de l'Environnement pour un Développement Durable
CO ₂	Carbon dioxide
CO ₂ eq	Carbon dioxide equivalent
DGE	Energy Administration
ECOWAS	Economic Community of West African States
EIA	Energy Information Administration
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNI	Gross National Income
GTZ	Gesellschaft Technische Zusammenarbeit (Germany)
IEA	International Energy Agency
IEPF	Institut de l'Énergie et de l'Environnement de la Francophonie
IPCC	Intergovernmental Panel on Climate Change
N ₂ O	Nitrous oxide
PWT	Penn World Table
SSN	SouthSouthNorth
UN	United Nations
UN-DESA	United Nations Department of Economics and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation.
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
US	United States
WAEMU	West African Economic and Monetary Union
WB	World Bank
WEC	World Energy Council

1 INTRODUCTION

Energy has strong links with poverty reduction through household income, health, education, gender and environment (UN 2002). In addition, most economic activities are not possible without energy, and no country in modern times has sustainably reduced poverty without massively increasing its use of energy (UN 2005). Currently, 2.4 billion people in developing countries rely on traditional biomass and 1.6 billion do not have access to electricity and energy services. This situation limits opportunities for poor people and erodes environmental sustainability at local, national and global levels (UN 2005). Enhanced energy services are thus necessary conditions to achieve the Millennium Development Goals.¹ However, governments in developing countries face serious challenges to improve energy services for the poor. For this reason, domestic investments in renewable energy production and energy efficiency initiatives will play an important role in the global GHG emission mitigation strategies. The CDM provides exactly this international investment opportunity. This explains why the current study focuses on the energy sectors' development and its implication for CDM projects in Benin, Burkina Faso, Niger and Togo.

Section 2 of this paper assesses the renewable energy potentials. This is followed by an analysis of current power situations in section 3. As investments in energy technologies are challenging for developing countries, section 4 discusses costs of electricity production technologies. Currently, energy demand and supply are very low in the case study countries and related CO₂ emissions are also very low. In order to assess the future trend of CO₂ emissions level as well as the future CDM potential, electricity demand is projected until 2020 in section 5. Implications for CDM are then shown in section 6. Section 7 discusses causes of the failure of renewable energy projects in case study countries. Finally, concluding words are presented in section 8.

¹ For more details, see: (<http://esa.un.org/un-energy/pdf/UN-ENRG%20paper.pdf>).

2 RENEWABLE ENERGY POTENTIAL

Renewable energy (RE) potential describes the contribution that RE makes towards power supply. As far as renewable energy potential assessment is concerned, four aspects have to be considered, namely, theoretical potential, technical potential, economic potential and expected market potential.

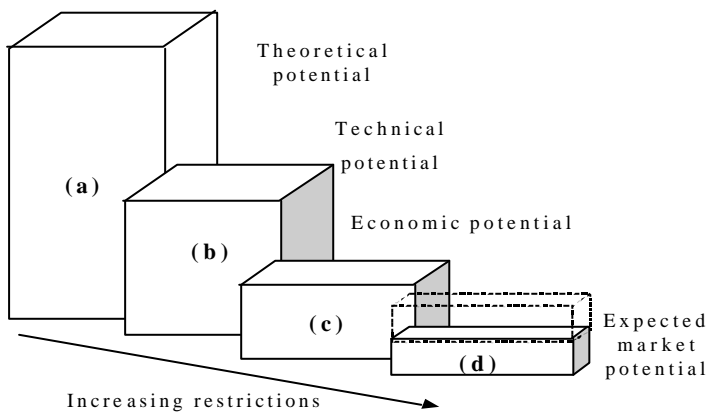
a) Theoretical potential refers to a physical energy supply within a region at a certain time, e.g. the potential energy contained in the water of a river or the kinetic energy of the wind at a certain time of the year.

Technical potential describes the technical restrictions² to make the potential energy usable.

Economic potential refers to the meaningful economic use as compared to other forms of energy such as energetic amortisation.³

Expected market potential describes the expected actual contribution towards power supply.⁴ Figure 1 gives a schematic representation of the concept.

Figure 1: Energy potentials



Source: Own figure.

² Restrictions refer to location, ecological restrictions, structural restrictions, storage and transportation restrictions and restrictions on production capacities.

³ Energetic amortisation refers to the period during which a certain device can perform as much energy as it was necessary for the manufacturing of that device.

⁴ Within a longer period, this potential is capable of being completely developed. Support programmes or energy and environmental political decisions can directly affect usage possibilities.

Based on the above potential notion, the renewable potential of each country has been assessed.

The renewable energy sources that exist in these countries are: Hydroelectric, biomass and bioenergy, solar energy and wind energy. Hydroelectric refers to the energy content of the electricity consumed from hydroelectric power plants, that converts the potential and kinetic energy of water into electricity (see photo 1 below)

Photo 1: Hydroelectricity power plant storage type;



Photo Source: <http://www.nrel.gov/data/pix/searchpix.cgi>; and Czisch (2001).

As far as the hydropower options are concerned, due to their negative impacts on environment the large scale hydro is getting decreasing support from international investors, while the small scale hydro such as run-of-river (photo 2), due to their limited impacts on environment, is gaining more support.

Photo 2: Run-of-River type



Photo Source: <http://www.nrel.gov/data/pix/searchpix.cgi>; and Czisch (2001).

Biomass and bioenergy can be exploited in solid, liquid or gaseous form. Biogas is derived principally from the anaerobic digestion of biomass and solid wastes, which are combusted to produce heat and electrical power. Energy from liquid biomass uses liquid derivatives from biomass as fuel (e.g. ethanol). In this research, due to the lack of information on the liquid biomass only solid biomass is taken into consideration (see photo 3). In some industrialized country contexts, biomass energy technology is already competitive.

Photo 3: Modern biomass power plant



Photos source: Czisch (2001).

However, the issue of lack of information and supporting institutional framework to facilitate its introduction in some developing countries is one of the important barriers for large-scale dissemination.

Wind power exploits the kinetic energy of wind in wind turbines to generate electrical power (see photo 4). The environmental impact⁵ of wind energy technology is limited.

⁵ Impacts stressed by ecologists are: noise pollution, and other environmental problems, such as the killing of birds and bats. A 2002 study in Spain estimated that 11,200 birds of prey (many of them already endangered), 350,000 bats, and 3,000,000 small birds are killed each year by wind turbines and their power lines (<http://www.aweo.org/ProblemWithWind.html>) .

Due to the improvement contributed by research, the cost of electricity generated from wind is steadily reducing.

Photo 4: Wind turbines



Photos source: Czisch (2001).

Solar energy is harnessed using two primary methods. Solar-thermal power exploits solar radiation for hot water production and electricity generation by flat plate collectors or thermo-electric plants (see photo 5). Solar power from photovoltaics involves the conversion of solar energy to electricity in photovoltaic cells (see photo 6). However, solar energy technologies are not financially competitive with the other renewable energy technologies.

Photo 5: Solar thermal power plant



Photo source: <http://www.Kjesolar.com>.

Photo 6: Photovoltaic plant



Photo Source: <http://www.nrel.gov/data/pix/searchpix.cgi>.

The following section will present the electricity features in the case study countries and their renewable energy potential.

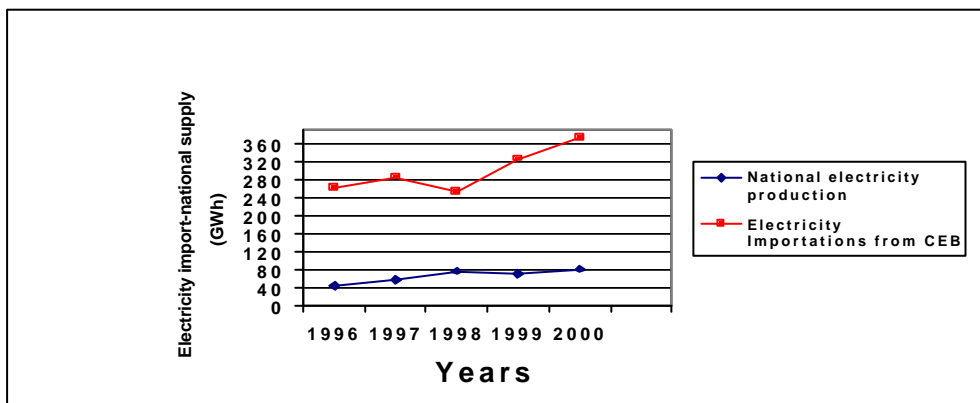
3 CURRENT POWER SITUATION IN THE STUDIED COUNTRIES

3.1 Benin

The power system in Benin consists of an interconnected transmission grid system serving the major cities and several dispersed isolated systems. The electricity supply is

assumed through the Communauté Electrique du Benin (CEB), a mixed society between Benin and Togo. A national electricity supply company, Société Béninoise d’Energie Electrique (SBEE), owned by the government, is the national component of the CEB. The SBEE is in the process of privatisation for the past two years. The CEB provides some electricity from local production but the bulk is imported from Ghana and Ivory Coast. In 2000, imports from the Volta River Authority (VRA) - Ghana, reached 43%, and the Communauté Ivoirienne d’Electricité (CIE) - 33% of supply (DGE-Benin 2001). The local supply system is composed of hydroelectric plant Nagbeto (65 MW) serving Benin and Togo, two gas turbines (25 MW each), that actually run on kerosene, and about 20 isolated diesel generating power stations with a total installed capacity of 40 MW disseminated in the country. As during the last few years, a steady decrease of river flow in West Africa has been recorded due to drought, imports into Benin have decreased. Hence, the efficiency of the thermal power generating stations has been improved in order to improve electricity supply. These have led to a rise in efficiency from around 20 – 25% to between 32% - 40%. An objective of the government is to improve efficiency to at least 40% in the medium term in all stations (DGE-Benin 2001).

Figure 2: Electricity importation, national supply and total electricity supply growth



Source: (DGE-Benin, 2001).

Strategy to face the electricity demand challenge

To increase the energy supply, the government of Benin adopted the following strategies:

- Construction of hydropower station, Adjarala, on the Mono river (100 MW installed capacity);
- Increase in thermal operating system capacity (40 to 50 MW installed capacity), combined cycle electricity production (120 MW installed capacity);
- Interconnection with Nigeria (project CEB - NEPA);
- Pursuit of electrical power imports from Ghana;
- Pursuit of electricity generation from diesel power generators.

In this strategy, the construction of the West African gas pipeline connecting Benin, Togo, Ghana and Côte d'Ivoire is stressed. This project will be supported until 2018 (World Bank, 2004b), due to the huge natural gas potential available in Nigeria (35.5 Mm³/day) that exceeds the demand from other countries by eight times.

Obviously, the energy supply improvement strategy of the country does not stress the use of domestic power generation from other energy sources, i.e. renewable energy sources. In the following section, the renewable energy potential in Benin, will be addressed.

Renewable energy potential in Benin

The renewable energy potential in Benin is shown in table 1 below. From the different renewable energy sources only hydro is quite well assessed with a total potential of around 700 MW (DGE-Benin 2003). Here, the research will make assumptions and assess solar, wind and biomass potential.

Traditional biomass represents about 85% of the energy consumption of the country (WAEMU 2005), but there is a lack of reliable data. Currently biomass is not used for electricity generation; agricultural residues and all other form of biomass residues are directly burned in the open air. In this research, only biomass used in modern biomass

electricity generating utilities is considered. For the potential biomass assessment the research uses information on biomass electricity generation in India which is one of the world's leading biomass electricity producing countries. There, to run a biomass electricity generation plant of 1 MW installed capacity, one needs around 10,000⁶ tons of biomass residues per year (Sutter 2003). As there is no study on agricultural residues in Benin, it has not been possible to address this issue in the frame of the current research. Hence, agricultural residues are not included in the renewable energy potential assessment.

As far as solar energy is concerned, the country has an average daily solar radiation availability of about 6-7 kWh/m²/day and an average 8 h per day “peak watts” (Wp) the whole year (DGE-Benin 2003). Solar energy is being used in telecommunications and hospital lighting. However, there is a lack of data on its use. Based on the high costs of the kWh from PV, we will not include solar potential in the renewable energy assessment.

As for wind energy, there is a wind speed of about 6m/s on the Atlantic coast (DGE-Benin, 2003). Furthermore, the grid is around fifteen kilometres away from the coast. Hence, transportation costs for generated electricity will not be too high.

To assess the potential, the research uses the following formula:

$$EP(MW) = CL(km) * T (unit/km) * C (MW/unit)$$

where *EP* is the electricity potential, *CL* the coast line, *T* the number of turbines per km and *C* the average capacity per unit of turbine. From the calculations the wind energy potential is around 106 MW.⁷

From the table, Benin has approximately 806 MW renewable energy potential.

⁶ The biomass demand assessment is based on the following assumptions: PLF = 0.85%, Hu biomass dry = 13MJ/kg, Moisture content = 22%, efficiency of power plant = 28%. (Centre for Energy Environment and Technology, 2001).

⁷ The calculations are based on 50m between 2 wind turbines, 125 km coast line, a capacity of 850 kW per turbine. There are many wind turbines that can be used in the region. The study selects one of them on a random basis. Hence, we have $EP = 125km * 0.05 * 20/km * 850kW$ [The coefficient 5% is used based on the

Table 1: Renewable energy potential in Benin

	Benin			
	Technically exploitable capability (MW)	Installed capacities (MW)	Actual generation (GWh)	Used Percentage
Hydropower	700	35	175 ⁸	5%
Wind energy	106	-	-	-
Total	806	35	175	4%

Source: WAEMU (2005); IEPF (2004); IEA (2003c).

3.2 Burkina Faso

Until 1989, the total electricity supply was only own thermal production from a total 213 MW installed capacity disseminated among 35 diesel power generating stations. As for hydropower, four hydropower stations for a total of 32 MW installed power are running (IEPF 2004). Since 2001, the country has been importing electricity from Côte d'Ivoire. On-going negotiations with Ghana's Volta River Authority will increase electricity import to the country.

Vulnerability of the system

Since more than 70% of the electricity is from diesel power stations and the country is totally dependent on oil imports, the electricity price is highly dependent on oil price variability on the international oil market. In addition, the hydro capacity is not enough to provide electricity security to the country.

Strategy to face the electricity demand challenge

To reduce dependence on electricity imports, the government has adopted the following strategies:

- Amelioration of carbonisation systems
- Valorisation of agricultural residues
- Optimisation of production equipment
- Promotion of co-generation

German coast line ratio used for electricity generation. This ratio is considered very conservative (BMU 2003)].

8 Estimate based on 5000 FLH (BMU 2004).

- Promotion of renewable energy sources
- Promotion of national and international interconnections

Renewable energy potential in Burkina Faso

The renewable energy potential in Burkina Faso is based on the same basic assumptions as in the case of Benin. Furthermore, there is no coast and the wind speed in the desert area is around 3-4 m/s. Hence, the minimum 5 m/s required for wind farm installation is not achievable. Therefore, wind potential will not be assessed in Burkina Faso.

Altogether, the renewable energy potential is shown in table 2

Table 2: Renewable energy potential in Burkina Faso

	Burkina Faso			
	Technically exploitable capability (MW)	Installed capacities (MW)	Actual generation (GWh)	Used Percentage
Hydropower	200	32	160	16%
Total	200	32	160	16%

*Calculation is based on the same assumption as in Benin.

Source: WAEMU (2003), IEPF (2001).

From the table, Burkina Faso has around 200 MW renewable energy potential. This potential is relatively low compared to Benin's potential.

Now, let us examine the electricity situation and renewable energy potential in Niger.

3.3 Niger

Current energy situation

Biomass is the most important energy source with a contribution of about 90%. While oil contributes about 8%, electricity contributes only around 2% of total energy consumption. The country imports 54% of electricity from Nigeria (UNFCCC 2003b). The national electricity production is shared between coal power stations (39%) and diesel power utilities (7%). Since the country imports oil, its energy dependence lies at around 61%. Due to the lack of investment, the important coal mine deposits of the

country cannot be used for electricity generation and electricity security. Actually, the government of Niger is promoting mineralised coal use for cooking purpose as wood or biomass are becoming scarce and expensive.

Vulnerability of the supply system

Niger is highly dependent on the import of electricity and hydrocarbon from Nigeria. Oil price variations on international oil markets and deficits in electricity production in Nigeria greatly influence the electricity supply. Furthermore, since 1994, electricity demand growth has been around 6.5% per annum (UNFCCC 2003b). The total installed capacity of 140 MW is not enough to meet this growing demand. Only 5% of the population has access to electricity. This is a real challenge to Niger's government.

Strategy to face electricity challenge

To increase electricity supply in the short and medium run and secure electricity supply to the population, the government of Niger has decided to:

- Promote renewable energy sources
- Promote energy efficiency
- Intensify interconnections

As discussed earlier, this strategy is also weak considering the growing electricity demand in the country.

In the following section, the renewable energy potential will be assessed.

Renewable Energy potential in Niger

For the same reason as discussed in Benin, biomass potential will not be assessed in Niger. As far as solar and wind energy are concerned, there are some applications but an estimation of national potential is not available. The research will not assess wind potential due to the same reason as in Burkina Faso. Based on the same assumption as in Benin we will not include solar potential in the assessment. The results are summarised in table 3 below.

Table 3: Renewable energy potential in Niger

	Niger			
	Technically exploitable capability (MW)	Installed capacities (MW)	Actual generation (GWh)	Used Percentage
Hydropower	235	-	-	-
Solar energy*		0.4	1.2	
Total	235	0.4	1.2	0.1%

Source: Energy Ministry-Niger (2005); EIA (2003); IEPF (2004).

From the table, renewable energy potential in Niger is around 235 MW. This is relatively low compared to the potential in Benin.

In the following section, the electricity issue in Togo will be addressed.

3.4 Togo

The electricity production system in Togo is composed of four main diesel power utilities and hydropower generating utilities with a total installed capacity of about 130 MW. As far as hydropower is concerned, the installed capacity is around 65 MW at Nagbeto on the Mono river, shared with Benin.⁹ In addition, an additional hydropower utility of an installed capacity of around 1.6 MW at Kpimé contributes to the supply system (UNFCCC 2003a, IEPF 2001; Small-Hydro Atlas 2002). The total electricity consumption in Togo was approximately 0.45 TWh in 2002. While hydroelectricity contributes to about 0.15 TWh (33%), the main electricity supply (78%), comes from fossil fuel power generating utilities and electricity imports. In 2004, the country signed an electricity import accord together with Benin, to import electricity from Nigeria.

Vulnerability of the supply system

Togo is highly dependent on imports from the Volta River Authority (VRA) in Ghana, and Côte d'Ivoire. In addition, hydrocarbons are imported to produce electricity. Hence, the fluctuations of oil prices on international oil markets and low rain fall in West Africa can lead to a serious disturbance in electricity production and supply in Togo.

⁹ From this joint venture between Togo and Benin, 30MW electricity is supplied to Togo and 35MW to Benin through the Communauté Electrique du Benin (CEB).

Furthermore, since 1994, electricity demand growth has been at around 7.8% per annum (UNFCCC 2003a). The total installed capacity of 130 MW is not enough to supply the growing electricity demand. Only 10% of the population has access to electricity (IEPF 2001). Moreover, due to climate change, decreases in river level are predicted from 2015 onwards, which in turn will lead to a decrease in the hydroelectric power supply. At the same time the country will face rapid demand growth (UNFCCC 2003a). This figure represents an important challenge to the Government of Togo if total access to electricity is to be achieved in the medium and long term.

Strategy to face the electricity challenge

Since the main electricity production is hydroelectricity imports supplemented with thermal power stations owned by the government, the energy sector is liberalised in order to allow private investments in the electricity sector. Presumably, this will increase the supply possibilities to the electricity system. In addition, energy efficiency measures will be implemented and alternative energy sources will be promoted to generate electricity (UNFCCC 2003a). But the impacts of this strategy on the actual supply system are not obvious. Although it advocates renewable energy potential, the strategy does not provide a measurable target for the introduction of the renewable energy sources in the energy system. Here again, the strategy is not strong enough.

Renewable energy potential in Togo

Togo and Benin share the same climatic conditions. Hence, the same assumptions are made as in Benin case. As for wind energy, the coast line in Togo is around 65 km compared to 125 km in Benin. Based on this information, and the same assumptions as in Benin, the renewable energy potential in Togo is summarised in table 4 below.

From the table, we see that the hydroelectric potential of the country is around 450MW. As for solar and wind sources, the theoretical solar potential of the country is about 5.5 kWh/m²/day, while the wind speed is around 5-6 m/s at the Atlantic coast (WAEMU 2005).

From the table, total renewable energy potential is around 505 MW, which is higher than in Burkina Faso and Niger. From this potential, around 7% is used for electricity generation. This is a relatively low contribution from renewable energy.

Table 4: Renewable energy potential in Togo

	Togo			
	Technically exploitable capability (MW)	Installed capacities (MW)	Actual generation (GWh)	Used Percentage
Hydropower	450	30	150	7%
Wind energy**	55	N	N	N
Total	505	30	150	6%

** Calculation based on 65 km coast line, 5% coast line availability, 20 wind turbines per km and 850 kW per turbine.

Source: WAEMU (2005); IEPF (2001); UNFCCC (2003a).

What could be learned

From what has been discussed so far, it is obvious that Benin and Togo have a relatively important renewable energy potential and a low electricity access rate. In addition, the strategy of the countries to overcome the electricity challenges stress electricity imports from the sub-region. This more preferred option is based on the fact that electricity imports are usually the lowest cost option. The same reasoning is also the rationale behind the abandonment of the renewable energy sources in the energy balance in the countries. In contrast to Benin and Togo, renewable energy potential in Niger and Burkina Faso is lower. This is mainly due to wind energy available in Benin and Togo.

Meanwhile, there is no clear commitment on renewable energy contribution to the energy balance in the countries. Hence, the research suggests the target of the Latin America and Caribbean countries (LAC) which states that renewable energy sources should contribute to at least 10% of energy balance by 2010 (GTZ 2003). Since the renewable energy contribution to energy balance in the studied countries is currently very low, it might be reasonable to set the same target, but over the 15 years to come. Hence, a contribution of around 0.7% each year could be expected from renewable energy sources. Moreover, it is conceivable that some renewable energy technologies such as photovoltaic are still costly so that countries might not be able to afford them.

It would be interesting to understand whether only the price difference between the produced electricity from the different technologies can account for the abandonment of the renewable energy sources by these countries. To address this issue, the cost of the different electricity production technologies will be discussed in the following section.

4 COSTS OF ELECTRICITY PRODUCTION TECHNOLOGIES

Before the issue of electricity cost at national level is addressed, it makes sense to discuss electricity production costs at an international level. This will provide information on their cost improvements to date and in the medium term, and at the same time the prospects of their introduction in the case study countries.

4.1 International electricity costs

The renewable energy sources should be compared with each other for their value for CO₂-reduction according to sound scientifically based criteria, such as:

- Availability on global scale: are there physical limits at stake?
- Cost efficiency: price per kWh and amount of CO₂-reduction per invested euro or dollars.
- No major environmental objections (WBGU 2003).

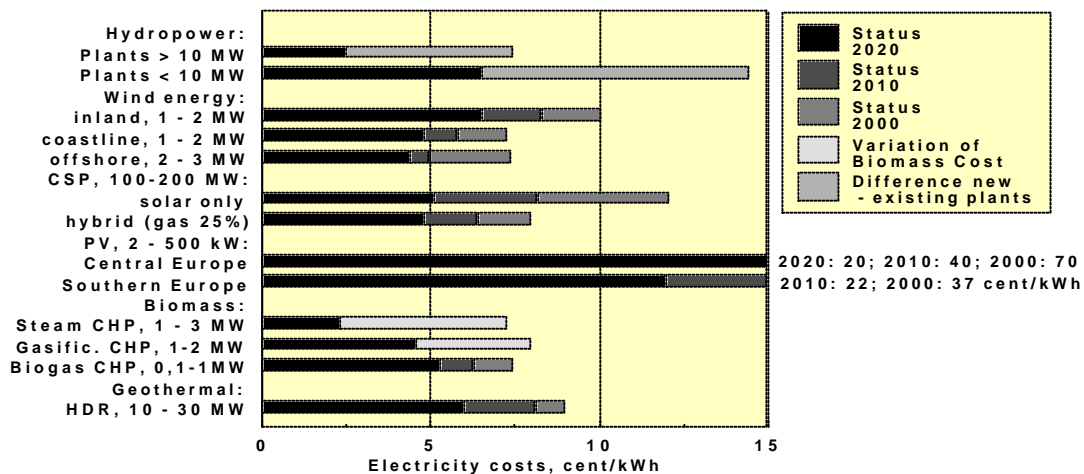
The world has enough potential of renewable energy sources, but various technologies to harness them are used at different development levels. This leads to a difference in the price of produced electricity from the different technologies. The following figure 3 shows the actual and future price development of the different renewable energy technologies.

Figure 3 shows energy generation costs of typical RE technologies that are useable in Western Europe. They represent the present status and the likely achievable cost reductions in the future and show a very large spread. This results from the great variety of energy sources and their regional differences, the broad spectrum of conversion

technologies, the very large range of capacity from about 1 kW to some several tons of MW as well as different prices for biofuels.

Excluding photovoltaics, whose actual costs are typically high, the representative costs of RE range from 2.5 to 15 cent/kWh (Figure 3). Only few RES-technologies generate competitive electricity today, e.g. older depreciated hydro power plants or plants using cheap biomass residues. A large fraction of RES technologies offers electricity in the range of 7 to 8 cent/kWh, among others wind in coastal regions, hybrid solar thermal power plants, biogas and biomass gasification plants. If market growth of RE takes place on a large scale, the electricity generation costs of most RE-technologies will decline to 4 to 5 cent/kWh. At this time, new fossil power plants may have reached the same cost range because of increasing fuel prices.

Figure 3: Survey of current electricity generation costs of representative RE-technologies (total length of bars) and possible cost reduction until 2010 and 2020, (CSP = concentrating solar power; CHP = combined heat power; HDR = hot dry rock)



Source: Renewable technologies and costs- Encyclopaedia version II, BMU (2004).

Under these conditions, the largest part of technical RE potentials could be exploited economically. Only photovoltaics, with 70 cent/kWh, will still be too expensive to be used to a large extent in the general electricity supply. Although PV technology is actually not cost efficient, its autonomy leads to a high preference from consumers. Actually, the research suggests the use of cost efficient renewable technologies for CDM projects in the case study countries based on the existence of barriers to their

implementation. Now that the electricity cost issues at the international level have been analysed, let us analyse the price issue at the case study country level.

4.2 Sub-regional electricity costs

Since some renewable energy technologies are actually cost-effective, one could ask why the governments in the studied countries do not introduce these technologies. Before an answer to this question is given, let us analyse the common energy policy of the WAEMU. To overcome the energy challenge in the union, the council of the head of states has set up 6 objectives:

- Energy security
- Optimal use of the energy resources
- Promotion of renewable energies
- Promotion of energy efficiency
- Promotion of rural electrification
- Environmental protection.

To achieve these goals, the commission set up a common energy policy (PEC) composed of 10 programmes.¹⁰ The 10th programme mentions the use of the Rio and Kyoto conventions funding instruments supplementary to the traditional international funding instruments, to finance the common energy policy (WAEMU 2001).¹¹ An analysis of the common energy policy forces one to say that the policy is not detailed enough to lead to a concrete action. There are no quantified targets. It is known from the PEC that less than 1% of the renewable energy potential of the WAEMU contributes to the electricity supply. It is also obvious that the electricity access rate is less than about 20% in the union and the electricity is about 5% in energy balance (WAEMU 2001),

one of the lowest in the world. Based on all those statistics one would have expected a stronger energy policy, such that until 2020, electricity access could be increased to 50%, renewable energy contribution to electricity supply increased to 10% etc.. Hence, the PEC is more or less a declaration of intention or a weak policy paper. As a consequence, the electricity access rate of the countries does not improve. The countries depend on oil and the rainfall ratio to supply electricity. Yet a good combination of the various sources of energy potential could make an important contribution to the electricity supply of the countries.

In addition, an assessment of the electricity price difference between the different countries of the WAEMU (see Table 5) leads to a close look of the role of interconnection in the PEC. It is obvious that the purchase tariffs from Côte d'Ivoire are more cost-efficient than own production to replace imports. While the kWh imported from Côte d'Ivoire costs 5.2 cents to Benin and Togo, own production costs would be 63% higher. As for Burkina Faso, the imported kWh is 42% cheaper than own production.

Table 5: Purchase tariffs from Côte d'Ivoire Vs generation to replacement costs

	Purchase tariffs from Côte d'Ivoire (\$cent/kWh)	Generation to replace costs (\$cent/kWh)	Difference (%)
CEB, Benin/Togo	5.2	14	63
SONABEL, Burkina Faso	5.7	9.8	42

Source: USAID (2003).

To achieve a cost-efficient electricity supply, one could advocate to stop domestic electricity production and import everything. But the limit to this strategy is that the electricity from Côte d'Ivoire, Ghana and Nigeria is based on hydropower and depends on seasonal rainfall. The droughts in 1992 and 1998 have shown the limits of having only this electricity supply strategy. Also, a growing population and increasing industrialisation in exporting countries, could led to an export reduction. For example,

10 The ten programmes are: acceleration of the inter connection of the electrical supply, installation of an integrated energy planning system, Improvement of the supply of hydrocarbons, diversification of the energy resources, a rational use of the energy sources, acceleration of the sub-regional inter connection of the electricity supply networks, development of the rural electrification, rationalisation of the use of woody fuels, funding of the programs (WAEMU 2001).

11 For more details, see UEMOA,(PEC 2001).

the Ghanaian energy authorities are reconsidering export contract with CEB due to growing domestic electricity demand (World Bank 2004a).

Altogether, it is necessary that the WAEMU sets up a capacity building and a renewable technology development programme in order to be able to profit from the decreasing price of the renewable energy technologies that are foreseen to be accessible to least developing countries in the 15 to 20 years to come. These specific important issues are missing in the Common Energy policy of the WAEMU. Only when all these issues are addressed, can the WAEMU be in a position to achieve electricity security and cheaper electricity to its people at the country level.

Since the WAEMU energy policy is not the main issue of this research, it will not be discussed further. Now let us examine the renewable energy option or prospect for the case study countries, based on a comparison of the actual national electricity production costs and the cost of the state-of-the art renewable energy technology costs.

4.3 National electricity costs

In order to analyse alternatives to the current electricity supply structure, the cost per kWh of the technologies applicable to West African countries' conditions are examined. For the further discussion, the research assumes that international renewable energy technology prices are applicable in the case study countries. Hence, *ceteris paribus*, the price comparison of the different technologies in the Western European countries is used as a proxy. It is assumed that there are enough water, wind, sunshine and biomass sources to install the required capacity in each country. Hence, a comparison of the costs per kWh of the existing technologies to harness renewable energy in the West African countries as well as the related investment costs are shown in the table 6.

Table 6: Investment cost and price comparison between the different energy production technologies

Energy Sources	Investment costs	Expected costs
Biomass: electric	300-900 \$/KW	4-10 c/KWh
Biomass: Heating	250-750 \$/KW	1-5 c/KWh
Wind power	1,100-1,700 \$/KW	3-10 c/KWh
Photovoltaic	5,000-10,000 \$/KW	5-25 c/KWh
Solar thermal: electric	3,000-4,000 \$/KW	4-10 c/KWh
Solar heating	500-1,700 \$/KW	2-10 c/KWh
Hydropower	1,000-3,500 \$/KW	2-10 c/KWh

Source: Geller (2003). Energy Revolution, p. 19.

As for the investment costs, biomass and solar technology need lower investments than hydro and wind power. In addition, a comparison of the electricity imports from Côte d'Ivoire (5.2 \$c/kWh) with the price of biomass (4-10\$c/kWh), wind power (3-10 \$cent/kWh) and solar thermal electricity (4-10 \$c/kWh), shows that a cautious selection of these renewable technologies offers a possibility to introduce them in the actual WAEMU electricity supply strategy. Hence there are other technologies competitive with the actual electricity purchase in the sub-region. Moreover, if the price of the domestically produced electricity to replace imports is taken into account, namely 14 \$ cent in Benin and Togo and 9.8 \$ cent in Burkina Faso (see previous discussion), it becomes obvious that the above technologies are very competitive with the actual electricity supply system. Since these technologies have not been introduced to date¹², one could ask why? And an answer is the "lack of financial means"¹³, inadequate public awareness to the benefits of renewable energy, lack of favourable pricing policies and inadequate renewable energy regulatory framework (World Bank 2004b). Of course, these factors increase investment risks so that higher risk premium has to be added to the capital costs. In the end, the renewable energy is no more competitive. Therefore it will make sense to analyse whether the CDM could make a contribution to the introduction of some renewable energy technologies in the WAEMU electricity supply strategy. This issue will be addressed in chapter 7. Before discussing the issue of the

¹² Less than 1% of the renewable energy potential contributes to the energy balance of the WAEMU countries (PEC, 2001).

¹³ The financial barrier refers to high up-front investment, which investors in some developing countries could not provide.

contribution of the CDM to the supply system of the case study countries, let us examine the crucial issue of electricity demand in the case study countries.

5 ASSESSMENT OF THE ELECTRICITY DEMAND IN THE CASE STUDY COUNTRIES

There are different ways of assessing electricity demand. The National Aeronautics and Space Administration (NASA) took night light emissions as indicator of electricity demand. Photo 7 below shows night emissions of the earth. Currently, the studied countries are located in a very low electricity demand area as indicates the arrow on the photo. The following sections will assess current and future electricity demand based on simplified and comprehensive methods

Photo 7: Astronomic picture of the night, light emissions as indicator for electricity demand

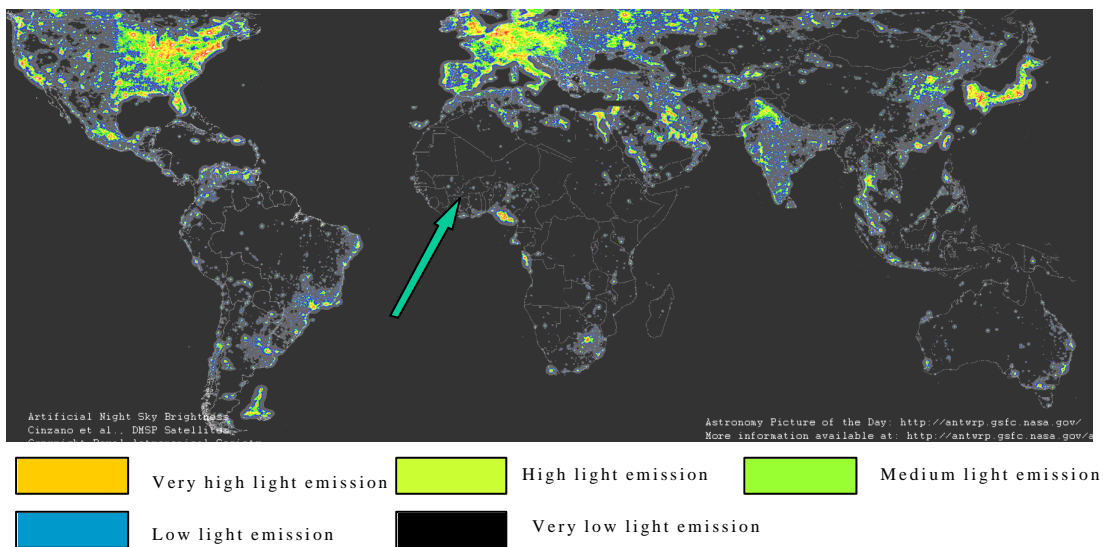


Photo source: <http://antwrp.gsfc.nasa.gov>

5.1 Simplified assessment methods

The energy requirement in a region or in a country could be assessed based on a bottom up scenario. The required energy for households is divided into heat energy¹⁴ and power requirement for light, electrical appliances and for cooking purposes. The required data

is different from region to region depending on climatic conditions and considering the specific site conditions. Since the case study countries are Sub-Saharan countries, there is no need for space heating. However, as air conditioning is mainly limited to administration offices and hotels' buildings, this demand is not that high and is not taken into consideration in this study. Therefore, only electricity demand for light electrical appliances will be discussed. In addition, an aggregation of household energy requirement gives the overall energy requirement for a country. An aggregation of the countries' requirements gives the energy requirements for a region or sub-region. The following equations allow the determination of electricity consumption. Household requirements (E_h) result from the usage data of all electrical devices existing in a household for different uses: light, cooking, communication and cooling.

$$E_h \text{ (MW/y)} = \sum \beta \text{ (kW)} \times h + \alpha \text{ (kWh)}$$

Where:

β (kW) is the connected load for the device

h is the full load hours in the year

α is the losses in kWh

The aggregation of the above formula leads to the total household energy requirement (E).

$$E \text{ (MWh/y)} = \{E_h \text{ (MW/y)}\} \times n$$

Where n is the number of households.

In a country where all data required for the assessment are available, the assessment is computed easily. Unfortunately, in most developing countries the data is not recorded. This is the case in the case study countries. Thus, a standard electricity consumption per household, based on basic, extended and normal electricity needs in the case study countries is derived.

Basic electricity needs refer only to lighting, 3 h /day, and radio/TV service, 4 h/day. As for extended needs, they refer to one hour more electricity services for the previous items, supplemented with refrigerator service. As far as normal needs are concerned, they use more powerful radio/TV and refrigerators. Moreover, electricity use for water pumps, water treatment and schools and hospitals is included (see table 7). To simplify the assessment at this level, industry and transport consumption as well as some forms of public electricity demand are not taken in to consideration. This assumption will be removed when considering a more sophisticated and comprehensive assessment method.

Table 7: Daily household electricity demand assessment

	Basic Needs	Extended Needs	Normal Needs
User appliances			
Lighting	3 x 11W x 3h	4 x 15 x 4h	4 x 15 x 4h
TV/Radio	30 W x 4 h	30W x 5h	60W x 5h
Refrigerators	-	10W x 24h	30W x 24h
Others	100 Wh	300 Wh	1,500 Wh
Central service for 50 households			
Water Pumps	300 Wh	6,000 Wh	10,000 Wh
Water Treatment	1,500 Wh	3,000 Wh	5,000 Wh
Others	1,000 Wh	1,500 Wh	3,000 Wh
Daily Consumption/Household	3 kWh	11 kWh	21 kWh

Source: El Bassam & Maegaard (2004).

Since the precise number of households belonging to each category is not known, this study suggests the use of the mean value (12 kWh/d) of the three consumption categories for the estimations. In addition, it is assumed that each household is composed of 5 people. Based on these assumptions, table 8 below shows the electricity demand in the case study countries.

Table 8: Electricity demand in Benin, Burkina Faso, Niger and Togo

	Total population (million)	Number of households (million)	Electricity demand per household (MWh/year)	Total (TWh/year)
Benin	6.750	1.350	4.4	6
Burkina Faso	12.625	2.525	4.4	11
Niger	10.650	2.130	4.4	9
Togo	5.250	1.050	4.4	5

Source: Own table based on IEA (2003c,d); World Bank (2004b).

Total electricity demand in Benin would be about 6 TWh/y, 11 TWh/y in Burkina Faso, 9 TWh/y in Niger and 5 TWh/y in Togo. Clearly these electricity demand estimates based only on the actual population in the countries and do not reflect the reality, as population is not the only driving force behind electricity demand. In order to get an accurate estimate of the electricity demand, the following section will present a more complex or comprehensive demand assessment methodology based on different forces driving electricity demand.

5.2 A comprehensive electricity demand assessment methodology

The first part of this section shows the driving forces and the methodology used to determine the electricity demand in Benin, Burkina Faso, Niger and Togo in the next 20 years, based on the assumption of different economic development scenarios. The methodology has been used originally in the assessment of electricity demand in the Middle East-North African countries (DLR 2005), where the electricity demand has been forecast for up to 2050. Since the energy issue discussed in the present research deals with CDM, only energy forecasts up to 2020 have been analysed. In fact, in the discussion on CDM lifetime the existence of two other commitment periods after the first commitment period starting from 2008 to 2012 has been assumed.

a) Driving forces

The scenarios for the electricity demand were calculated using GDP per capita and population as driving forces: $Y_E = f(x, x_1)$

Where Y_E is total electricity demand, x is GDP per capita and x_1 is population.

Other factors, like electricity price, could influence electricity demand. This single issue is not directly addressed, but indirectly through the introduction of energy efficiency measures.

Population: All scenarios share the same population prospect – the World Population Prospect by the UN, middle path, revision 2002 - including the age structure of the population. The latter is not taken into account explicitly, but will be used to discuss the feasibility of economic growth and what might happen if the labour force and not the

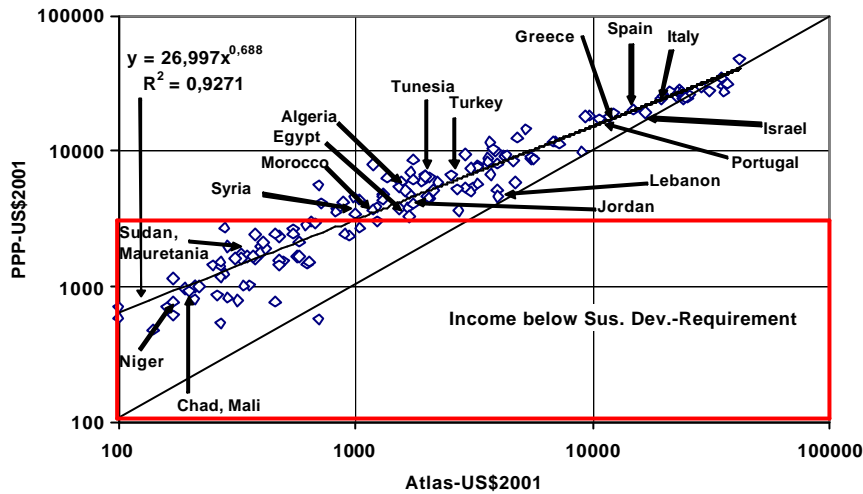
population are considered as driving forces. The data was taken from the Statistisches Bundesamt (2003 and FAO (2004) In addition, it should be noted that according to the scenario in the next 20 years, most of the states under investigation will experience a demographic transformation due to relatively high fertility rates, which will raise the share of the population's working force. Of course, this assumes that the countries succeed in employing the youth in the next decades, which is a challenge as the growth rate of the labour force is one to two percentage points higher than the growth rate of the population.

GDP per capita: Regarding economic development, firstly one has to decide which indicator should be used. In the following, the Gross National Income (GNI) in Purchasing Power Parity (PPP) US\$-2001 per capita will be used. While the Gross Domestic Product is a better measure of economic activities within a country, the GNI is a better measure of the population's income. A gross concept in comparison to a net concept is used in order to take the capital endowment into account and also due to data availability and reliability reasons. The PPP is assessed on the basis of a US-basket of goods and services to minimise differences due to currency fluctuations and to allow comparability.

To give an impression of the current economic state, countries of different economic levels across the world, such as European countries, Mediterranean countries, Middle East countries and southern Saharan states, are identified in figure 4. In 2003, the German Advisory Council on Global change (WBGU) suggested a minimum GNI per capita (in PPP), below which it seems impossible to provide certain fundamental health and educational services to all people as a sustainable development criterion (WBGU 2003). It is obvious that all the WAEMU countries do not have a GNI per capita above the required minimum. The case study countries have an income below the sustainable development requirement (delimited square in figure 4).

This suggests that from a sustainable development viewpoint, increasing the GNI per capita is top priority in itself. In a further section, the sustainable development issue will be addressed (chapter 7).

Figure 4: Comparing Gross National Income (GNI) per capita in 2001 in US-\$2001 (PPP) vs. Atlas US-\$2001 sample size 154



Source: World Bank, 2004b; Statistisches Bundesamt (2003).

To calculate scenarios¹⁵, the average annual growth rate of 1.2 % of the GDP per capita (in 1995 US\$ (PPP)) for the United States and Canada (2000-2030) in the reference scenario of the IEA is used (IEA 2002, p. 137ff.) as a benchmark until 2050¹⁶. For each country, two possible convergence paths with reference to the 2050-GDP per capita of the United States are defined: the same growth rate of the GNI per capita as the United States, i.e. 1.2 %/a ("following up" (FU)) and quartering the relative difference of GNI per capita from 2001 until 2050 ("closing the gap" (CG)). For the case study countries, the implied annual growth rates of GNI per capita and the past growth rates are shown in table 9. As the USA has one of the highest GDP per capita, it is used as a benchmark. So their GDP per capita can serve as an indicator for the state-of-the-art¹⁷ production

¹⁵ The research is dealing with scenarios and not forecasts. A scenario is a description of an event if certain conditions are realised.

¹⁶ From past experience it might be argued that this growth rate is a little too low. For example, the long run experience of industrialised countries suggests an annual growth rate of 1.6-1.8%; the last decades suggest a growth rate of over 2% per year. Concerning the last decades however, it should be noted that the accommodation for quality changes with the help of so-called hedonic price functions - used to derive USA's GDP growth rates - probably tends to exaggerate the growth in comparison with those of other countries. Currently more countries are introducing this kind of accommodation and are using it in more sectors. Given the methods employed here, it seems to be appropriate to use a cautious estimate. A cautious growth rate of 1.2%/a is used for the USA GDP growth rate.

¹⁷ The state-of-the-art is the appropriate reference as potential growth rates depend on the possible contribution of imitation – and adaptation – or innovation to socio-technological development.

frontier that may be achievable for all countries. Quartering the relative difference in 50 years refers to the literature on economic growth. Such a speed of convergence – if convergence exists at all - is within the range of the estimations in the literature. (Barro and Sala-i-Martin 1995). In "closing the gap", a required annual growth rate for each country is carried out by means of the following equation:

$$A(1+X)^{50} = \frac{3}{4}(1,012)^{50}*B$$

Where,

A is the GDP per capita of a developing country,

X is the required GDP growth rate to a developing country to close the gap,

B is the per capita GDP in USA.

The resolution of the equation filtered out a per capita GDP growth rate of 9.3%, 9.4%, 7.2%, 12.9% for Benin, Burkina Faso, Niger and Togo respectively over the 50 years. From the experience of the countries over the last 20 years, none of them has reached such a high level of per GDP growth. Moreover, if substantial social, political and economic changes might lead to such a GDP growth level, it is questionable whether the countries could sustain this over 50 years. It is possible that they reach such a level only in the short run. Therefore the research suggests that the annual growth rates of the counties are restricted to 7%/a, as there seems to be an upper boundary on long-run-growth stemming possibly from the speed of change a society might master. 7%/a is in this respect cautious. For these countries, given their past performance and the very high growth rate of the population¹⁸, and considering additional data on education, an average of almost 4-4.5 %/a of GDP per capita growth rate over the next 50 years can be considered very optimistic, while the 7.2-12.9%/a – which would result without the 7%-restriction – seems to be unrealistic.

With a GDP per capita ranging from 800 to 1,500 US-\$1996(PPP), the four countries are very poorly performing countries according to United Nation's ranking

18 Average growth rate is about 2.6% per year.

(UNDP 2004). In the past ten years, the economic development did not even match the population growth. From that perspective the first aim is clearly to prevent a further decline of per capita GDP. In the following-up scenario this turn around will be achieved, but with a growth rate of 1.2 %/a. The GDP per capita will be fairly low even in 2050 (1380-2800 US\$-1996 (PPP)).¹⁹ With the closing the gap scenario, the GDP is about 4,360 US\$-1996(PPP) in Niger, about 8,320 US\$-1996(PPP) in Benin, about 9,190 US\$-1996(PPP) in Burkina Faso and about 11,570 US\$-1996(PPP) in Togo. This means that Niger will have reached Paraguay level today in 2050. Benin will have reached Mexico's current development level, Burkina Faso will have reached Costa Rica's current level, and Togo will have reached Argentina's²⁰ current level, all in 2050. Furthermore, the GDP of the countries by 2020 are even lower. This implies lower electricity demand. For the countries, the difference between the two economic scenarios is considerable. However, to reach the outcomes in the following up scenario within the near future will be hard to achieve and will in all likelihood require broad and successful socio-economic measures. Therefore, both scenarios will be analysed.

Table 9: Average annual Growth rates of GDP and GDP/capita in both scenarios and between 1990 and 2000 (in %)

	Growth rate GDP/capita following up (FU)	Growth rate GDP, following up (FU)	Growth rate GDP/capita closing the gap (CG)	Growth rate GDP, closing the gap (CG)	GDP/capita Growth Rates 1990-2000	GDP Growth rates, 1990-2000
Benin	1.2	3.8	4.4	7	1.8	4.6
Burkina Faso	1.2	3.7	4.5	7	1.2	3.5
Niger	1.2	2.1	3.7	7	-1.8	1.6
Togo	1.2	1.8	4.5	7	-0.4	2.3

Source for past growth: World Bank (2005).

b) Electricity demand

Link between GDP per capita and electricity consumption per capita.

¹⁹. A growth rate of 1.2 %/a doubles a value approximately every 50 years.

²⁰ For more information on GDP/capita PPP of the countries see World Bank (2005).

The relation between GDP per capita and electricity consumption per capita is necessary for deriving the electricity demand. With the population growth, the overall electricity demand can be assessed. Based on past development experiences, an approach based on regressions is used to carry out hypothetical links between GDP per capita and electricity demand per capita. But past experiences may be misleading as technological, economic, political or social developments may change development patterns. Moreover, unexpected breaks may take place, like the change in energy consumption patterns in industrialised countries after the first oil crisis in the 70's. Notwithstanding, a cautious investigation of possible changes allows us to include these kind of changes in an analysis. In addition, it is well known that past experience might be quite accurate at predicting developments in the near future because capital stocks and societal conventions or rules and life style are changing slowly. In the long run this is not true. At least the forms of regression function might not be determined a priori or might not be isolated by statistical performance. Extrapolating different functions may, however, yield very different results in the long run (IEA 2003a,b). To address this issue, the development of *population* and *GDP per capita* are used as driving forces and the methodology links scenarios for population and GDP per capita with the energy demand. As the population scenario is thoroughly discussed, further attention is given to the economic scenario. As discussed above, the two scenarios cover a considerable range of possible future developments. Moreover, two alternative functional links between GDP per capita and electricity demand per capita will be discussed and used. With two alternative economic developments and two alternative links to energy demand, combined with an additional comparison with technological oriented scenarios for industrial countries, it is possible to cover a wide range of possible future trends that are free of contradictions.

Generally, the smaller the unit under investigation, the higher the uncertainties that should be taken into account in interpreting the results for small individual countries.

The methodology used to calculate electricity demand can be described as follows:

- i) Regressions are run every year in the period 1960-2001. The regressions between the GDP per capita and total final consumption (TFC) of electricity per capita were calculated using power functions for a number of countries, such as USA, Canada,

England, Germany, France, etc. (IEA 2003a, PWT 2002). GDP data from the World Bank GDP was used for the sake of comparison.

$$Y1 = a \cdot X^b,$$

where Y1 is the explained variable (per capita electricity demand), X is explicative variable (GDP per capita), a is the absolute term and b the exponent.

ii) As far as the two parameters of the regression equations are concerned, time trends were estimated using power functions and alternatively linear functions. Power functions gave a significantly better fit for the first term (a). For the second term (b) it was hard to distinguish a linear trend from a power trend. Hence, both were used, resulting in two alternative links between GDP per capita and electricity consumption per capita. The linear trend gives a scenario with high efficiency gains (HE) while the power trend results in increasing electricity intensities and low efficiency gains (LE).

iii) As for the TFC for electricity, the gross electricity demand was derived by using data from IEA (2001) on distribution losses, consumption in the energy sector and so called "own use". These consumptions were split into a proportional and a fixed term. The fixed term is meant to accommodate the use for oil production. The proportional term was linearly reduced to a level that is now common in industrial countries (i.e. 8 %). It should be noted that the data on these terms is not of a high quality and is sometimes missing. Fortunately, the impact is generally negligible. For these reasons, distribution loss in this research does not play an important role.

iv) Additionally, the resulting overall functions were calibrated to individual countries assuming a linear mix of the current values and the estimated value. The weight of the estimated value is assumed to increase linearly from a current 0 to 1 in 2050.

v) The two scenarios are carried out by combining high economic growth with high efficiency growth and low economic growth with low efficiency growth, as the increase of efficiency is coupled to investment and a higher growth rates results in higher investment rates and a higher share of new devices and production machines.

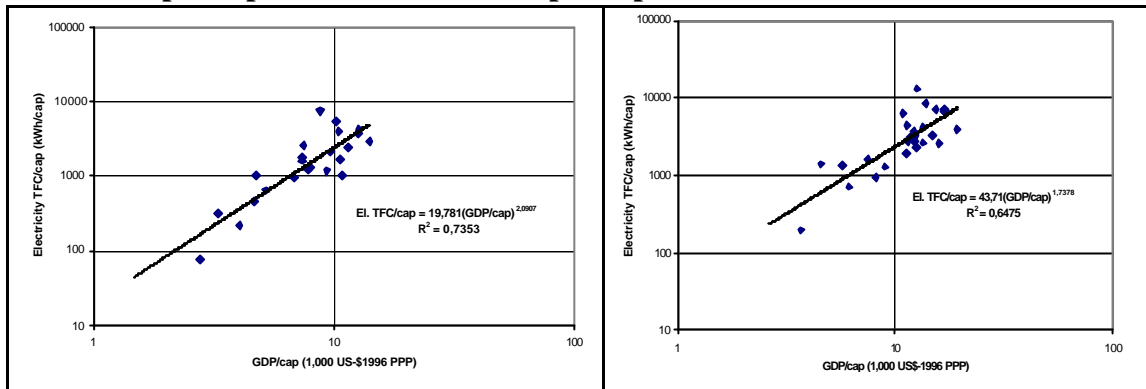
Actually, five steps give a better understanding of the overall method's confidence when a single point is discussed in more detail. These steps are analysed below.

Step 1: Using data from PWT (2002) and IEA (2003c,d), regressions for GDP per capita and total final energy consumption per capita were calculated for different years using power functions. Overall power functions delivered the best fits, although polynomials of a certain order might do as well²¹. As no functional form is a priori adequate, the research suggested the use of power functions based on convenience and ease of use. Figure 5 shows six examples of results.

The correlation is generally quite high but is decreasing along the time line. With a sample that contains a broad set of countries, i.e. low income, middle income and high income countries, the correlation is stronger than with only one country group, e.g. compare R^2 in figure 5 d) and 5 e). Using only one country group, there might be no strong correlation between the two variables. Moreover, certain country groups show exceptional behaviour. In figure 5 e) two of these groups are marked: transition economies and northern countries. In these cases, regressions were calculated with and without each or all of these country groups. The statistics lead to the conclusion that the general approach is suitable for a long-term analysis covering middle-income countries that will reach the levels of today's industrial countries. Even in high-income countries there is no evidence of a falling electricity demand, although the energy intensity of GDP might be reduced.

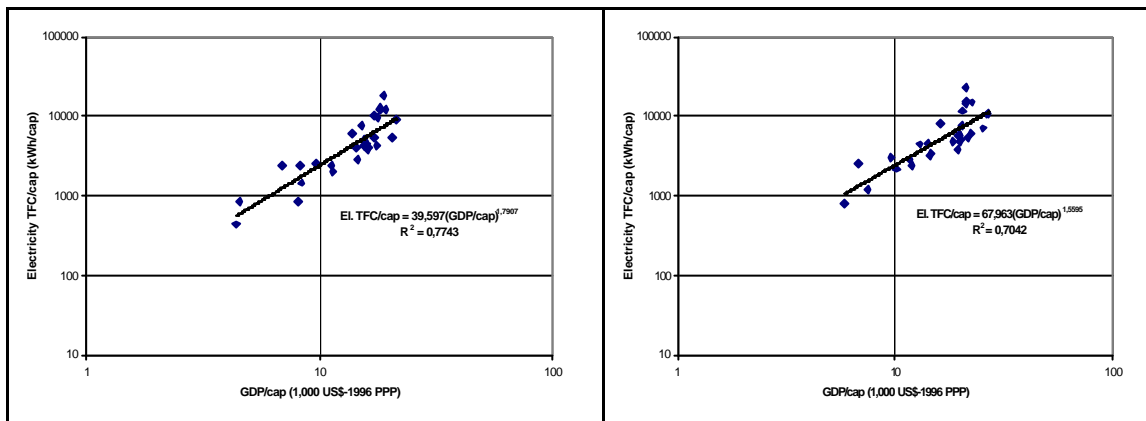
21 Trivially, a polynomial of the order of the sample size generally gives a perfect fit. Without any degrees of freedom it is statistically worthless. Only polynomials with a maximal degree of four were used

Figure 5: Examples for correlation between Total Final electricity Consumption per capita and GDP or GNI per capita



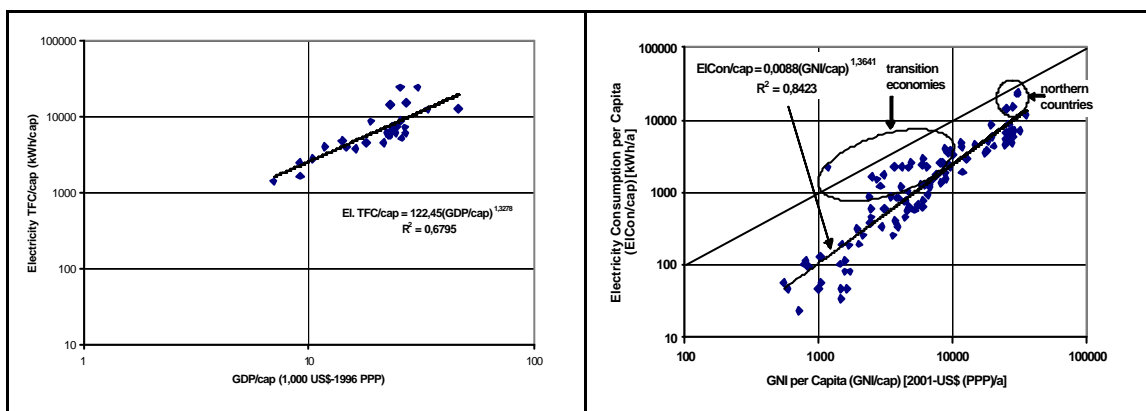
a) In the year 1960

b) In the year 1970



c) In the year 1980

d) In the year 1990



e) In the year 2000

f) Different sample and data

Source: (WTP 2002), (IEA 2003a, b, c), (Statistisches Bundesamt 2003)

A power function would carry out proportional growth rates of GDP per capita and of total final consumption of electricity per capita. The factor is given by the exponent. For

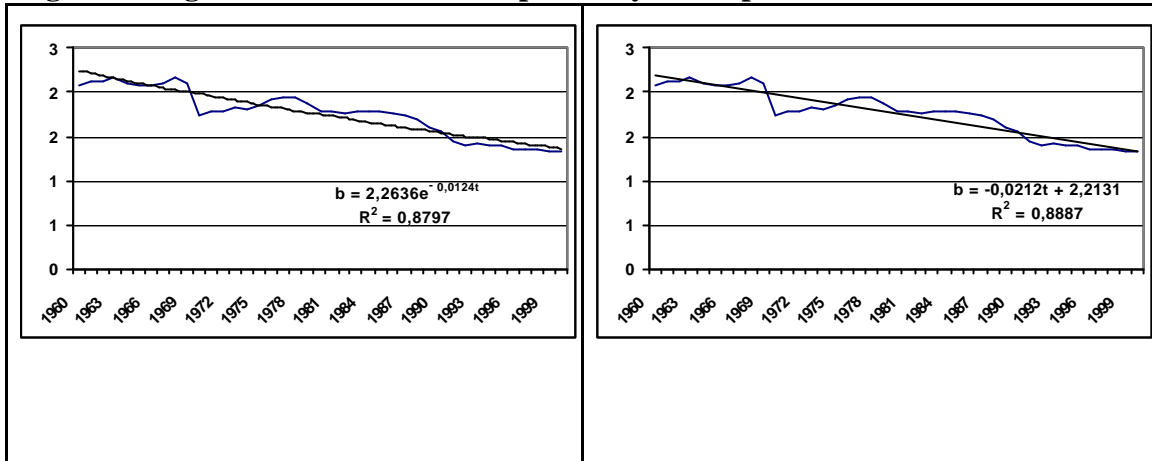
example, the 1.3641 in figure 5 e) implies that a 1% higher GDP per capita is combined with a 1.3641 % higher total final consumption of electricity per capita. Obviously, all regressions suggest that the electricity consumption per capita increases proportionally with a higher GDP per capita. In addition, it is obvious that the exponent is decreasing over time while the absolute term is increasing. Therefore it does not seem to be appropriate to use a power function with constant parameters.

Step 2: Figure 6 a)-d) shows the development of the exponents and the absolute term from the sample including every year from 1960 to 2000. For both parameters an exponential as well as a linear time trend can be seen. Other functional forms delivered worse, while polynomials of higher order did not increase the fit by significant margins. The two functions of the regressions of the exponent's time trend are hard to distinguish. So both equations are used.

As for the absolute term this is not true. The exponential function shows a significantly better fit.

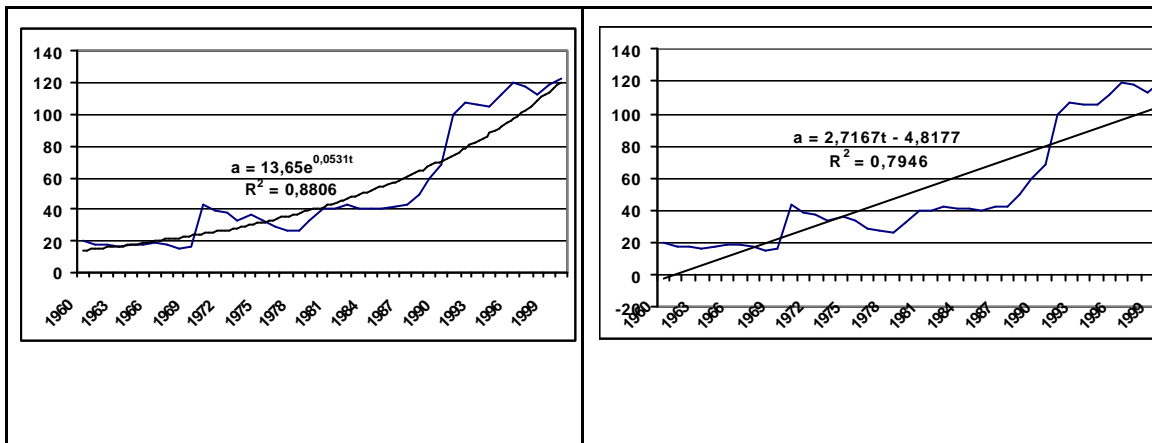
Based on the scenarios, until 2050 the link between the economic growth and the electricity demand will be provided by a power function whose absolute term follows the exponential time trend according to figure 6 c), and whose exponent follows either an exponential time trend according to figure 6 a) or a linear time trend according to figure 6 d). As the linear regression function of the exponent in comparison with the exponential regression function results in a lower electricity demand, the respective scenarios will be called "high efficiency gains (HE)" while the scenarios using the exponential function will be called "low efficiency gains (LE)".

Figure 6: Regressions for the time dependency of the parameters



a) Exponential regression for exponent

b) Linear Regression for exponent



c) Exponential regression for absolute term

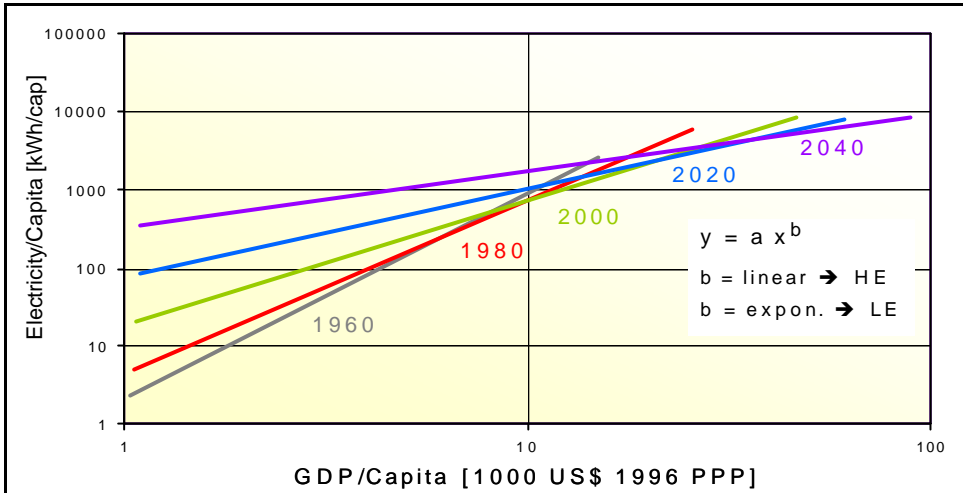
d) Linear Regression for absolute term (not used)

Using the two economic scenarios, the two functions linking economics and electricity and the population scenario, four scenarios of the TFC of electricity can be carried out assuming a typical (an average) country.

Figure 7 shows the different functions for the years 1960 to 2040.

From figure 7, it is obvious that the slope of the fit function changes overtime. At the same time, the dependency of the exponent and the absolute terms on the growth rates of GDP per capita and TFC of electricity are no longer proportional. The link is now time dependent. Also with the change of the parameters, the TFC of electricity per capita will develop in different ways for countries with different GDP per capita at the beginning but equal growth rates of GDP per capita.

Figure 7: Fit functions for the years 1960 to 2040 for a sample of 25 (150) countries showing the correlation and extrapolation of total final electricity consumption per capita as function of GDP per capita for the high efficiency trend HE



Source: Own figure

Step 3: So far, the approach is not country specific in the sense that for two countries starting with the same GDP per capita and experiencing the same growth rate of GDP per capita the resulting path for TFC of electricity per capita will be identical. Actually, this step will introduce a first country specific component and the notion of TFC will be abandoned in favour of a concept that is more appropriate for further work.

The notion of distribution losses, consumption in the energy sector and the so-called own use for each country was introduced by the International Energy Agency (IEA 2003c, 2004). It was assumed that distribution losses and "own use" are indicators of inefficiencies and that the relative values of these positions compared to the total final demand of electricity will be reduced linearly to 8 % by 2050.

For countries that show a high value, this linear reduction of losses will of course decrease the growth rate of energy demand over the whole period but will in terms of growth rates of electricity reduce these growth rates, especially near 2050.

Step 4: So far, the methodology described will generally not exactly predict the present electricity demand per capita of any particular country. The real values, however, are distributed statistically around this estimate. Therefore it is necessary to calibrate the starting point of the function for every country. For the calibration it was assumed that the deviation from the estimated value is contingent and that each country will realise the estimated value in 2050. The difference between the present real electricity demand per capita and the fit functions of the scenarios will decrease over time.

An electricity consumption per capita that is higher than the estimated value for a certain GDP per capita is judged as some kind of inefficiency or special economic structure that will disappear over time. An electricity demand per capita that is smaller than the estimate is interpreted as a lack of a stock of production machinery etc., which is to be expected with such an income, or again a specific structure of the economy. Again, it is assumed that these deviations from the estimated and extrapolated function will be reduced to zero until 2050. An electricity demand path for a country, which currently has a relatively high per capita demand, will therefore be expected to experience a decrease (or limited increase) in energy intensity.

Step 5: Altogether, the steps so far lead to four scenarios for electricity demand for each country: closing the gap & low efficiency gains (CG/LE), closing the gap & high efficiency gains (CG/HE), following up & low efficiency gains (FU/LE) and following up high efficiency gains (FU/HE). To limit the number of possibilities it is assumed that the economic scenarios (closing the gap, following up) will occur in every country simultaneously. Therefore, the huge amount of possibilities stemming from mixing following up and closing the gap at a country level is avoided.

Moreover, the four scenarios were reduced to two by comparing the results with technology oriented studies and thereby testing their plausibility. The two scenarios selected are "closing the gap & high efficiency gains" (CG/HE) and "following up & low efficiency gains" (FU/LE). The combination "following up & high efficiency gains" results in a decrease of energy intensity that is too high to be in line with technological discussions and is thought to be implausible (WBGU, 2003). On one hand, the economic growth rates in following-up are typically not high enough to expect a fast spread of new technologies and give strong incentives for the development of

these technologies. On the other hand, if the introduction of strong policy measures to combat climate change would reduce the growth of GDP per capita this scenario might be possible.

Moreover, it can be argued that fast economic development will increase the spread and development of new machinery which is likely to be associated with high efficiency gains. However, from the discussion of similar scenarios for different industrialised countries, it is not plausible that these kinds of efficiency gains will be realised without specific policy measures. Since scenarios are dealt with here and not predictions, their realisation requires technical, financial, social and political efforts. They will not take place automatically or spontaneously.

The analysis of the steps so far lead to four scenarios for electricity demand for each country: closing the gap & low efficiency gains (CG/LE), closing the gap & high efficiency gains (CG/HE), following up & low efficiency gains (FU/LE) and following up high efficiency gains (FU/HE). To limit the number of possibilities it is assumed that the economic scenarios (closing the gap, following up) will occur in every country simultaneously. Therefore, the huge amount of possibilities stemming from mixing following up and closing the gap at a country level is avoided. Moreover, the four scenarios were reduced to two by comparing the results with technology oriented studies and thereby testing their plausibility. The two scenarios selected are "closing the gap & high efficiency gains" (CG/HE) and "following up & low efficiency gains" (FU/LE). The combination "following up & high efficiency gains" results in a decrease of energy intensity that is too high to be in line with technological discussions and is thought to be implausible (WBGU 2003). On one hand, the economic growth rates in following-up are typically not high enough to expect a fast spread of new technologies and to give strong incentives for the development of these technologies. On the other hand, if the introduction of strong policy measures to combat climate change would reduce the growth of GDP per capita this scenario might be possible. The results for the two chosen scenarios will now be discussed in detail.

Table 10 shows the four scenarios. Since the countries have a willingness to develop, the scenario CG/HE will be adopted, while FU/LE will show what would have happened in case the countries do not undergo CG/HE.

Table10: The four main scenario variants for economic growth. CG/HE will be described in detail

4 Scenario Variations for Economic Growth:	
CG/HE	Closing 25 % of the per Capita GDP Gap with USA by 2050 High Efficiency of the Power Sector
CG/LE	Closing 25 % of the per Capita GDP Gap with USA by 2050 Low Efficiency of the Power Sector
FU/HE	Following Up with the per Capita GDP Gap with USA until 2050 High Efficiency of the Power Sector
FU/LE	Following Up with the per Capita GDP Gap with USA until 2050 Low Efficiency of the Power Sector

6 SCENARIOS OF ELECTRICITY DEMAND

Before analysing the results of the two scenarios it is important to be reminded of their meaning and aim. The aim of the CG/HE scenario is to investigate whether a high economic growth can be accommodated by the energy system without compromising sustainable development goals, especially on greenhouse gas emissions.

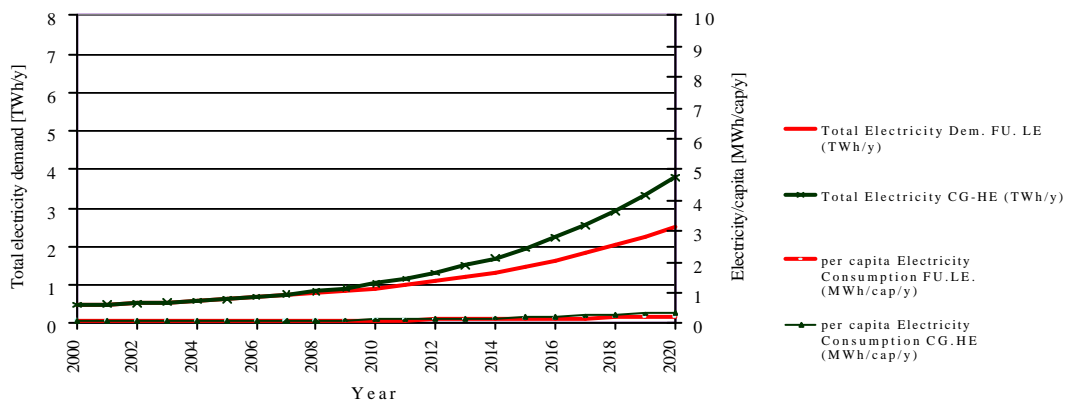
Second, as for the FU/LE scenario, an economic growth rate is assumed that might be somewhat disappointing for the case study countries. With its low efficiency gains, its rising energy intensities, this scenario might be seen as somewhat cautious on economic and technological development. However, for the next two decades it is not too far removed from the other scenario. Alternatively, the technological side of this scenario might be interpreted as a continuing trend to substitute other energy carriers by electricity and the increase of electricity consuming machines and consumer goods. In the following, the results in Benin, Burkina Faso, Niger and Togo will be analysed. The total electricity demand equals total final consumption (TFC) of electricity per capita multiplied by total population.

Results

- *Benin*

The electricity demand in the two scenarios is presented in the figure 8 below. As for the following up-low efficiency, the total electricity demand increases from 0.5 TWh/y in 2000 to about 2.8 TWh/y in 2020. The per capita electricity demand will rise from 110 kWh/y in 2000 to about 240 kWh/y in 2020. As far as the closing the gap high efficiency is concerned, the total electricity demand increases from 0.6 TWh/y in 2000 to about 4 TWh/y in 2020. The per capita electricity demand in this scenario increases from 80 KWh/y to 360 KWh/y. A rapid increase in the electricity demand appears around 2016, earlier than the FU-LE scenario. Still, the demand in CG-HE is higher than FU-LE. A comparison of the actual total electricity supply in 2003 (625 GWh) (Ministry of Energy - Benin 2004) with the results of the scenarios in 2003 (FU-LE 618 GWh; CG-HE 518 GWh), shows a difference of 1% and 17% from FU-LE and CG-HE respectively. The model could therefore be a good guidance to design and implement policy measures. However, per capita electricity in 2020 will still be low compared to current average per capita consumption in Sub-Sahara Africa, between developing countries and world average: 360 kWh/an against 500 kwh/an, 900 kWh/an 2500 kWh/an respectively (World Bank 2004b, IEA 2003c, EIA 2003).

Figure 8: Electricity demand and electricity demand per capita in Benin according to the scenarios CG/HE and FU/LE

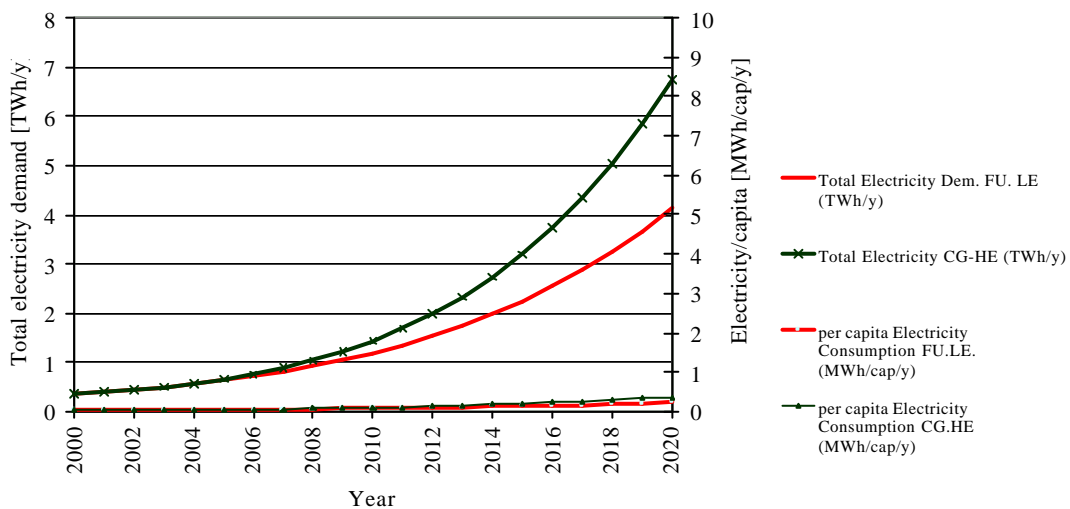


Source: Own figure

- **Burkina Faso**

The electricity demand in the two scenarios is presented in figure 9 below. Under up-low efficiency, the total electricity demand increases from 0.4 TWh/y in 2000 to about 4 TWh/y in 2020. The per capita electricity demand will rise from 30 kWh/y in 2000 to about 220 kWh/y in 2020. Under the closing the gap high efficiency scenario, the total electricity demand increases to about 7 TWh/y in 2020 and per capita demand to 360 kWh/y in 2020. A comparison of the actual total electricity supply in 2003 (430 GWh)²² (Ministry of Energy - Burkina Faso, 2004) with the results of the scenarios in 2003 (FU-LE 563 GWh; CG-HE 502 GWh) shows a sensible difference of about 24% and 14% respectively. Obviously the deficit is higher than the deficit in the case of Benin. The same analysis is made as in Benin case with respect to per capita electricity demand in 2020 compared to current demand in Sub-Sahara Africa, between developing countries and world average.

Figure 9: Electricity demand and electricity demand per capita in Burkina Faso according to the scenarios CG/HE and FU/LE



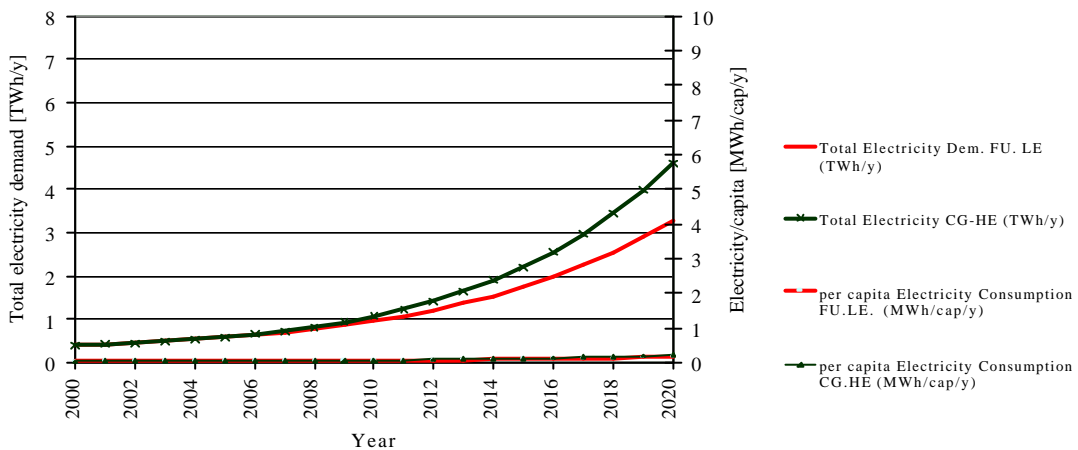
Source: Own figure

²² The electricity supply in this figure does not include importation. Data on importation are not available.

- *Niger*

The electricity demand in the two scenarios is presented in figure 10 below. In the up-low efficiency case, the total electricity demand increases from 0.4 TWh/y in 2000 to about 3.3 TWh/y in 2020. The per capita electricity demand will rise from 40 kWh/y in 2000 to about 160 kWh/y in 2020. As far as the closing the gap high efficiency is concerned, the total electricity demand increases to about 4.6 TWh/y in 2020, the per capita electricity demand to 230 kWh/y in 2020. A comparison of the actual total electricity supply in 2003 (205 GWh) (Mine and Energy Ministry Niger 2004) with the results of the scenarios in 2003 (FU-LE and CG-HE, 499 GWh) shows a high deficit of about 59%. Obviously the deficit is higher than the deficit in the case of Benin.

Figure 10: Electricity demand and electricity demand per capita in Niger according to the scenarios CG/HE and FU/LE



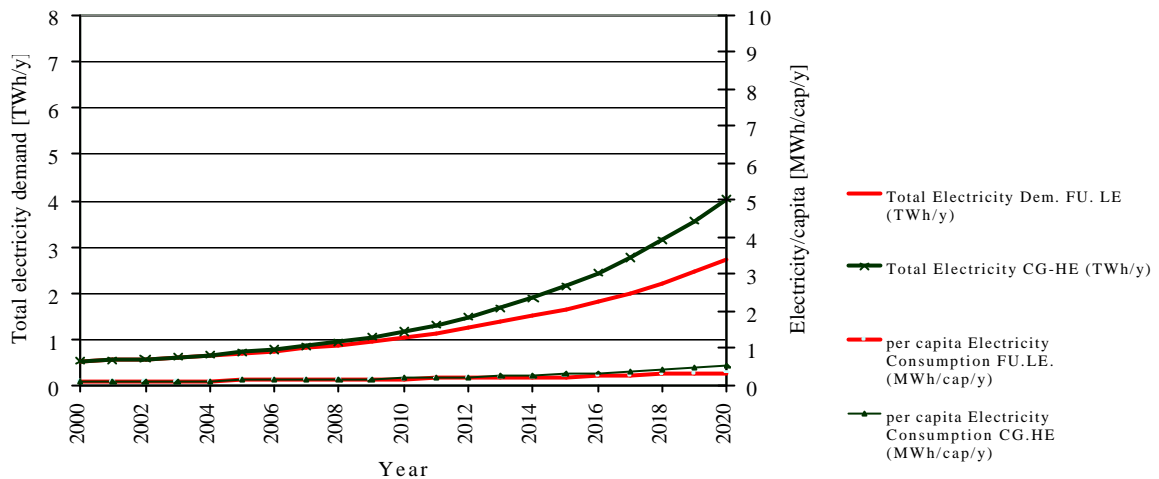
Source: Own figure

- *Togo*

The electricity demand in the two scenarios is presented in figure 11 below. As for the following up-low efficiency, the total electricity demand increases from 0.5 TWh/y in 2000 to about 2.7 TWh/y in 2020. The per capita electricity demand will rise from 110 kWh/y in 2000 to about 350 kWh/y in 2020. As far as the closing the gap high efficiency is concerned, the total electricity demand increases to about 4 TWh/y in 2020, the per capita electricity demand to 520 kWh/y in 2020. A comparison of the

actual total electricity supply in 2003 (250 GWh) (IEPF, 2004) with the results of the scenarios in 2003 (FU-LE and CG-HE, 618 GWh) shows a huge deficit of about 40%.

Figure 11: Electricity demand and electricity demand per capita in Togo according to the scenarios CG/HE and FU/LE



Source: Own figure

7 IMPLICATIONS OF THE LOW ELECTRICITY DEMAND FOR THE CDM

Based on electricity demands assessed so far, we make a projection of the subsequent CO₂ emissions in the WAEMU countries until 2020. The rationale is to show the possible CDM market development. Projections are based on electricity demand²³ each year and the mean CO₂ eq. emissions factor in electricity grids as calculated in chapter 6. For the assessment, we assume the mean value to remain constant during the whole period. Hence,

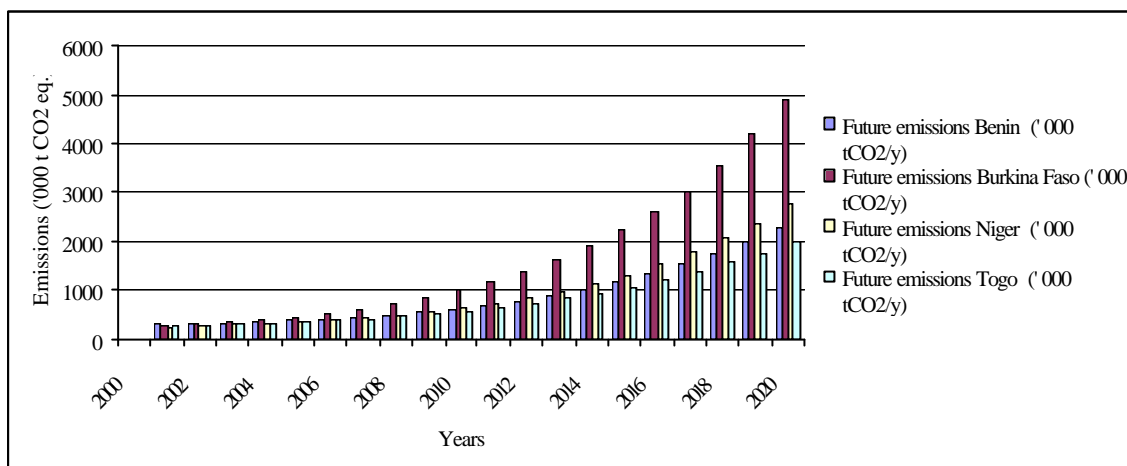
²³ CG/HE electricity demand scenario is used as it represents a higher electricity demand.

$$E (t) = Q (MWh) \times C (t/MWh)$$

where E is total emissions per year, Q is total electricity demand per year, and C is emission factor or baseline.²⁴

The results of the projections are summarised in the figure 12 below.

Figure 12: CO₂ emissions projections in electricity sectors until 2020



Source: Own figure.

Although emissions have substantially increased compared to current emissions, it is unlikely that in the long term, this improves countries competitiveness in the international CDM market, unless substantial changes occur in the current CDM rules.

8 CAUSES OF THE FAILURE OF RENEWABLE ENERGY PROJECTS IN THE SUB-REGION

Several renewable energy projects have been introduced in the 80s in the case study countries to harness their renewable energy potential. Unfortunately, this initiative has been unsuccessful due to several reasons such as: inadequate institutional framework,

²⁴ Carbon emissions factors used are: 0.6 t CO₂/MWh, 0.7 t CO₂/MWh, 0.6 t CO₂/MWh and 0.5 t CO₂/MWh respectively in Benin, Burkina Faso, Niger and Togo (For more details see Discussion Paper N° 356).

lack of information, unavailability of technical and financial support and the lack of market.

As far as inadequate institutional framework is concerned, there is limited coordination on existing activities on renewable energy between different government agencies, research and academic institutions, financial institutions and private sector. This leads to a lack of coordinated advocacy at the decision making levels and hence, the delay of required policy changes in favour of a widespread adoption of renewable energy. As for the information issue, there is limited knowledge on the renewable needs and the ability for services of target groups. Moreover, there is a lack of empirical knowledge of the costs and benefits of the range of technologies available (IEA 2003a). In fact, there is little knowledge of the renewable energy technologies and the public is not aware of them. With respect to technical and financial support issues, there is a lack of technology providers that coordinate the development and the dissemination of the renewable energy technologies. This leads to a lack of private sector capacity in, distribution, installation and maintenance of the rare renewable energy devices. For example, photovoltaic projects in West Africa (Ministry of Energy Niger, 2003; Ministry of Energy Benin, 2001). Furthermore, the low, heavily subsidised electricity tariffs do not reflect the costs for transaction and distribution (Karekezi 1992, Karekezi et al., 2004, Karekezi 2006). Currently, the electricity price for end users in the WAEMU is in average around 12 \$ cent/kWh (World Bank 2004b), while investment costs for PV is around 25 \$ cent/kWh and 10 \$ cent/kWh for biomass electricity, wind power and hydro (Geller 2003). As discussed in section 4, to these prices must be added a prime for risks, taxes and a profit margin. In the end, final price will likely be above the current price. This makes the renewable energy technologies non-competitive. In addition, there is no well designed financial framework supporting the introduction of the renewable energy technologies which require high up front investment. As far as market issue is concerned, the market for renewable energy technologies in the countries is small (El Bassam and Maegaard 2004). In fact, through the development programs several renewable energy technology have been introduced in hospitals, schools and other public owned facilities. Due to their low purchasing power, private

consumers could not afford the costly renewable energy services.²⁵ This in turn limited the use of the renewable energy technologies to the public sectors, preventing economies of scale which would be achieved otherwise.

9 CONCLUSION

Altogether, the issues discussed so far must be addressed before the countries profit from their important renewable energy potential.

Altogether, actual and future electricity demand in all the case study countries is low. It is obvious that the actual production systems could not provide electricity to all people. In addition, the case study countries will need a fast and continuing extension of the energy supply to allow a modest improvement of economic conditions over the next fourteen years. An increasing power supply should be seen as mandatory. The success of such a programme will depend on whether the countries have the possibility to finance these investments by themselves or whether they can find foreign funding. Concerning public investments, the current GDP per capita in the countries raises doubts. Efficiency gains will not significantly reduce the need for supply expansion.

A comparison of the electricity demand from the simplified assessment and the closing the gap methodology shows a higher electricity demand²⁶ in the simplified assessment method. This difference could be explained by a low economic development in the countries and consequently, a lower electricity demand, whereas these constraints have not been taken into account in the simplified method. In addition, a mean value for per capita electricity was used and the electricity services referred to in the simplified methodology are not all gained in the countries in the short term.

²⁵ Consumers use to by batteries which are also expensive. However, its use per consumer is limited to radio and torch. In addition, the frequency of batteries' replacement is so limited that consumers do not care about.

²⁶ The electricity demand in the simplified methodology gives 6 TWh, 11 TWh, 9 TWh and 5 TWh for Benin, Burkina Faso, Niger and Togo respectively, while actual electricity demand from CG/HE shows an electricity demand around 1TWh in each country.

Since the electricity demand under the closing the gap-high efficiency scenario is based on a wide range of constraints such as population, GDP growth, efficiency gain, etc, the result of that assessment could be qualified as conservative.

As electricity demand in case study countries will not be very high, since economic development is projected to remain low, despite an increase in CO₂ emissions, emissions will remain at a low level. Hence, the countries studied cannot be as competitive as current competing CDM countries, i.e., China, India, Brazil, etc. Strengthening energy co-operation within West African Economic and Monetary Union may reduce transaction costs, making it possible to use the available energy potential.

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